Journal of Chemical Health Risks

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JCHR (2025) 15(1), 391-399 | ISSN:2251-6727

# Establishing Local Diagnostic Reference Levels in Adult Uroscan CT Examinations using Size-Specific dose Estimates (SSDE) and Ctdivol in Morocco

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***(Received: 16 November 2024 Revised: 11 December 2024 Accepted: 11 January 2025)***

**KEYWORDS**
CTDIvol, SSDE, DRLs, ED, CT scans.

**ABSTRACT:**
$CTDI_{vol}$ is a commonly used dose metric in CT scans, calculated based on a 16 cm or 32 cm diameter phantom. However, $CTDI_{vol}$ does not provide an accurate representation of the patient's actual dose. The Size-Specific Dose Estimate (SSDE) is a dose parameter that takes into account the patient's body size, specifically the Effective Diameter (ED). This study aims to report the SSDE and $CTDI_{vol}$ values for adult uroscan examinations in Morocco in order to establish local diagnostic reference levels (DRLs) for CT exams and to determine the correlation between these two metrics.

The study was conducted at the University Hospital of Casablanca with a sample of 52 adult patients undergoing uroscan examinations. SSDE values were calculated using the method described in AAPM Report No. 204. The results showed that, in general, SSDE values were higher than CTDIvol values for the same patients. Furthermore, the highest SSDE and CTDIvol values were observed: 26.18 mGy and 20.95 mGy, respectively, for the GE Revolution EVO 64-slice scanner, and 15.10 mGy and 10.79 mGy for the GE Optima CT 540 16-slice scanner. These results highlight the influence of patient size

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JCHR (2025) 15(1), 391-399 | ISSN:2251-6727

on dose calculations, with SSDE showing potential as a key parameter in establishing DRLs, as indicated by the high correlation coefficient ($R^2 = 0.8992$).

## Introduction

Computed Tomography (CT) scanning is a rapidly evolving medical imaging technology. Its ability to generate high-quality cross-sectional images has greatly enhanced disease diagnosis, leading to an increase in its usage. This growing use necessitates proper monitoring to ensure radiation protection and standardization across healthcare facilities [1]. The radiation dose from CT scans is significantly higher 10 to 100 times than that of conventional X-rays, making radiation-related risks a key concern in the use of CT as an imaging technique [1][2].

CT scan dose parameters include the Dose Length Product (DLP) and the Volumetric Computed Tomography Dose Index (CTDIvol), which represent the total radiation dose for a single scan [3-9]. DLP is calculated by multiplying the CTDIvol, as indicated in the scan report, by the scan length [10]. CTDIvol is derived from CTDI, measured using a 100 mm pencil ion chamber on a phantom with diameters of 32 cm for body scans and 16 cm for head scans [11]. However, the fixed size of these phantoms does not accurately reflect the varying dimensions of human bodies.

To address this, the American Association of Physicists in Medicine (AAPM) introduced a more patient-specific CT dose metric in task group report no. 204. This metric, known as the Size-Specific Dose Estimate (SSDE), incorporates a conversion factor based on the patient's Effective Diameter (ED), better accounting for individual body sizes [12]. SSDE is a more accurate reflection of the actual dose for patients of different weight categories, including underweight, normal weight, and overweight individuals [13]. The influence of body size on radiation dose is especially pronounced in pediatric patients [14]. SSDE has proven to be a more reliable dose estimate compared to CTDIvol, particularly in CT exams like myocardial perfusion SPECT/CT with Automatic Exposure Control (AEC) systems [15]. For pediatric head CT scans, SSDE values are generally lower than CTDIvol, indicating that CTDIvol may overestimate dose in these cases [16].

Given CT's significant contribution to radiation exposure in medical imaging, it is essential to establish Diagnostic Reference Levels (DRLs), which serve as benchmarks to identify potentially high radiation doses in clinical practice [17]. SSDE shows promise as a parameter for determining DRLs. Size-based DRLs enable facilities to tailor their protocols more precisely, ensuring appropriate radiation doses based on patient size and reducing unnecessary exposure. For example, size-specific DRLs developed for pediatric abdominal/pelvic CT scans in Japan demonstrated that SSDE provides a valuable indicator for assessing radiation dose exposure [18] [19].

This study aims to report SSDE values for adult abdominal CT scans, examine the correlation between SSDE and CTDIvol, and evaluate SSDE's potential as a DRL parameter. Incorporating SSDE into national DRLs could offer a more accurate assessment of radiation exposure in CT examinations [20].

## Materials and methods

### Sample Selection

This study included 52 adult patients, of both sexes, who underwent abdominopelvic uroscan CT scans for clinical reasons. A waiver of informed consent was granted to the patients. Data were extracted from our institutional archives for examinations performed between April 17, 2024, and May 25, 2024. The scans were performed using two devices, a (GE-Optima CT 540 16-slice, New York, US.) and a (GE-Revolution EVO 64-slice New York, US.), with consistent technical parameters for all patients. Patients had the option to refuse the use of their medical data for research purposes. The scans of these patients were therefore excluded from the study.

The CTDIvol, or Computed Tomography Dose Index Volume, is a CT scan dose parameter that accounts for the pitch component. Pitch is defined as the ratio of the table movement per rotation to the table travel distance (in mm) during a complete gantry rotation (360°), divided by the beam width (calculated as the number of

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JCHR (2025) 15(1), 391-399 | ISSN:2251-6727

detectors (N) multiplied by the width of each detector (T)) [10].

CTDIvol is expressed as shown in equation [1]. The CTDIw is a weighted combination of CTDI measurements taken at the center and periphery of a phantom, where the central CTDI is weighted by 1/3 and the peripheral CTDI by 2/3 [10]. The reference phantom used has diameters of 16 cm and 32 cm, meaning that the CTDIvol value does not yet accurately reflect the dose received by patients of different sizes [21].

$\mathrm{CTDI}_{vol} = \frac{1}{Pitch} \times CTDI_w$ **(1)**

The CTDIvol was calculated by the scanner based on the average tube current throughout the examination and was recorded for each scan series. For each patient, the anteroposterior (AP) and lateral (LAT) dimensions at the mid-level were measured from the axial CT images using digital calipers on the scanner console. These values were combined to provide a single measurement representing the patient's size (AP + LAT).

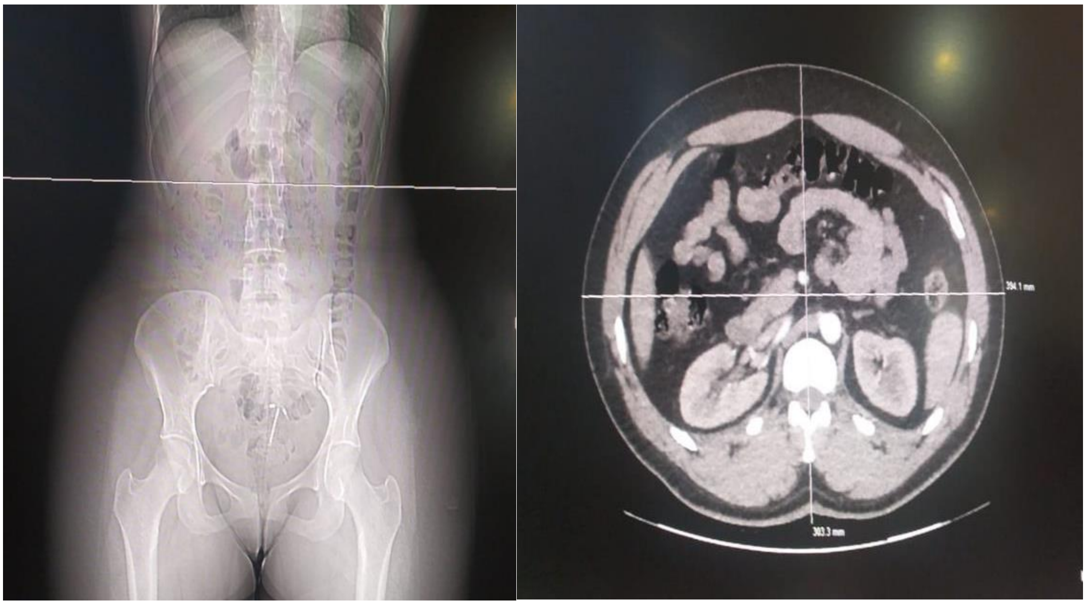

**Figure 1: Assessment of Size Factor (fsize) for Calculating Size-Specific Dose Estimates Based on CTDIvol**

The AAPM Report 204 offers tables based on AP + LAT, which are used to determine the size factor (fsize). When multiplied by the CTDIvol, this size factor provides the SSDE. Alternatively, analytical expressions can be applied to calculate the effective diameter and the size factor, as shown in equation (2) [22].

SSDE = fsize × CTDIvol **(2)**

The effective diameter (ED) used for the calculations is based on the measurement of the anteroposterior diameter (DAP) and the lateral diameter (DLAT), as shown in equation (3) [12] [22].

$D_e = \sqrt{\mathrm{DAP} \times \mathrm{DLAT}}$ **(3)**

This study also determines the correlation between CTDIvol and SSDEDE. This correlation is assessed by calculating the coefficient of determination ($R^2$), which measures the extent to which the independent variable explains the dependent variable. When $R^2$ is close to 1, it indicates that the independent variable provides a strong explanation of the dependent variable. Conversely, if $R^2$ is far from 1 or approaches 0, it suggests a weaker explanatory power of the independent variable. According to Hair et al., an $R^2$ of 0.75 is considered strong, an $R^2$ of 0.50 moderate, and an $R^2$ of 0.25 weak [23].

This correlation is utilized to evaluate the potential of SSDEDE in establishing Diagnostic Reference Levels (DRLs) [24]. A strong correlation between Dw and SSDE implies that the SSDE value could be implemented as an institutional DRL [25]. BAPETEN's guidelines indicate that the DRL value for each facility is set at the median (second quartile) of the data distribution. Other studies also recommend using the median (second quartile) to establish the clinical DRL value based on SSDEAP, SSDELAT [25].

**Results and discussion**

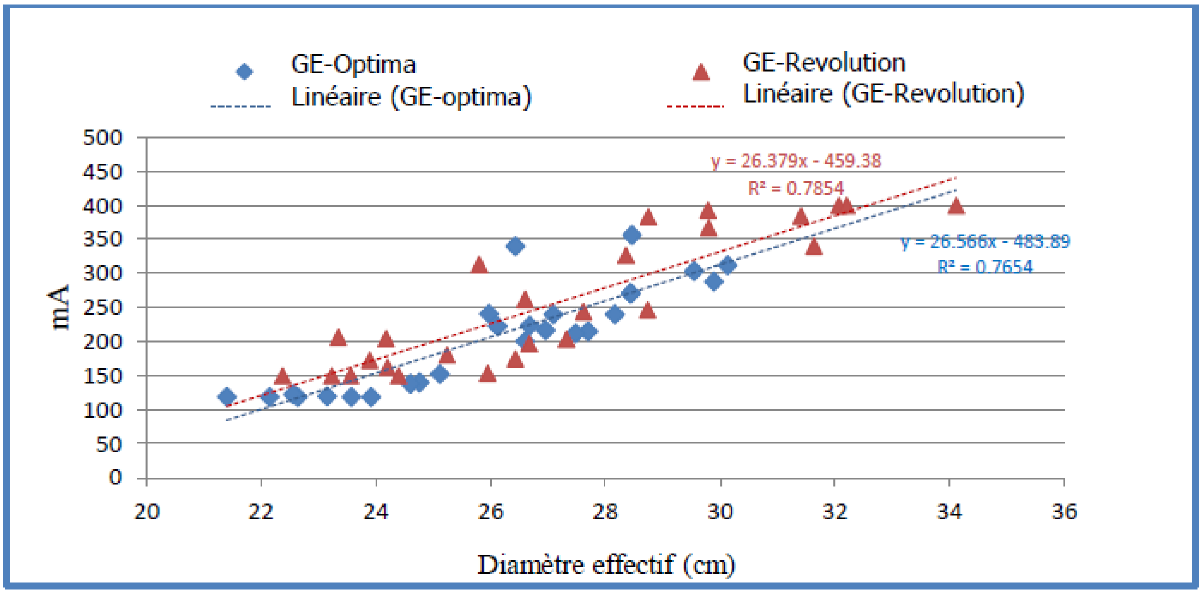


**Figure 2: Variation of Current (mA) as a Function of Effective Diameter**

This figure illustrates a clear positive linear relationship between the tube current (mA) and the effective diameter. Both the GE-Revolution and GE-Optima scanners exhibit a strong correlation with $R^2$ values of 0.78 and 0.76, respectively. The increase in current as the effective diameter grows suggests that the automatic exposure control system adjusts the current based on patient size to ensure consistent image quality across different body types. This adjustment is crucial for optimizing dose delivery while maintaining diagnostic image quality, particularly in larger patients who may require higher currents to reduce noise.

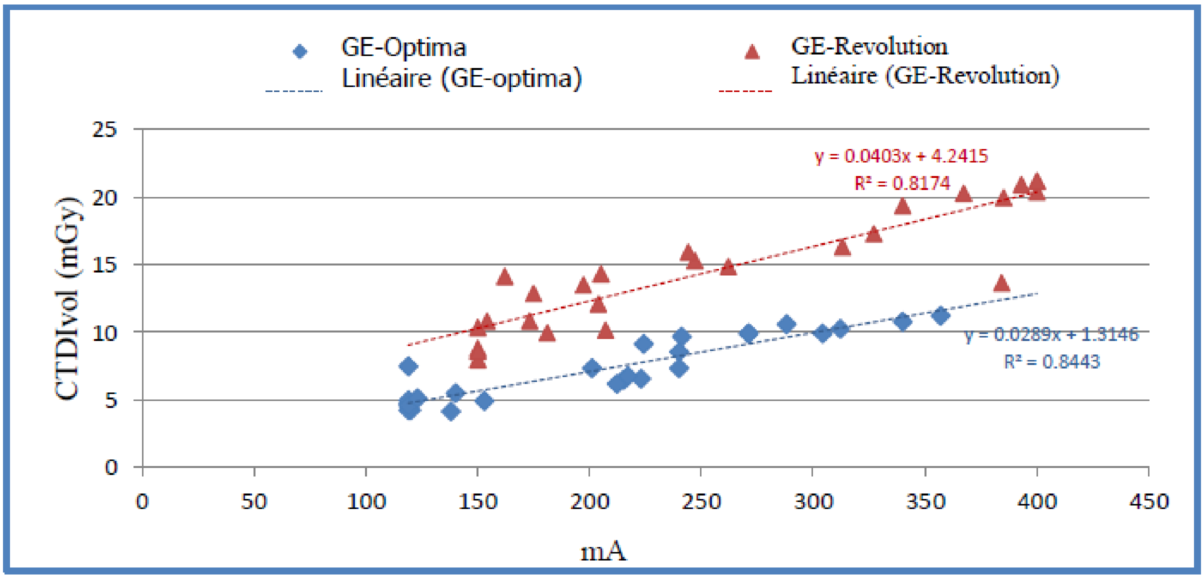


**Figure 3: Variation of CTDIvol as a Function of mA**

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JCHR (2025) 15(1), 391-399 | ISSN:2251-6727

This figure shows the relationship between CTDIvol and the tube current (mA), demonstrating a strong positive linear correlation for both GE-Revolution and GE-Optima scanners, with $R^2$ values of 0.81 and 0.84, respectively. The increase in CTDIvol with increasing current highlights the direct proportionality between the radiation dose and the tube current used during CT examinations. This linear trend confirms that higher tube currents, necessary for larger patients or for high-quality imaging, result in higher radiation doses. These findings underline the importance of dose optimization strategies, such as automatic exposure control, to balance image quality and patient safety.

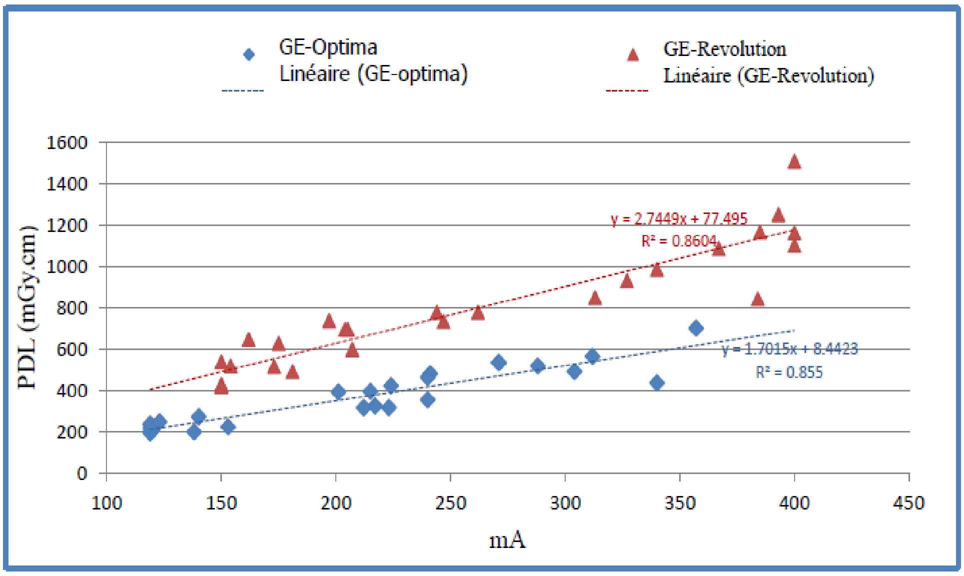


**Figure 4: Variation of Dose Length Product (DLP) as a Function of mA**

The graph shows a strong positive correlation between the Dose Length Product (DLP) and tube current (mA) for both scanners. The correlation coefficients ($R^2$ = 0.85 for GE-Optima and $R^2$ = 0.86 for GE-Revolution) indicate that DLP increases proportionally with mA. This finding suggests that higher tube currents, which are necessary to maintain image quality in larger patients or more complex scans, lead to higher radiation doses.

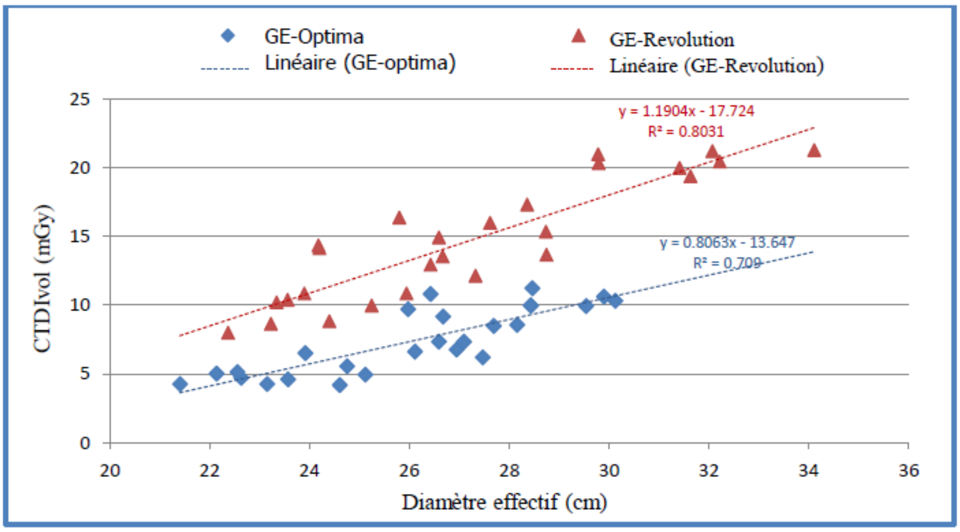


**Figure 5: Variation of CTDIvol as a Function of Effective Diameter**

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This figure demonstrates a strong positive linear correlation between CTDIvol and the effective diameter, with $R^2$ values of 0.80 for GE-Revolution and 0.71 for GE-Optima. As the effective diameter increases, so does the CTDIvol, reflecting the adjustments made by automatic exposure control systems to account for larger patient sizes. This ensures that image quality is maintained but results in higher radiation doses for larger patients. The strong correlation highlights the impact of patient size on dose, which is essential for dose optimization and establishing size-specific Diagnostic Reference Levels (DRLs)

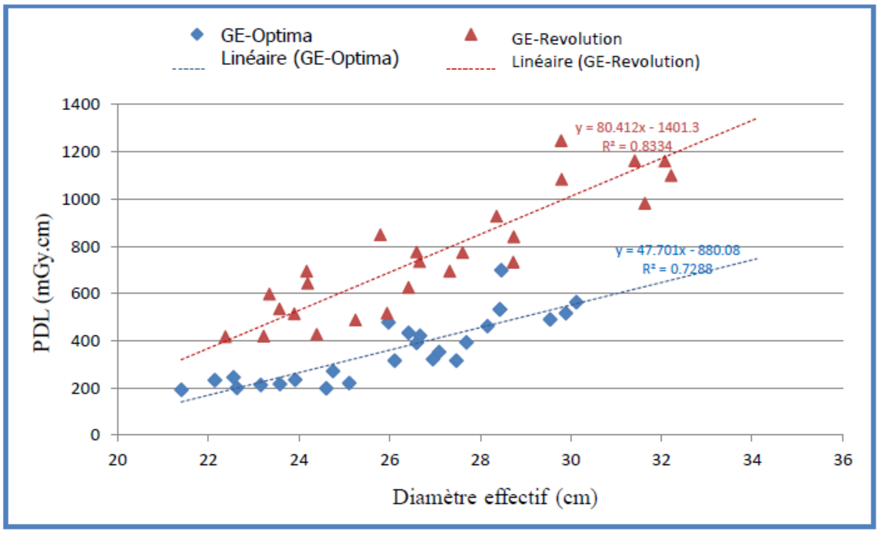


**Figure 6: Variation of DLP as a Function of Effective Diameter**

This figure shows a positive correlation between DLP and the effective diameter, with $R^2$ values of 0.83 for GE-Revolution and 0.72 for GE-Optima. The increase in DLP with effective diameter reflects how patient size influences the total radiation dose. Larger patients require higher tube currents, leading to a corresponding rise in DLP.

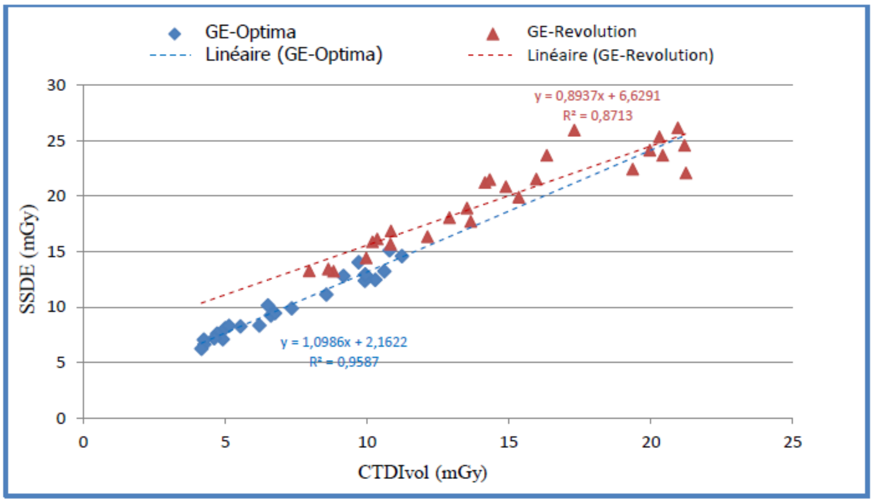


**Figure 7: Variation of SSDE as a Function of CTDIvol**

The graph illustrates a very strong positive correlation between SSDE and CTDIvol, with correlation coefficients of $R^2 = 0.87$ for GE-Revolution and $R^2 = 0.95$ for GE-Optima. The SSDE increases with CTDIvol, showing that the size-specific dose estimate (SSDE) closely follows the CTDIvol but provides a more individualized representation of the patient's dose. The high correlation indicates that SSDE is a reliable

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metric for assessing patient dose, and its use could enhance the accuracy of dose monitoring in clinical practice

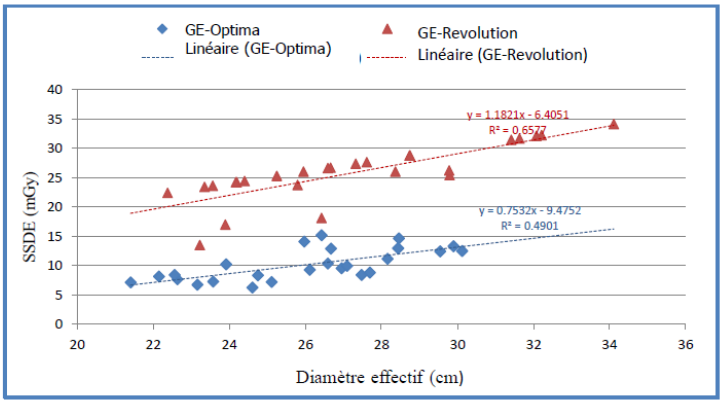


**Figure 8: Variation of SSDE as a Function of Effective Diameter**

This figure shows a moderate positive correlation between SSDE and the effective diameter, with $R^2$ values of 0.65 for GE-Revolution and 0.50 for GE-Optima. As the effective diameter increases, the SSDE rises, though the correlation is not as strong as for CTDIvol.

These analyses highlight the significance of both CTDIvol and SSDE as essential metrics in dose optimization and patient safety in CT imaging. The strong correlations observed between dose parameters and patient size underline the importance of adjusting scan settings based on individual characteristics to ensure effective radiation protection.

- **Evaluation of Diagnostic Reference Levels (DRLs)**

Although the impact of patient size on radiation dose is well established, national dose limits (LOD) previously provided only a single value for each exam, based on a standard-sized phantom representing an average patient, a single patient size, or averaged data for all patient sizes.

In this study, we will calculate local Diagnostic Reference Levels (DRLs). For this purpose, the Dose Length Product (DLP), volumetric dose index (CTDIvol), and Size-Specific Dose Estimate (SSDE) were evaluated by determining the 75th percentile as the Diagnostic Reference Levels and comparing them to the DRLs established by the United States.

In this study, for the calculation of Diagnostic Reference Levels (DRLs), we focus exclusively on the GE optima 16-slice scanner, as it is the most commonly used generation in Morocco.

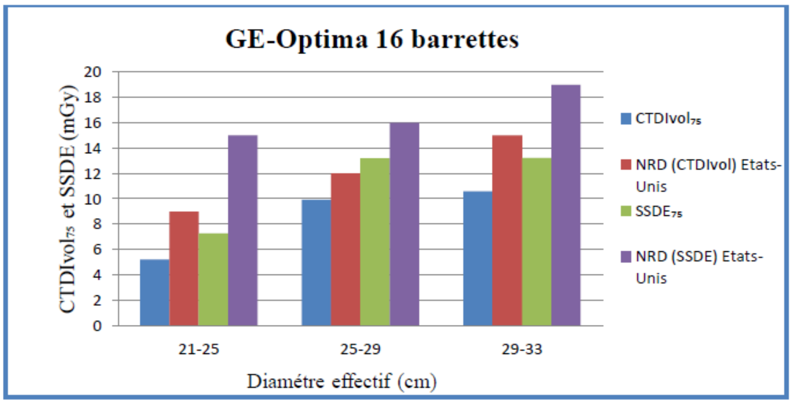


**Figure 9: CTDIvol$_{75}$ et SSDE$_{75}$ de GE-Optima 16 barrettes selon la morphologie comparée aux NRD des Etats-Unis.**

The graph in Figure 9 presents comparative data for three size ranges: 21-25 cm, 25-29 cm, and 29-33 cm. Four indicators are compared, including $CTDIvol_{75}$ (75th percentile for CTDIvol) and $SSDE_{75}$ (75th percentile for SSDE) compared to the Diagnostic Reference Levels (DRLs) proposed by the United States in 2017 [12]. The results show that the $CTDIvol_{75}$ and $SSDE_{75}$ values for the GE-Optima 16-slice scanner in Morocco are consistently lower than the DRLs set by the United States for all size categories. This indicates that the radiation doses measured in this study fall within a safe and acceptable range, aligned with international standards. It also suggests that the current practices in the use of the GE-Optima 16-slice scanner are optimized, providing sufficient image quality while maintaining low patient radiation exposure. The fact that the local values are lower than the US DRLs demonstrates a commitment to patient safety and dose reduction, highlighting the efficiency of the scanning protocols used in Morocco. This outcome reinforces the importance of continuous monitoring and adherence to DRLs to ensure that doses remain within acceptable limits without compromising diagnostic quality. In conclusion, Figure 10 supports that the dose levels in Morocco, as measured by the $CTDIvol_{75}$ and $SSDE_{75}$, are well-optimized and meet international standards, making a strong case for the adoption of these practices as local benchmarks.

## Conclusion

This study allowed for the comparison of CTDIvol and SSDE values obtained during computed tomography exams for adult patients in Morocco, using two GE scanners (Revolution EVO 64-slice and Optima 16-slice), with the Diagnostic Reference Levels (DRLs) proposed by the United States. The results show that the CTDIvol and SSDE values measured in Morocco are consistent with or even lower than international DRLs, indicating good control of the doses administered to patients. These findings emphasize the importance of dose optimization and the use of size-specific dose indices to ensure minimal exposure while maintaining high diagnostic image quality. Integrating SSDE into imaging protocols could further refine local DRLs and enhance patient radiation protection.

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