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CT Dose Optimization in Eastern Libya: A Prospective Multicenter Audit of Examination-Specific Variation in CTDIvol, DLP, and Derived Scan Length

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تحسين جرعة التصوير المقطعي المحوسب في شرق ليبيا: تدقيق مستقبلي متعدد المراكز للتباين الخاص بالفحوصات في مؤشر جرعة التصوير وطول المسح المُشتق جرعة التصوير المقطعي المحوسب الحجمي

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Abstract:
CT dose depends partly on scanner design, but day-to-day practice is also shaped by how each service applies its protocols, including scan start and end points, additional phases, and local review against diagnostic reference levels (DRLs). This prospective multicenter assessment assessed examination-specific variation in volume CT dose index (CTDIvol), dose-length product (DLP), and derived scan length across CT services in Eastern Libya. The final cleaned dataset included 229 adult CT examinations from four hospitals. Albyda Medical Center was analyzed as two separate service contexts because the Casualty and In-Patient CT units followed different workflows. Examination names were standardized before analysis. As direct z-axis scan range was unavailable, derived scan length was calculated as DLP/CTDIvol and used only as a practical indicator of longitudinal coverage, rather than as a direct anatomical measurement. Dose indicators were summarized using medians and interquartile ranges, and site comparisons were performed within matched examination or protocol groups. Chest CT and abdomen/abdomen-pelvis examinations showed significant inter-site differences in DLP and derived scan length, while brain CT differed mainly in CTDIvol. Paranasal sinus CT and the local CTU/KUB protocol group showed significant variation across CTDIvol, DLP, and derived scan length. Local 75th percentile DLP values were above selected external comparators for brain CT, chest CT, HR chest, and paranasal sinus CT. These findings support targeted protocol review, tighter control of scan range, and repeated dose audit linked to DRL-based optimization.

Keywords: Computed tomography, CT dose audit, Radiation protection, CTDIvol, Dose-length product, Derived scan length, Scan-range governance, Diagnostic reference levels, Libya.

الملخص:
تعتمد جرعة التصوير المقطعي المحوسب (CT) جزئيًا على تصميم جهاز التصوير، إلا أن الممارسة السريرية اليومية تتأثر أيضًا بكيفية تطبيق كل مؤسسة لبروتوكولات التصوير الخاصة بها، بما في ذلك نقاط بدء وانتهاء المسح المقطعي، والمراحل الإضافية، وآليات المراجعة المحلية بالاستناد إلى المستويات المرجعية التشخيصية .(DRLs) هدفت هذه الدراسة المستقبلية متعددة المراكز إلى تقييم التباين المرتبط بنوع الفحص في مؤشر جرعة التصوير المقطعي المحوسب الحجمي (CTDIvol)، وحاصل ضرب الجرعة والطول(DLP) ، وطول المسح المُشتق، عبر خدمات التصوير المقطعي المحوسب في شرق ليبيا. شملت مجموعة البيانات النهائية بعد التنقيح 229 فحص تصوير مقطعي محوسب للبالغين من أربعة مستشفيات. وتم تحليل مركز البيضاء الطبي باعتباره جهازين منفصلين، نظرًا لاختلاف سير العمل بين وحدتي التصوير المقطعي المحوسب الخاصة بقسم الأسعاف والحوادث وقسم الإيواء الداخلي. كما جرى توحيد مسميات الفحوصات قبل إجراء التحليل الاحصائية. ونظرًا لعدم توفر بيانات مباشرة عن مدى المسح على المحور الطولي(z-axis) ، تم احتساب طول المسح المُشتق باستخدام المعادلة DLP/CTDIvol، واستُخدم فقط كمؤشر عملي على التغطية الطولية للمسح، وليس بوصفه قياسًا تشريحيًا مباشرًا. تم تلخيص مؤشرات الجرعة باستخدام الوسيط والمدى الربيعي، كما أُجريت المقارنات بين المواقع ضمن مجموعات الفحوصات أو البروتوكولات المتناظرة. وأظهرت فحوصات الصدر والبطن/البطن والحوض فروقًا ذات دلالة بين المواقع في كل من DLP وطول المسح، في حين ظهرت الاختلافات في فحوصات الدماغ بصورة رئيسية في قيم .CTDIvol كذلك، أظهرت فحوصات الجيوب الأنفية ومجموعة بروتوكولات CTU/KUB المحلية تباينًا ملحوظًا في CTDIvol و DLPوطول المسح المُشتق. كما تجاوزت قيم P75 المحلية لـ DLP بعض القيم المرجعية الخارجية المختارة في فحوصات الدماغ، والصدر، والصدر عالي الدقة(HR chest) ، والجيوب الأنفية.
تدعم هذه النتائج أهمية المراجعة الموجهة لبروتوكولات التصوير، وتعزيز ضبط مدى المسح، وتكرار تدقيق الجرعات في إطار التحسين القائم على المستويات المرجعية التشخيصية.

الكلمات المفتاحية: التصوير المقطعي المحوسب؛ تدقيق جرعات التصوير المقطعي؛ الوقاية الإشعاعية؛ مؤشر جرعة التصوير المقطعي المحوسب الحجمي(CTDIvol) ؛ حاصل الجرعة والطول؛ طول المسح المُشتق؛ حوكمة مدى المسح؛ المستويات المرجعية التشخيصية؛ ليبيا.

Introduction:

Computed tomography (CT) has become a routine part of diagnostic imaging because it is fast, widely available, and useful across a broad range of clinical problems. Its clinical value is clear in everyday radiology practice, but CT also remains a major contributor to medical radiation exposure. For this reason, optimization should be treated as a continuing part of service governance rather than as a one-time technical adjustment. It should also not be reduced to simply lowering dose in every case. A more practical approach is to make dose behavior visible, measurable, and open to regular review. In working CT departments, protocol selection and scan boundaries may be influenced by workload, scanner presets, local practice, radiologist preference, emergency pressures, and formal optimization processes [1], [2].

CTDIvol and DLP are commonly used in CT audits because they are available from scanner-generated dose reports. CTDIvol reflects scanner output and protocol intensity, whereas DLP also accounts for the longitudinal extent of the acquisition. This distinction is important. A scan may have a reasonable CTDIvol but still produce a high DLP if the coverage is broad, phases are repeated, or local anatomical limits are not clearly defined. Automatic exposure control and automatic tube current modulation (AEC/ATCM) adjust tube current, but they do not determine the cranio-caudal start and stop points, the number of phases, or whether the scan is extended [1], [3].

Diagnostic reference levels (DRLs) are best viewed as signs for review rather than as patient dose limits. When a local value is above a DRL, the appropriate response is to examine the protocol and practice pattern thoughtfully, not to assume inappropriate care [4]. In countries or regions without national CT DRLs, external benchmarks can still support local review, provided the examination mapping is clear and missing categories are not estimated from unrelated examinations. Recent DRL work has also encouraged clinical-indication-based levels, because broad labels such as “abdomen” or “head” can include very different procedures [5].

In Eastern Libya, multicenter CT dose-governance data remain limited. The hospitals included in this audit use different scanner platforms and different local examination labels, so a single pooled comparison across all CT scans would not be meaningful. We therefore focused on harmonized adult examination/protocol categories. The aim was to outline CTDIvol, DLP, and derived scan length within those groups, and to compare local 75th percentile DLP values with selected external DRL comparators.

Materials and Methods:

This prospective observational multicenter audit was conducted during routine adult CT practice in Eastern Libya. Four hospitals participated. Albyda Medical Center was analyzed as two separate CT service contexts, Casualty and In-Patient, because the two units operated through distinct clinical workflows. The final analytical site labels were AMC Casualty, AMC In-Patient, Cyrene Teaching Hospital CTH, Omar Al Mukhtar General Hospital OGH, and Sousa General Hospital SGH. No scanning protocol was changed for the audit, and patients were not exposed to any additional radiation.

The analysis was based on the confirmed cleaned dataset, which was used as the working dataset after the agreed cleaning decisions had been applied. These choices included harmonization of examination labels, phase-normalization of DLP values, and exclusion of rare or poorly com

parable labels from grouped inferential testing. The main recorded dataset contained 229 adult CT examinations. Low-frequency and mixed categories were retained for transparency and are listed in Supplementary Table S1.

Adult CT investigations were included when the required scanner-generated dose variables were accessible. Paediatric examinations were excluded because Paediatric dose optimization and DRL interpretation require a separate framework. As each CT unit used its own abbreviations and coding system, raw examination labels were mapped into predefined groups: brain, chest, HR chest, abdomen/abdomen-pelvis local protocol, chest-abdomen-pelvis (CAP), paranasal sinuses, local CTU/KUB protocol group, and neck. All statistical assessments were performed within these examination/protocol groups rather than across the full mixed dataset.

Scanner details were verified as follows: AMC Casualty, Philips Incisive 128-slice; AMC In-Patient, Toshiba/Canon Aquilion 160-slice; CTH, GE Revolution Maxima 128-slice; OGH, Toshiba/Canon Aquilion 160-slice; and SGH, Philips Incisive 128-slice. AEC/ATCM was active in protocols across the participating sites, in keeping with its established role in CT dose modulation[3]. Vendor-specific modulation settings, reconstruction methods, noise targets, and installation years were not reported because these details could not be verified consistently.

The primary dose indicators were CTDIvol (mGy) and DLP (mGy.cm), both taken from the cleaned scanner-dose dataset. CTDIvol was treated as an index of scanner output, while DLP was used for DRL benchmarking [1], [4]. Direct z-axis start and end positions were not available. Therefore, derived scan length was calculated as DLP/CTDIvol and interpreted cautiously as a service-audit indicator of longitudinal coverage behavior, not as direct DICOM-measured anatomical coverage.

For multiphase examinations, the cleaned dataset used phase-normalized DLP. Where applicable, total DLP was divided by the number of acquisition phases as pragmatic procedure. This was a practical step to improve comparability between single-phase and multiphase examinations, and was not intended to provide phase-specific dosimetry.

Local DLP distributions were assessed using the 75th percentile. UK national DRLs were used as the primary comparator when a direct category match was available[6]. Registry-based work has also supported the use of CT DRLs and achievable doses for adult CT optimization[7]. Saudi SFDA DRLs were used for brain/head, chest, and abdomen-pelvis[8], while UAE MOHAP CT DRLs were used where matched values were available[9]. Abdomen and abdomen-pelvis were analysed together because the same local protocol was used. The local CTU/KUB group was compared with the UK urogram value, as CT KUB and CT urography followed the same local protocol in the participating sites. Categories without a defensible match were left unavailable rather than estimated from unrelated examinations.

Continuous variables were reported as medians and interquartile ranges. Kruskal-Walli's testing was used to compare CTDIvol, DLP, and derived scan length within each examination/protocol category. Site/unit groups with fewer than three examinations were excluded from the relevant inferential comparison because very small cells could produce unstable site-level results. Spearman rank correlations were added as supportive summaries of the relationships between DLP, derived scan length, and CTDIvol. Regression using DLP as the outcome and derived scan length as a predictor was not used, because derived scan length was calculated from DLP and CTDIvol and would therefore create circular interpretation. P-values were interpreted as audit signals, not as proof that a protocol was inappropriate.

Institutional or departmental permission was obtained. No formal ethics approval number was issued. The audit used anonymised routine CT dose data only. There was no patient intervention, no protocol change, and no patient-identifiable information.

Results:

The results are presented in the order of the review questions: examination distribution, site-level dose indicators, DRL benchmarking, inter-site comparisons, and supportive correlation analysis. All comparisons are reported within examination/protocol categories. A pooled all-examination dose comparison was not presented because the mixed examination categories would make such a comparison misleading.

Examination distribution:

The confirmed cleaned dataset included 229 cases in the main mapped analysis (23 cases of rare examinations were excluded for not matching the study criteria). These examinations came from four hospitals, with Albyda Medical Center represented by two service contexts: AMC Casualty and AMC In-Patient. Raw examination labels differed across sites because each CT unit used its own abbreviations and coding style. Before analysis, these labels were harmonized into unified examination/protocol categories.

Brain CT, paranasal sinus CT, and the local CTU/KUB protocol group were among the largest categories. Chest CT and abdomen/abdomen-pelvis also contributed substantially to the dataset. Low-frequency or non-comparable labels were retained descriptively as “Other mapped / rare examinations”, but they were not used to drive grouped inferential comparisons.

Table (1): Examination distribution by CT service unit/site in the cleaned analysis dataset.

Examination / protocol category	AMC Casualty	AMC In-Patient	CTH	OGH	SGH	Total
Brain	10	10	2	8	6	36
Chest	7	3	12	3	6	31
HR chest	0	0	0	8	0	8
Abdomen / abdomen-pelvis local protocol	2	3	5	16	1	27
Chest-abdomen-pelvis (CAP)	0	3	0	11	0	14
Paranasal sinuses	3	12	5	12	4	36
Local CTU/KUB protocol group	0	6	20	13	5	44
Neck	4	1	0	5	0	10
Other mapped / rare examinations	1	6	5	8	3	23
Total	27	44	49	84	25	229

Note. AMC Casualty and AMC In-Patient are two CT service contexts within Albayda Medical Center. Other mapped (rare) examinations were kept for descriptive transparency but excluded from grouped inferential comparisons; the detailed composition is given in Supplementary Table S1.

Site-level dose indicators:

The site-level summaries showed that dose behavior differed by protocol. In brain CT, relatively high median CTDIvol values were noticed across the sites, while derived scan length varied less than in body protocols. Chest CT showed a wider spread in DLP and derived scan length; SGH and AMC In-Patient had higher median DLP values than AMC Casualty and CTH. In the abdomen/abdomen-pelvis local protocol group, AMC In-Patient had higher median DLP and derived scan length than the other units, although the number of cases from this unit was small. CAP examinations were available only from AMC In-Patient and OGH, with AMC In-Patient showing both longer median scan length and higher median DLP. Paranasal sinus CT showed clear site-level differences in CTDIvol, DLP, and derived scan length. The local CTU/KUB group also presented variation: CTH had high CTDIvol but short derived scan length, whereas AMC In-Patient and SGH had longer derived scan lengths and higher DLP values. These findings are best interpreted by considering CTDIvol, DLP, and derived scan length together. No single metric fully captures the dose pattern across sites and protocols. Very small site-level cells are included for transparency, but they should be interpreted descriptively rather than as stable estimates of local practice.

Figure 1 presents the DLP distribution for the main examination/protocol categories. Figure 2 uses the same site and category order to show derived scan length. Reading the two figures together helps distinguish overall dose burden from longitudinal coverage behavior, without relying on a pooled summary across unrelated CT examinations.

Table (2): Site-level CT dose indicators by examination/protocol category in the cleaned analysis dataset.

Examination / protocol category	Site/unit	n	CTDIvol, mGy median (IQR)	DLP, mGy.cm median (IQR)	Derived scan length, cm median (IQR)
Brain	AMC Casualty	10	57.50 (52.30-57.50)	924.30 (887.40-924.30)	16.97 (16.07-22.23)
Brain	AMC In-Patient	10	49.24 (49.24-65.72)	1070.32 (647.26-1163.04)	15.62 (11.34-21.81)
Brain	CTH	2	52.55 (48.77-56.33)	900.00 (900.00-900.00)	17.49 (16.23-18.74)
Brain	OGH	8	60.50 (60.50-60.50)	1019.35 (945.00-1074.00)	16.85 (15.62-17.75)
Brain	SGH	6	51.00 (46.64-54.16)	1044.89 (995.02-1161.96)	23.03 (20.93-24.04)
Chest	AMC Casualty	7	6.00 (3.75-10.10)	143.40 (134.15-203.82)	37.70 (13.60-41.86)
Chest	AMC In-Patient	3	10.78 (7.98-12.18)	454.95 (331.32-474.44)	40.02 (38.20-41.11)
Chest	CTH	12	9.10 (8.60-52.65)	235.18 (152.42-288.19)	11.69 (5.87-33.19)
Chest	OGH	3	9.40 (6.05-9.40)	335.00 (223.00-354.50)	39.79 (37.71-40.45)
Chest	SGH	6	14.09 (13.63-15.16)	515.41 (492.32-628.92)	37.85 (35.11-39.71)
HR chest	OGH	8	12.25 (11.10-14.23)	400.00 (322.57-444.75)	30.01 (28.60-32.25)
Abdomen / abdomen-pelvis local protocol	AMC Casualty	2	11.60 (10.30-12.90)	324.40 (268.15-380.65)	27.16 (25.35-28.96)
Abdomen / abdomen-pelvis local protocol	AMC In-Patient	3	30.83 (28.43-31.41)	1474.84 (1182.05-1646.65)	56.66 (42.75-56.75)
Abdomen / abdomen-pelvis local protocol	CTH	5	12.99 (12.00-184.12)	348.77 (186.55-600.00)	14.30 (3.69-14.36)
Abdomen / abdomen-pelvis local protocol	OGH	16	18.80 (17.48-20.28)	456.88 (373.88-499.00)	23.76 (21.21-25.71)
Abdomen / abdomen-pelvis local protocol	SGH	1	23.21 (23.21-23.21)	577.89 (577.89-577.89)	24.90 (24.90-24.90)
Chest-abdomen-pelvis (CAP)	AMC In-Patient	3	15.08 (13.80-18.44)	975.43 (734.66-1007.94)	47.73 (43.57-56.21)
Chest-abdomen-pelvis (CAP)	OGH	11	18.00 (10.40-20.80)	502.00 (310.50-566.50)	28.38 (24.92-30.45)
Paranasal sinuses	AMC Casualty	3	22.90 (21.85-40.20)	334.60 (319.50-373.97)	14.61 (10.90-14.62)
Paranasal sinuses	AMC In-Patient	12	27.27 (26.02-28.66)	502.42 (469.06-555.05)	18.69 (17.91-19.31)
Paranasal sinuses	CTH	5	12.50 (10.80-25.42)	108.73 (108.73-137.50)	11.00 (4.28-11.14)
Paranasal sinuses	OGH	12	36.30 (36.30-36.30)	422.70 (409.00-491.00)	11.64 (11.27-13.83)
Paranasal sinuses	SGH	4	29.45 (27.96-30.29)	522.79 (497.21-551.14)	17.78 (17.75-18.24)
Local CTU/KUB protocol group	AMC In-Patient	6	34.23 (26.08-35.10)	1530.89 (1071.84-1819.97)	52.84 (27.87-53.71)
Local CTU/KUB protocol group	CTH	20	96.22 (11.70-183.40)	327.92 (232.20-419.70)	3.61 (2.24-15.33)
Local CTU/KUB protocol group	OGH	13	10.40 (9.40-10.40)	485.00 (430.00-528.00)	50.77 (46.15-51.73)
Local CTU/KUB protocol group	SGH	5	22.20 (20.85-26.89)	1184.94 (980.39-1319.54)	53.38 (53.37-58.13)
Neck	AMC Casualty	4	14.90 (10.85-21.07)	305.95 (197.97-414.78)	22.55 (8.46-38.37)
Neck	AMC In-Patient	1	16.32 (16.32-16.32)	282.32 (282.32-282.32)	17.30 (17.30-17.30)
Neck	OGH	5	9.40 (8.40-9.40)	297.50 (271.00-315.00)	33.51 (28.83-36.28)

It should be declared, values are median (interquartile range). Derived scan length was calculated as DLP/CTDIvol because direct z-axis scan range was not available. Site-level entries with small numbers, especially n = 1-3, are included for transparency and should be interpreted descriptively. Other mapped / rare examinations listed in Table 1 were not included in this main descriptive dose table and are detailed in Supplementary Table S1.

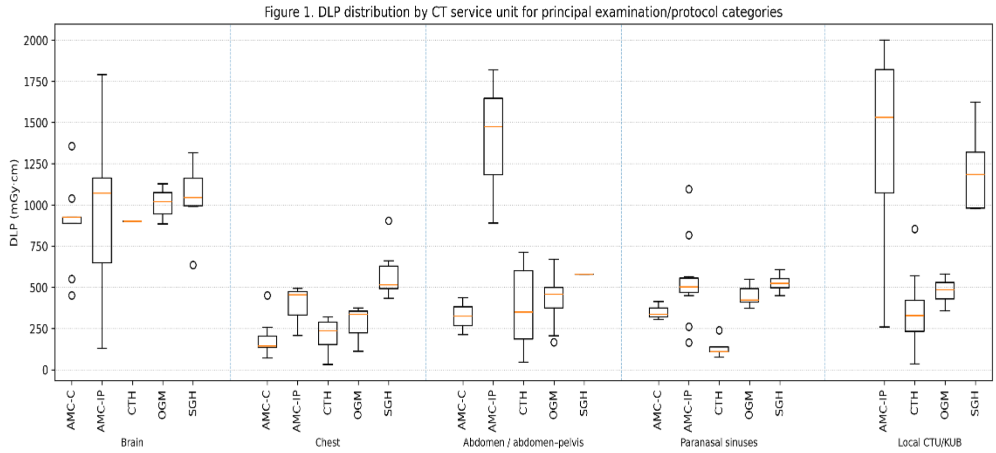

Figure (1): Distribution of dose-length product values across CT service units for the principal examination/protocol categories. Boxplots show the median, interquartile range, and DLP distribution within each site/unit. The figure includes brain, chest, abdomen/abdomen-pelvis local protocol, paranasal sinuses, and the local CTU/KUB protocol group. HR chest, CAP, neck, and other low-frequency categories were not included because their site representation was limited or less suitable for visual comparison.

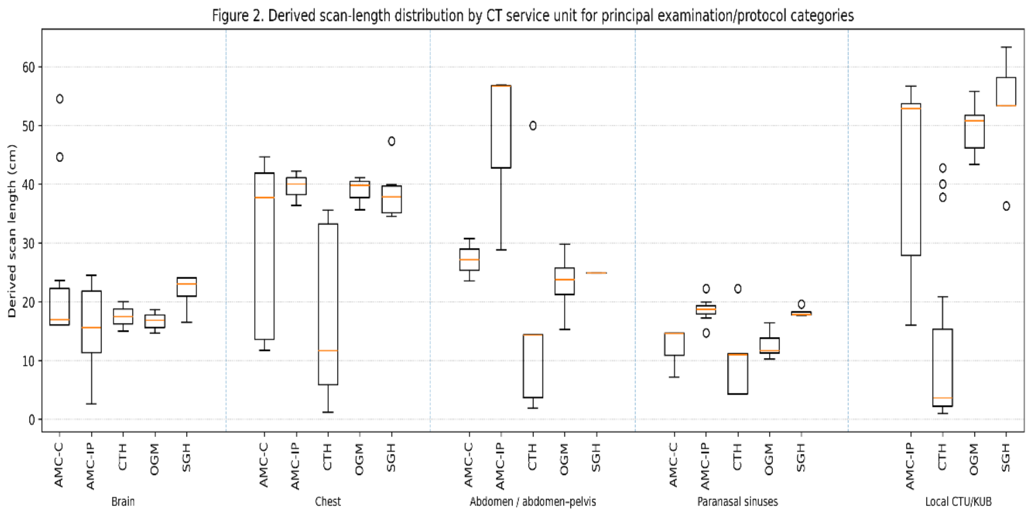

Figure (2): Distribution of derived scan length across CT service units for the principal examination/protocol categories. Derived scan length was calculated as DLP/CTDIvol because direct z-axis scan range was not available. The site and category order matches Figure 1 so that DLP and longitudinal coverage can be compared more easily. The figure shows audit-level variation in derived scan length and should not be read as independent causal modelling.

DRL benchmarking:

Benchmarking against selected external DRLs identified several categories requiring closer protocol review. Local P75 DLP values for brain CT, chest CT, HR chest, and paranasal sinus CT were above their selected external comparators. The abdomen/abdomen-pelvis local protocol group was slightly above the UK abdomen-pelvis benchmark but below the Saudi and UAE abdomen-pelvis comparators. CAP was below the UK CAP benchmark, and the local CTU/KUB protocol group was also below the selected UK urogram benchmark.

These comparisons should be interpreted as quality-improvement indications, consistent with the role of DRLs as optimization tools rather than dose limits [4]. They do not demonstrate inappropriate practice. External DRLs may differ in patient population, scanner technology, indication mix, and protocol definition. The Saudi and UAE values were retained because of their regional relevance, but they cannot replace locally developed Libyan DRLs [8], [9]. Figure 3 gives a simple visual summary using one primary external comparator for each category. The fuller UK, Saudi, and UAE comparisons are kept in Table 3 so that the figure remains readable.

Table (3): Local 75th percentile DLP values compared with selected external DRL benchmarks.

Local examination / protocol category	n	Local P75 DLP (mGy.cm)	UK DRL (mGy.cm)	Saudi DRL (mGy.cm)	UAE comparator (mGy.cm)	Benchmark interpretation
Brain	36	1079.65	790	1026	695 / 820	Above UK, Saudi, and UAE head benchmarks
Chest	31	441.87	290	430	275	Above UK, Saudi, and UAE chest benchmarks
HR chest	8	444.75	300	Not available	Not available	Above UK HR chest benchmark
Abdomen / abdomen-pelvis local protocol	27	555.45	530	706	810 / 1025	Slightly above UK; below Saudi and UAE
Chest-abdomen-pelvis (CAP)	14	603.50	660	Not available	Not available	Below UK CAP benchmark
Paranasal sinuses	36	513.97	160	Not available	Not available	Above UK paranasal sinus benchmark
Local CTU/KUB protocol group	44	648.70	890	Not available	Not used for primary benchmarking	Below UK urogram benchmark
Neck	10	380.85	Not available	Not available	Not available	Not benchmarked

Worth mentioning that, in the table above that the local P75 values were calculated from the confirmed cleaned analysis dataset. External DRL comparators came from official UK and Saudi sources and from the UAE MOHAP CT dose survey [6], [8], [9]. For abdomen and abdomen-pelvis, external abdomen-pelvis DRLs were used because participating sites used the same local protocol for both categories. For the local CTU/KUB protocol group, the UK urogram DRL was selected as the primary reference because CT KUB and CT urography were performed using the same local protocol in the participating sites. Missing DRL mappings were left unavailable rather than estimated from unrelated categories. DRL exceedance was treated as a protocol-review flag, not evidence of inappropriate practice.

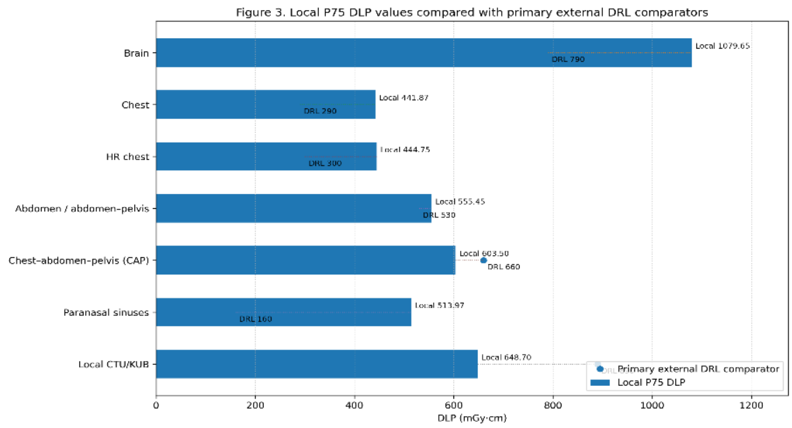

Figure (3): Local 75th percentile DLP values compared with primary external diagnostic reference level comparators. Local P75 DLP values were calculated from the confirmed Phase 5 cleaned analysis dataset. For readability, the figure uses one primary external comparator for each examination/protocol category; the fuller UK, Saudi, and UAE details are retained in Table 3[8], [9], [10]. The UK benchmark was used when the category mapped directly. For the local CTU/KUB protocol group, the UK urogram DRL was selected because CT KUB and CT urography followed the same local protocol in the participating sites. DRL exceedance was interpreted as a protocol-review signal, not as evidence of inappropriate practice.

Inter-site comparisons:

Inter-site variability differed by examination category. In brain CT, CTDIvol differed significantly between the included sites, whereas DLP and derived scan length did not. Chest CT showed significant site-level differences in DLP and derived scan length, but not in CTDIvol, suggesting that longitudinal coverage contributed to dose variation in this category. Abdomen/abdomen-pelvis showed a similar pattern for DLP and derived scan length, although CTDIvol did not reach statistical significance.

For CAP, derived scan length differed significantly between the two contributing sites, while CTDIvol and DLP did not. Paranasal sinus CT and the local CTU/KUB protocol group showed significant inter-site differences across CTDIvol, DLP, and derived scan length. Neck examinations did not show significant differences between sites, although the number of cases was limited.

Table (4): Inter-site comparison summary for CTDIvol, DLP, and derived scan length by examination/protocol category.

Examination / protocol category	Metric	Sites/units included	k	N	H	p-value	Interpretation
Brain	CTDIvol	AMC Casualty; AMC In-Patient; OGH; SGH	4	34	11.184	0.011	Significant inter-site difference
Brain	DLP	AMC Casualty; AMC In-Patient; OGH; SGH	4	34	3.617	0.306	Not significant
Brain	Derived scan length	AMC Casualty; AMC In-Patient; OGH; SGH	4	34	5.351	0.148	Not significant
Chest	CTDIvol	AMC Casualty; AMC In-Patient; CTH; OGH; SGH	5	31	6.071	0.194	Not significant
Chest	DLP	AMC Casualty; AMC In-Patient; CTH; OGH; SGH	5	31	16.377	0.003	Significant inter-site difference
Chest	Derived scan length	AMC Casualty; AMC In-Patient; CTH; OGH; SGH	5	31	15.352	0.004	Significant inter-site difference
HR chest	CTDIvol	OGH only	1	8	-	-	Not tested; single site only
HR chest	DLP	OGH only	1	8	-	-	Not tested; single site only
HR chest	Derived scan length	OGH only	1	8	-	-	Not tested; single site only
Abdomen / abdomen-pelvis local protocol	CTDIvol	AMC In-Patient; CTH; OGH	3	24	5.041	0.080	Not significant
Abdomen / abdomen-pelvis local protocol	DLP	AMC In-Patient; CTH; OGH	3	24	7.647	0.022	Significant inter-site difference
Abdomen / abdomen-pelvis local protocol	Derived scan length	AMC In-Patient; CTH; OGH	3	24	9.528	0.009	Significant inter-site difference
Chest-abdomen-pelvis (CAP)	CTDIvol	AMC In-Patient; OGH	2	14	0.303	0.582	Not significant
Chest-abdomen-pelvis (CAP)	DLP	AMC In-Patient; OGH	2	14	2.673	0.102	Not significant
Chest-abdomen-pelvis (CAP)	Derived scan length	AMC In-Patient; OGH	2	14	5.097	0.024	Significant inter-site difference
Paranasal sinuses	CTDIvol	AMC Casualty; AMC In-Patient; CTH; OGH; SGH	5	36	16.647	0.002	Significant inter-site difference
Paranasal sinuses	DLP	AMC Casualty; AMC In-Patient; CTH; OGH; SGH	5	36	19.074	<0.001	Significant inter-site difference
Paranasal sinuses	Derived scan length	AMC Casualty; AMC In-Patient; CTH; OGH; SGH	5	36	20.583	<0.001	Significant inter-site difference
Local CTU/KUB protocol group	CTDIvol	AMC In-Patient; CTH; OGH; SGH	4	44	14.423	0.002	Significant inter-site difference
Local CTU/KUB protocol group	DLP	AMC In-Patient; CTH; OGH; SGH	4	44	24.205	<0.001	Significant inter-site difference
Local CTU/KUB protocol group	Derived scan length	AMC In-Patient; CTH; OGH; SGH	4	44	29.782	<0.001	Significant inter-site difference
Neck	CTDIvol	AMC Casualty; OGH	2	9	2.965	0.085	Not significant
Neck	DLP	AMC Casualty; OGH	2	9	0.240	0.624	Not significant
Neck	Derived scan length	AMC Casualty; OGH	2	9	0.060	0.806	Not significant

Note: k is the number of involved sites, N is the number of performed examinations, H is the degree of separation in the ranked data. Nevertheless, Kruskal-Wallis tests were performed within examination/protocol categories only. Site/unit groups with fewer than three observations in a category were excluded from that inter-site test to reduce unstable comparisons; for this reason, N in this table may be lower than the category total in Table 1. For two-site comparisons, the same Kruskal-Wallis framework was kept as a rank-based two-group comparison for consistency. p-values are reported as descriptive audit signals, not as proof of inappropriate practice.

Supportive correlation analysis:

The supportive correlation analysis showed that DLP was not associated with the same factor across all examination categories. In paranasal sinus CT, the local CTU/KUB protocol group, and neck examinations, DLP had a stronger association with derived scan length than with CTDIvol. Brain CT showed a modest association between CTDIvol and DLP, while the association between derived scan length and DLP did not reach statistical significance. CAP also showed a stronger CTDIvol-DLP association than scan length-DLP association, although the sample size was small. For chest CT and abdomen/abdomen-pelvis, DLP was associated with both derived scan length and CTDIvol. This is important for interpretation. Scan-length governance appears to be an important optimisation target in several categories, but it should not be treated as the only driver of DLP variation.

Table (5): Supportive Spearman correlations between DLP and derived scan length or CTDIvol by examination/protocol category.

Examination/protocol category	n	Scan length vs DLP, rho	p-value	CTDIvol vs DLP, rho	p-value
Brain	36	0.280	0.098	0.350	0.036
Chest	31	0.447	0.012	0.471	0.007
HR chest	8	0.667	0.071	0.617	0.103
Paranasal sinuses	36	0.675	<0.001	0.504	0.002
Abdomen / abdomen-pelvis local protocol	27	0.720	<0.001	0.738	<0.001
Chest-abdomen-pelvis	14	0.424	0.131	0.706	0.005
Local CTU/KUB protocol group	44	0.658	<0.001	0.292	0.054
Neck	10	0.927	<0.001	-0.073	0.841

Note. Spearman correlations are shown as supportive audit-level summaries. Because scan length was derived from DLP/CTDIvol, these correlations should not be interpreted as independent causal modelling. Regression using DLP as the outcome and derived scan length as a predictor was not used as a primary analysis because it would risk circular inference.

Discussion:

This audit showed that CT dose variation across the participating services was examination-specific. CTDIvol, DLP, and derived scan length did not follow the same pattern across all protocols. In chest CT and abdomen/abdomen-pelvis, significant differences in DLP were accompanied by significant differences in derived scan length, while CTDIvol was not significantly different after the planned testing rules were applied. Brain CT showed a different pattern: CTDIvol differed significantly, whereas DLP and derived scan length did not. Paranasal sinus CT and the local CTU/KUB protocol group showed broader variation involving all three indicators. Taken together, these findings suggest that dose variation cannot be explained by a single factor. Scanner output, scan coverage, and protocol structure all contributed, but their relative importance differed by examination type.

Scan-length governance deserves particular attention because AEC/ATCM was active across the participating protocols. These systems adjust tube current according to attenuation and protocol targets, but they do not determine cranio-caudal boundaries, phase selection, or local examination limits[3]. As a result, DLP can increase with wider scan extent even when CTDIvol appears acceptable[1]. The supportive correlation findings are consistent with this interpretation, although they were not used as causal modelling. DLP correlated more strongly with derived scan length in paranasal sinus CT, the local CTU/KUB group, and neck examinations. In contrast, CTDIvol had the stronger relationship with DLP in brain CT and CAP. Because derived scan length was calculated from DLP/CTDIvol, regression modelling would have created circular interpretation and was therefore avoided.

DRL benchmarking identified the categories where review should begin. Brain CT, chest CT, HR chest, and paranasal sinus CT exceeded their selected external comparators. Abdomen/abdomen-pelvis was slightly above the UK comparator but below the Saudi and UAE comparators. CAP and the local CTU/KUB group were below the selected UK comparators. These results should not be interpreted as evidence that care was unsafe or inappropriate. DRLs are investigation thresholds and optimization tools, not dose limits[4]. Their purpose is to show where protocol settings, scan boundaries, indication mix, and image-quality expectations require closer review.

The practical implications differ by category. Brain CT may need more attention to scanner-output settings than to scan length alone. Chest CT and abdomen/abdomen-pelvis point toward scan-boundary review, especially because body imaging includes a mix of clinical indications. Paranasal sinus CT should be reviewed early because it exceeded the selected comparator and varied significantly in CTDIvol, DLP, and derived scan length. The local CTU/KUB group also requires closer review. A shared protocol for CT KUB and CT urography may be convenient, but the two examinations do not always answer the same clinical question. Indication-specific pathways may therefore be more appropriate.

This study has several limitations. Direct z-axis coverage was not available, so scan length had to be derived rather than measured from DICOM geometry. For that reason, derived scan length was treated only as an audit-level indicator of longitudinal coverage behavior. Phase-normalized DLP reduced artificial inflation from multiphase studies, but it did not provide phase-specific dosimetry. This is important because unnecessary multiphase acquisition can be a source of avoidable CT exposure [11]. Patient-size-adjusted dose estimates were not included because size-related parameters were incomplete and inconsistent across sites. Formal image-quality scoring was also unavailable. Although these examinations were used for routine radiologist reporting and no repeated documented complaints were reported, that is not equivalent to structured image-quality assessment. Finally, external DRLs were used because local Libyan DRLs have not yet been established, and some site/examination cells were small.

For Libya, the main lesson is not to reduce dose indiscriminately. The greater need is structured, examination-specific governance: standardized naming, periodic CTDIvol and DLP monitoring, scan-boundary review, indication-aware protocols, and locally derived DRLs. This is consistent with expert guidance that local DRLs can help identify outliers and support continuing optimization [12] Future audits should add direct z-axis extraction, indication-level classification, phase-specific coverage, patient-size-adjusted dose estimates, and formal image-quality assessment.

Conclusion:

This prospective multicenter audit demonstrated examination-specific CT dose variation across participating services in Eastern Libya. Under routine AEC/ATCM use, some protocols showed meaningful inter-site differences in DLP and derived scan length, while others differed more clearly in CTDIvol. The findings therefore do not support a single explanation for dose variation. Scan-length governance is an important and practical optimization target in several CT protocols, but scanner output and protocol settings also remain important.

External DRL benchmarking identified brain CT, chest CT, HR chest, and paranasal sinus CT as early priorities for protocol review. Abdomen/abdomen-pelvis was slightly above the UK comparator and below the Saudi and UAE comparators, while CAP and the local CTU/KUB protocol group were below the selected UK comparators. These results should be used to guide structured local review rather than to imply inappropriate practice.

Further work should include direct z-axis extraction, indication-level classification, phase-specific coverage, patient-size-adjusted dose estimates, and formal image-quality assessment. These additions would allow future audits to move beyond identifying variation and begin assessing whether that variation is clinically justified, technically avoidable, or both.

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