APPLICATION OF DRLS FOR RADIATION OPTIMIZATION AND IMAGE QUALITY IMPROVEMENT IN COMPUTED TOMOGRAPHY

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Abstract— **Computed tomography (CT) is widely employed in medical diagnostics due to its high contrast resolution and multiplanar reconstruction capabilities. However, CT examinations are associated with relatively high doses of ionizing radiation, requiring optimization strategies to ensure diagnostic image quality with minimal radiation exposure. In this context, Diagnostic Reference Levels (DRLs) serve as benchmark parameters that help protocol standardization and dose control, without constituting regulatory limits. This study evaluated radiation dose levels in combined chest, upper abdomen, and lower abdomen (CH UA LA) examinations performed on three GE Healthcare CT scanners (Revolution EVO, LightSpeed VCT, and Optima CT 520) at an oncology hospital. Approximately 8,000 examinations were analyzed using the DoseWatch™ software, focusing on the dose descriptors CTDIvol and SSDE, the latter adjusted for patient body size. The results were compared to Dose Index Registry (DIR) reference values to identify deviations and guide protocol optimization. Findings demonstrated that in the Revolution EVO scanner, significant dose reduction was achieved in contrast-enhanced examinations, with median CTDIvol decreasing from ~17 to ~13 mGy and SSDE from ~18 to ~14 mGy, alongside reduced variability. In the LightSpeed VCT, a slight dose increase was observed in both non-contrast and contrast-enhanced studies, without substantial improvement in variability control. Conversely, in the Optima CT 520, dose levels increased – particularly in contrast-enhanced acquisitions – but with greater uniformity and reduced outliers, justified by the need for improved detection of small lesions. In conclusion, protocol standardization contributed to enhanced consistency and diagnostic quality, though its impact varied across scanners. The use of SSDE proved essential for individualized dose assessment, reinforcing its role in continuous optimization according to the ALARA principle (As Low As Reasonably Achievable).**

Keywords— **Computed Tomography (CT), Diagnostic Reference Levels (DRLs), CTDIvol, SSDE (Size-Specific Dose Estimate) and Radiation Dose Optimization.**

I. INTRODUCTION

Computed tomography (CT) is an imaging diagnostic modality widely employed in the investigation and diagnosis of various pathologies. The increasing use of this technique is attributed to its ability to produce high contrast resolution images and to the possibility of multiplanar reconstruction and visualization of anatomical structures [1,2].

However, despite its high diagnostic value, CT presents risk factors that may significantly impact its clinical application and patients' quality of life. From a radiological protection standpoint, the primary concern associated with CT – when compared to other radiological modalities – is the relatively high doses of ionizing radiation to which patients are exposed during examinations [3,4].

Given this scenario, it is essential to adopt measures aimed at optimizing radiological practice and mitigating the risks associated with radiation exposure. To this end, the International Commission on Radiological Protection (ICRP) established the concept of Diagnostic Reference Levels (DRLs). DRLs are reference dose values considered appropriate and safe for diagnostic procedures that involve ionizing radiation, with the goal of preventing unnecessarily high or inappropriate exposures. These levels are based on the principle of dose optimization, promoting the acquisition of diagnostically adequate images while minimizing patient exposure [5,6,7].

It is important to highlight, however, that DRLs should not be interpreted as regulatory dose limits. Rather, they serve as auxiliary tools in the continuous process of clinical protocol evaluation, review, and improvement. In this context, aiming to enhance control and standardization of radiological practices, the American College of Radiology (ACR) developed the Dose Index Registry (DIR), a platform that enables the collection, analysis, and comparison of technical parameters and dose levels used in imaging examinations. This initiative promotes continuous protocol improvement by benchmarking DRLs across different institutions within the network [8,9,10].

Based on these principles, the present study aimed to evaluate radiation dose levels in patients undergoing computed tomography examinations, with a focus on the analysis and revision of the combined protocol for Chest, Upper Abdomen, and Lower Abdomen across different CT scanner models. For this purpose, reference values established by the DIR were used to support the reduction of radiation dose indices and the standardization of protocols across different equipment models without compromising the diagnostic quality of the resulting images.

II. MATERIALS AND METHODS

The dosimetric analyses were conducted in the diagnostic imaging department of an oncology hospital located in the city of Barretos, in the state of São Paulo, Brazil. The assessment of radiation dose levels was performed for the routine combined acquisition protocol of Chest (CH), Upper Abdomen (UA), and Lower Abdomen (LA), using three different CT scanner models from the manufacturer GE Healthcare: Revolution EVO, LightSpeed VCT, and Optima CT 520.

Analyzed protocol

The choice of the combined routine CH, UA, and LA protocol was based on the fact that it represents approximately 75% of the total CT scans performed at the institution. Table 1 presents the main characteristics of the acquisition protocol analyzed in this study.

Dosewatch and analysis standardization

The data used for analysis were extracted from the DoseWatch™ 3.1 software server (GE Healthcare) over a 22-month period. During this period, approximately 80,000 exams of various types performed at the facility were retrieved. Since the study aimed to evaluate only the routine CH, UA, and LA protocol, specific filters were applied to standardize the raw data extracted. Table 2 lists the filtering criteria used for data standardization and subsequent analysis.

Table 1: Description and characteristics of the CH, UA, and LA combined protocol used in this study

Characteristic	Routine CH, UA, and LA Protocol
Anatomical region	Chest, Upper Abdomen, and Lower Abdomen
Intravenous contrast	1.3 mL/kg with a concentration of 350 mg of iodine/mL
Injection rate	The contrast flow rate varies depending on the patient's venous access, typically ranging from 2.5 mL/s to 5.0 mL/s for adequate contrast-enhanced imaging
Phases	- Pre-contrast: used to acquire images of the upper abdomen only - Post-contrast: venous phase (70-second delay), used to acquire images of the entire study (chest, upper and lower abdomen)
Reconstruction filters	Soft tissue filter for the entire acquired anatomy; high-resolution reconstruction applied only to lung parenchyma using a specific parenchymal filter
Width (W) / Window Level (L)	Soft tissues – W: 400 ; L: 40 Lung parenchyma – W: 1500 ; L: 700

Table 2: Filter criteria applied to standardize data extracted from DoseWatch for the routine CH, UA, and LA protocol

Scanner Model	Revolution EVO	LightSpeed VCT	Optima CT 520
Description	CT Scanner 1	CT Scanner 2	CT Scanner 3
Study	CH UA LA	CH UA LA	CH UA LA
Protocol	6.4	6.4	6.5
Irradiation Events	4	4	4
Series Type	Helical	Helical	Helical
Series Description	NC 2.5 mm CE 2.5 mm	NC 2.5 mm CE 2.5 mm	NC 2.5 mm CE 2.5 mm

The filtering criteria described above correspond to the specific protocol analyzed for each scanner. The protocol description refers to the protocol numbers visible on each device. The "irradiation events" filter refers to how many times the patient was exposed to radiation to complete the exam, standardized here as four events: scout (localizer) anteroposterior (AP); scout (localizer) lateral; pre-contrast phase of the upper abdomen; contrast-enhanced phase covering the chest, upper, and lower abdomen, totaling four exposures.

The series type was helical, with descriptions denoting contrast status: NC (non-contrast) and CE (contrast-enhanced), both with 2.5 mm slice thickness.

Additional filters related to acquisition parameters, such as kilovoltage (kV), tube current (mA), rotation time (s/rot), pitch factor, and detector coverage were also used to ensure that the analyzed data belonged to a highly specific group. After applying all standardization filters, approximately 8,000 exams were retained for analysis.

CT Dose Descriptors

In CT imaging, two key dose descriptors are used to identify, quantify, and control the levels of radiation, patients are exposed to during exams:

1. *$CTDI_{vol}$* (Computed Tomography Dose Index – volume): estimates the maximum radiation dose per unit volume in a single image slice;
2. *DLP* (Dose-Length Product): represents the total radiation dose delivered across the length of the scanned volume.

Since both metrics are derived from cylindrical polymethyl methacrylate (PMMA) phantoms of 16 cm or 32 cm diameter, assuming all patients have similar body structures and ignoring individual anatomical variations, some uncertainty may be introduced. To address this limitation, the *SSDE* (Size-Specific Dose Estimate) metric incorporates corrections to $CTDI_{vol}$ values based on patient-specific physical characteristics, typically, anteriorposterior (AP) and lateral (LAT) body dimensions.

Following the extraction of $CTDI_{vol}$ and SSDE values, this study conducted both qualitative and quantitative assessments of the data. These values were compared with reference values from the DIR at the 25th, 50th, and 75th percentiles. For any measurements that deviated substantially from reference standards, acquisition parameters were reviewed, and protocols were optimized and normalized across different equipment models, always ensuring the preservation of image quality.

Quantitative Analysis

The qualitative analysis conducted in this study aimed to verify the improvement in image quality, considering the optimization of radiation dose without compromising medical diagnosis, by evaluating the images after implementing changes to the acquisition protocol parameters.

The image analyses were performed in collaboration with the team of specialist radiologists from the department, ensuring that the modifications proposed in the study were effectively applied to the institution's clinical routine. In this way, it was possible to ensure that the changes resulted in images with adequate diagnostic quality, combined with an optimized radiation dose, promoting direct benefits to patient safety and care.

III. RESULTS

Radiation dose descriptor values (in mGy) obtained from CT exams were evaluated in two distinct periods: before and after specific modifications to the image acquisition protocol. The data analysis for all three CT scanners was also separated by acquisition phase — non-contrast (NC) and contrast-enhanced (CE) — using two dose parameters: $CTDI_{vol}$ (Computed Tomography Dose Index Volume): standardized dose index provided by the equipment, and SSDE (Size-Specific Dose Estimate): patient-specific dose estimate, accounting for individual body size.

The statistical analysis of radiation doses in CT exams was conducted using robust descriptive measures, including the median (P50), percentiles (P25 and P75), and interquartile range (IQR), comparing pre- and post-protocol modification periods on the Revolution EVO scanner. Figures 1, 2 and 3 presents the boxplot graph for the Revolution EVO, Lightspeed VCT and Optima CT scanners under analytical conditions.

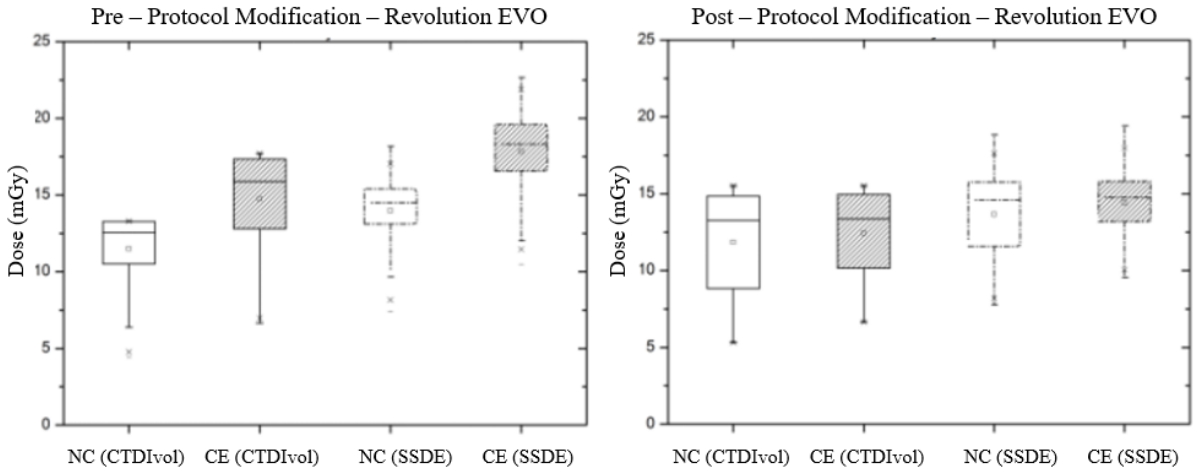

Figure 1: Boxplot representation of radiation dose data recorded on the Revolution EVO scanner using the CH UA LA protocol, pre- and post-modifications in the NC (non-contrast) and CE (contrast-enhanced) phases, for $CTDI_{vol}$ and SSDE parameters.

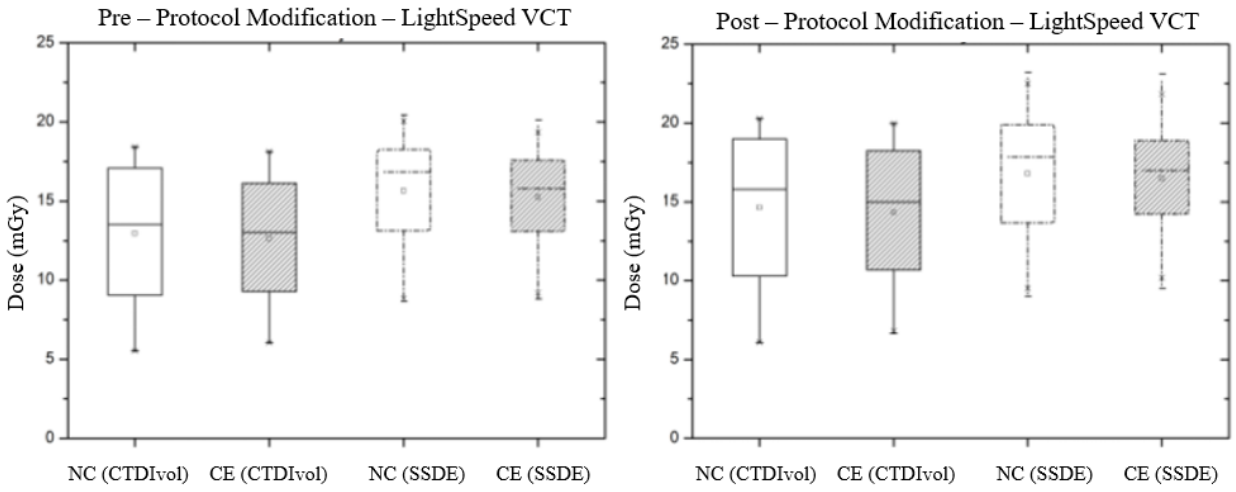

Figure 2: Boxplot representation of radiation dose data recorded on the LightSpeed VCT scanner using the CH UA LA protocol, pre- and post-modifications in the NC (non-contrast) and CE (contrast-enhanced) phases, for $CTDI_{vol}$ and SSDE parameters

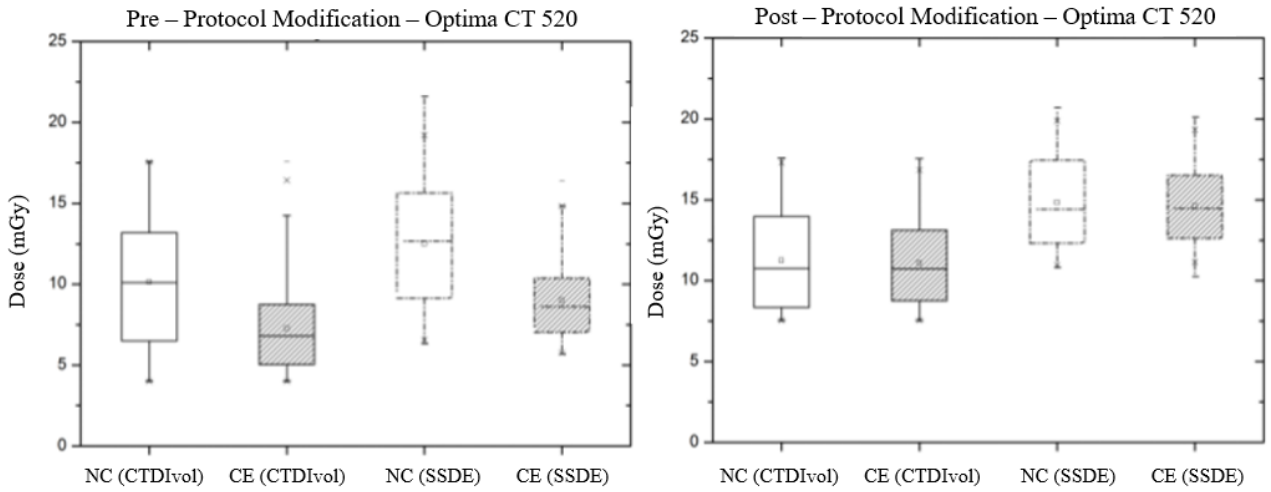

Figure 3: Boxplot representation of radiation dose data recorded on the Optima CT 520 scanner using the CH UA LA protocol, pre- and post-modifications in the NC (non-contrast) and CE (contrast-enhanced) phases, for $CTDI_{vol}$ and SSDE parameters

Although dose values increased, internal variability (IQR) showed a slight decrease, especially for SSDE, suggesting more consistent and homogeneous dose application. The lower variability and disappearance of outliers post-modification indicate a more standardized process with improved dose control. These changes are compatible with clinical practices that aim to optimize image quality while maintaining control over radiation exposure, balancing diagnostic efficacy with safety. The modifications made to the CH UA LA protocol for each scanner evaluated in this study are detailed in Table 3.

Table 3 presents the acquisition parameters for both the original protocol (pre-modification) and the modified protocol (post-modification).

In addition to dose optimization, these changes aimed to standardize the institutional protocol. However, complete parameter uniformity was not achievable due to technological and design differences among the scanners.

Initially, $CTDI_{vol}$ and SSDE dose metrics from the original protocols were quantified for all three CT scanners. These results were then compared with national Diagnostic Reference Level (DRL) benchmarks, and the diagnostic image quality was assessed. Based on these findings, targeted adjustments were made to optimize dose levels and improve the diagnostic quality of the acquired images.

Table 3: Acquisition parameters for the CH UA LA routine protocol (pre- and post-modification) in the three scanner models evaluated

Routine Protocol for Chest, Upper Abdomen, and Lower Abdomen (CH UA LA)
Pre- and Post-Modification

Parameters	Revolution EVO		LightSpeed VCT		Optima CT 520	
Description	NC	CE	NC	CE	NC	CE
Focal spots (mm)	1.20	1.20	1.20	1.20	1.20	1.20
Slice thickness (mm)	2.50	2.50	2.50	2.50	2.50	2.50
Spacing between slices (mm)	2.50	2.50	2.50	2.50	2.50	2.50
Number of macro rows in detector	64	64	64 →32	64 →32	24	24
Ten-time GE noise index	134	134	150	150	150 →142	182 →142
Nominal single collimation width (mm)	0.63	0.63	0.63	0.63	0.83	0.83
Nominal total collimation width (mm)	40	40	40 →20	40 →20	20	20
kVp	120	120	120	120	120	120
Maximum x-ray tube current (mA)	300 →350	400 →350	400	450	350	350
Pitch	1.375	0.984 → 1.375	1.375	1.375	1.375	1.375
Exposure time per rotation (s/rot)	0.70	0.50 →0.70	0.80	0.70 →0.80	0.80	0.80
Table speed (mm/s)	78.57	78.57	68.75 →27.50	78.57 →27.50	34.38	34.38
Table feed per rotation (mm/rot)	55.00	39.38 →55.00	55.00 →39.29	55.00 →34.38	27.50	27.50
Iterative recon level	10 →20	10 →20	-	-	30 →20	30 →20
Iterative recon annotation	AR10→AR20	AR10→AR20	-	-	SS30→SS20	SS30→SS20

IV. DISCUSSION

In the Revolution EVO scanner, a significant reduction in radiation dose was observed in contrast-enhanced examinations, for both $CTDI_{vol}$ and SSDE. The median decreased by approximately 4 mGy in these groups, accompanied by a decrease in IQR, indicating not only lower radiation exposure but also greater consistency in the protocols after the modification. This pattern suggests that the changes implemented in the equipment contributed to a real optimization of technical parameters, potentially through adjustments in reconstruction algorithms, automated acquisition protocols, or patient-adaptive dose calibration.

In contrast, the data from the LightSpeed VCT scanner showed a tendency toward increased average doses across all analyzed groups. Specifically, in contrast-enhanced (CE) exams using $CTDI_{vol}$, the median increased by about 1 mGy and the IQR rose from 7 to 9 mGy, indicating greater variability and less control over technical parameters. Although the SSDE-based groups maintained their variability (with constant IQR), the general increase in medians suggests that the adjustments made did not lead to dose reduction and, in some cases, may have resulted in an unnecessary increase in radiation exposure.

The results also revealed a significant increase in absorbed doses after protocol modification in the Optima CT 520 scanner, with higher $CTDI_{vol}$ and SSDE medians. This increase indicates a protocol enhancement aimed at improving diagnostic image quality, in line with clinical practices that balance radiation dose with image quality. A decrease in dose variability was also noted, particularly for SSDE, suggesting greater protocol standardization and control, likely due to technical improvements and staff training. The greater increase in SSDE compared to $CTDI_{vol}$ underscores the importance of using metrics that account for patient anatomy, reinforcing SSDE as a more accurate estimate of effective dose. Collectively, the findings point to examination optimization, with more homogeneous and justified dose levels, although continuous monitoring is recommended to ensure that the benefit-risk ratio remains favorable.

Finally, the data suggests that the protocol modifications improved dose uniformity according to the features and technology available in each equipment model. Moreover, the clinical examination standard was elevated, but ongoing monitoring is necessary to ensure that any dose increases remain justified by improvements in image quality and clinical benefit.

V. CONCLUSION

The appropriate use of the DoseWatch software, combined with detailed analysis of the obtained data, demonstrated that the Revolution EVO scanner showed a reduction in mean radiation doses following protocol updates, indicating gains in efficiency and greater standardization of examinations. The SSDE index proved to be a fundamental tool for evaluating patient effective dose, now with reduced variability, which reinforces the consistency of the new protocol and its alignment with the

dose optimization principles (ALARA – As Low As Reasonably Achievable).

For the LightSpeed VCT scanner, the analysis revealed no significant reduction in radiation doses after protocol modification. In this case, the changes were mainly aimed at improving image quality, especially in terms of reconstruction, rather than reducing radiation dose.

On the other hand, the Optima CT 520 scanner showed an increase in mean doses, particularly in contrast-enhanced examinations. This increase was intentional and justified by the objective of enhancing diagnostic quality, since the previous protocol showed limitations in detecting smaller lesions, compromising the accuracy of the radiological reports.

Overall, the results reinforce the importance of SSDE as a metric that is sensitive to patient anatomical variations, being essential for a more individualized dose assessment. Another key achievement of this study was the standardization of the CH UA LA protocol across different CT scanners, according to the technologies available in each tested model, in order to ensure the best possible image quality for the most appropriate radiation dose.

Additionally, continuous monitoring and periodic review of the modified protocols are recommended to ensure that dose levels remain within acceptable limits, without compromising diagnostic quality and always respecting the principles of radiation protection.

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