International Journal of Biomedicine 16(2) (2026) 187-196
http://dx.doi.org/10.21103/Article16(2)_OA5

ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF BIOMEDICINE

Quantitative Analysis of Computed Tomography Image Acquisition Factors and Demographic Characteristics in Pediatric Brain and Head Scans

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Abstract

Background: While computed tomography (CT) imaging is vital for diagnosing brain issues, it can expose children to unnecessary risks if not optimized. The aim of this study was to identify the key predictors of radiation dose in pediatric head and brain CT scans, including patient age, scan type, kilovoltage, and field of view (FOV), so that these assessed technical and demographic factors could be used to help radiologists develop dose-optimized protocols for pediatric populations in ways that will minimize radiation doses while maintaining diagnostic image quality.

Methods and Results: We investigated a sample of 138 patients aged 18 years or younger from a single institution who had undergone pediatric brain and head CT scans. Descriptive statistics and data visualization, including correlation tests, were initially performed to explore the data and assess the significance of relationships between the radiation dose indices (CT dose index volume [CTDIvol] and dose-length product [DLP]) and the associated predictors of radiation dose (age, scan type, peak kilovoltage [kVp], tube current, and FOV). The radiation dose indices were found to be higher for the head than for the brain CT scans, which indicated that the patients who underwent head CT were exposed to higher radiation doses. The diagnostic reference levels were set at the 75th percentile of the radiation dose indices for both test sites and age groups, as shown in the box plots. Highly significant linear relationships were found between patient age and the radiation dose indices, (CTDIvol and DLP), ($P<0.000$ for both), indicating that the required radiation dose tended to increase with age. In this study, the main radiation dose parameters in pediatric neuroimaging were significantly influenced by patient age, scan type, tube current, and kilovoltage. These findings underscore the critical need for age- and indication-adjusted CT protocols to minimize radiation exposure in children without compromising diagnostic utility. The most important finding of this study is the derivation of best-fit model equations for radiation dose indices using our patients' scan parameters. These equations can be used to predict (calculate) the optimal scan parameters for a single variable of the radiation dose indices, while keeping other variables constant. Insights obtained can help radiologists create safer, child-specific scanning protocols, improve radiology practices, and perform more research to minimize risks worldwide.(**International Journal of Biomedicine. 2026;16(2):187-196.**)

Keywords: computed tomography • children • brain scan • radiation dose

For citation: Abuhadi N. Quantitative Analysis of Computed Tomography Image Acquisition Factors and Demographic Characteristics in Pediatric Brain and Head Scans. International Journal of Biomedicine. 2026;16(2):187-196. doi:10.21103/Article16(2)_OA5

Abbreviations

CT, computed tomography; **CTDIvol**, CT dose index volume; **DLP**, dose-length product; **DRLs**, diagnostic reference levels; **FOV**, field of view; **kVp**, peak kilovoltage; **VIF**, variance inflation factor.

Introduction

Diagnostic radiology is a critical practice in medicine. Computed tomography (CT) is widely used in pediatric and adult patients and has transformed medical diagnostics through its fast, precise imaging capabilities, which can be applied to a range of clinical conditions.[1] Unlike other radiological imaging techniques, CT poses a high risk of radiation exposure because multiple thin slices of the target tissue must be captured, leading to multiple exposures in a single session to enable high-detail, multiplanar computer-generated reconstructions and 3D rendering of the image.

CT scans deliver significantly higher ionizing radiation doses, often 50 to 1,000 times more than conventional X-rays, making them a major contributor (up to 50% or more) to medical radiation exposure. This high-dose exposure increases risks for cancer, with some estimates suggesting a one in 1,000 to 2,000 chances of cancer per scan and a potential contribution to 2% of all cancers.[2]

Because CT doses are initially high, medical imaging optimization is particularly important in pediatrics to reduce radiation exposure for high-risk pediatric patients. As the clinical use of this technique continues to rise, optimization has become a critical requirement. One of the most serious concerns for individuals, specifically children, who undergo diagnostic CT is the elevated risk associated with ionizing radiation.[3,4] Several studies have shown that children are more vulnerable to radiation hazards than adults, as their rapidly developing tissues and longer life expectancy make them more prone to developing radiation-induced cancers later in life.[5] They also have smaller body sizes and receive a higher radiation dose per unit of tissue when conventional adult protocols are used.[6,7]

A troubling trend is the use of adult protocols for children in some radiology departments, as this leads to higher levels of radiation exposure in these patients.[8,9] Pediatric CT scans, such as brain scans, are often employed to diagnose neurological issues, so radiation exposure remains a major concern in pediatric brain CT despite its known clinical benefits. Minimizing radiation exposure in pediatric CT is thus essential to prevent or lessen its radiogenic effects.

According to El-Nachef et al.,[10] scan parameters should be optimized for pediatric patients to ensure diagnostic image quality while maintaining safety. In so doing, the basic goal of radiation safety should be adhered to, that is, to achieve quality diagnostic images using the principle of radiation doses that are "as low as reasonably achievable" (ALARA) Outdated protocols and equipment are still being widely used in many hospitals, particularly in those in low-resource settings, so patients are continuing to be unnecessarily exposed to high radiation.[11] Although the literature provides a solid foundation for radiation risks and dose-reduction practices, several critical research gaps persist. First, quantitative modeling is rarely used. In most studies, researchers have relied on descriptive analyses rather than multivariate regression to determine the independent contributions of scan parameters to radiation dose. Second, researchers in only a few studies have considered the radiation impact of specific scan types (brain or head) within controlled datasets, despite known differences in radiation exposure. Third, the volume of dose optimization research in low-resource settings, where outdated equipment and poorly standardized procedures continue to pose serious challenges, is significantly lacking.[12,13] Therefore, there is a need for empirical research to examine how various technical factors affect radiation dose in pediatric CT scans.

The aim of this study was to identify the key predictors of radiation dose in pediatric head and brain CT scans, including patient age, scan type, kilovoltage, and field of view (FOV), so that these assessed technical and demographic factors could be used to help radiologists develop dose-optimized protocols for pediatric populations in ways that will minimize radiation doses while maintaining diagnostic image quality.

Materials and Methods

Subjects

In this retrospective cross-sectional study, we evaluated CT head and brain procedures performed on 138 patients aged 18 years or younger (average age of 7.42 years) at a single hospital (Southern Hospital, Saudi Arabia).[14] The patients selected for this study met strict selection criteria. The basic inclusion criteria were:

- Patients ≤18 years of age
- Patients who have a brain or head CT scan for non-emergency diagnostic purposes
- Patients for whom complete data were available (patient age, peak kilovoltage [kVp], tube current [mA], FOV, CT dose index volume [CTDIvol], and dose-length product [DLP])

The basic exclusion criteria were:

- Patients who were <18 years of age but had incomplete data
- Patients who had scans performed in the emergency department
- Patients who were originally planned to receive a low-dose CT scan.

Relationship between Image Acquisition Factors and Radiation Dose in CT Scanners

Management of the radiation dose is required to optimize imaging protocols. In CT scans, two radiation dose indices (CTDIvol and DLP) are used in radiation dose management.[1,2]

The technical image acquisition factors applied during the CT scans in this study were X-ray, tube current (mA), peak kilovoltage (kVp), the size of the scanned area or FOV, and scan type (head or brain), in addition to age as a demographic factor. We therefore identified these factors as the key determinants of radiation dose for pediatric brain CT scans. The effects of these factors on CTDIvol and DLP, and thus the radiation dose, were subsequently determined.

Image Protocol (Imaging Procedures)

This study was primarily designed to evaluate the effects of demographic and technical factors in 138 pediatric patients, of whom 26 had pediatric CT head scans, and 112 had pediatric CT brain scans.

CT head scans are primarily requested for bone structure assessment (trauma, sinusitis, pre-surgical planning, and bony lesions) to allow clear visualization of fracture lines and bony architecture, while CT scans of the brain are indicated for soft tissue in the brain to diagnose various pathological conditions, including stroke, tumor, and bleeding within the brain substance. The protocol for CT head imaging typically begins with a non-contrast scan to rule out hemorrhaging, followed by a contrast injection, which is referred to as CT angiography or CT perfusion. Thinner slices are preferred to enable high-detail, multiplanar reconstructions and 3D rendering of bone structures.

CT Equipment

Brain CT scans were obtained using three scanners: a Toshiba Aquilion 128-slice CT scanner (Japan), a GE Discovery CT750 HD (64 slices), and a GE Revolution HD6 long CTM (128 slices) (USA). All the procedures were performed in accordance with the department's standard protocols.

Methods of Quantification of the Impact of Technical and Demographic Variables on the Radiation Dose

To assess the impact of the deterministic technical variables kVp, mA, and FOV on the two radiation dose indices (CTDIvol and DPL), we performed descriptive statistics, as well as correlation and multiple linear regression analyses.

The data obtained for the 138 patients concerning each factor in relation to radiation dose indices was presented in scatter plots to visualize (identify) the trend (positive or negative impact) and generate the regression line (the best-fit line between the scattered points) in the form of:

$$y = a + bx$$

where, y is the dependent variable (CTDIvol or DLP-the radiation dose indices); x is an independent variable (tube current, kilovoltage or FOV); a, the interception of the regression line with the x-axis which is the constant; b, is a factor of the independent variable (i.e., how many times, the independent variable changes with each change in the dependent variable).

The regression line has slope showing the trend of the correlation (whether positive or negative).

The objective of this study was to identify and quantify the impact of key technical and demographic factors on radiation dose in pediatric brain and head CT scans to inform the development of optimized, low-dose protocols.To be more specific, we examined the impact of the technical factors (mA, kVp, and FOV) on the radiation dose in terms of the radiation dose indices (CTDIvol and DPL) and, in doing so, derived the optimization equations for these parameters.

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 26 (IBM Corporation, Armonk, NY, USA). For all analyses, $P<0.05$ was considered statistically significant.

Results

To identify and quantify the impact of key technical and demographic factors on radiation dose in pediatric brain and head CT, we recorded and analyzed 138 CT scan results of the brain and head.

Impact of Demographic Factors on Radiation Dose

In addition to the descriptive statistics, box and scatter plots were generated to visualize the relationships between the independent variable, age, and the related scan type, with CTDIvol and DLP as the dependent variables. The majority of patients (112) underwent brain volume CT scans (Table 1), with most in the 5–9-year age group. Twenty-six patients had CT head scans.

Table 1.

Data summary of the scan types for the different age groups.

Age	Brain CT scan	Head CT scan
≤4 years	24	9
5–9 years	58	7
10–14 years	27	9
≥15 years	3	1
Total (138 patients)	112 (81.2%)	26(18.8%)

In Table 2, we present summary statistics for the demographic (age) and technical data during the CT scans under analysis, namely, X-ray tube current (mA), kVp, FOV, CTDIvol, and DLP.

Table 2.

Summary statistics for the variables under study.

Statistics	Age	mA	kVp	FOV	CTDIvol	DLP
Mean	7.7329	228.3425	112.6027	26	33.8166	643
Std. Deviation	4.20064	73.33884	9.68859	8	9.48062	208
Median	7.0000	222.0000	120.0000	32	31.6350	601
Maximum	17.00	378.00	120.00	32	73.84	1380
Minimum	1.00	50.00	100.00	16	6.00	157

Impact of Age as a Demographic Factor and Scan Type on CTDIvol

CTDIvol was one of the radiation-dose dependent variables affected by age and scan type. For various test sites and age groups—as well as for the reference points used in establishing the DRLs that fell within the 75th percentile—the median CTDIvol values consistently proved to be lower than the corresponding DRLs. As a radiation-dose index, CTDIvol was higher for the head CT than for the brain CT (Table 3).

Impact of Age and Scan Type on DLP

The DLP (the second radiation dose-dependent variable) for both the head and brain CT were always higher than the median levels for both. DPL, an index of radiation dose, was again higher for the head CT than for the brain CT, indicating that the head CT had a higher radiation dose than the brain CT (Table 4).

Figures 1–4 present box plots of CTDIvol and DLP levels for the different test sites and age groups.. The line in the middle of each box represents the median, while all the values above and below the plots are extreme values.

Table 3.

CTDIvol values for the different types of test sites, age groups, and diagnostic reference levels (75th percentile).

CTDIvol	Category	Mean±SD	Median	75th percentile
Test type	CT brain CT head	33.8073±9.45791 34.3333±10.05273	30.9000 35.0000	41.7750 43.0000
Age group	≤4 years 5–9 years 10–14 years ≥15 years	28.0824±7.06307 34.4283±8.96909 38.0679±9.42357 33.1111±11.82629	26.8850 31.3000 38.8900 35.0000	30.6725 43.1050 43.0825 39.5000

Table 4.

DLP statistics for the different test sites and age groups.

DLP	Category	Mean± SD	Median	75th percentile
Test type	CT brain CT head CT sinus	632.4475±196.72692 703.8000±243.86279 474.0000±74.74624	593.4000 783.0000 467.0000	771.0000 898.2500 -
Age group	≤4 years 5–9 years 10–14 years ≥15 years	500.8838±151.78631 639.6946±172.00276 756.6150±216.82333 737.8889±280.03636	451.0000 593.4000 766.5000 821.0000	585.9750 798.3950 932.0275 944.0000

With respect to the median CTDIvol for each age group (Figure 1), it was lowest for the age group ≤4 years; however, it increased in the next age group (5–9 years) and continued to rise with increasing age. It was highest in the 10–14-year age group, but declined slightly in the> 15-year age group. Irrespective of the decline, the median for the group aged ≥15 years remained higher than that of the other age groups. The same trend of CTDIvol with age was observed for the 75th percentile.

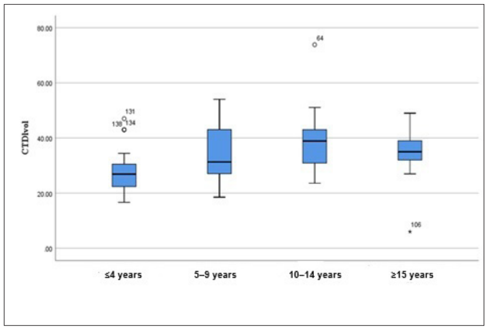

Fig. 1. *Box plot illustrating the CTDIvol levels for the different age groups.*

It can be clearly observed from Figure 2 that the median CTDIvol for the different test sites was highest for head CT, followed by brain and then sinus CT.

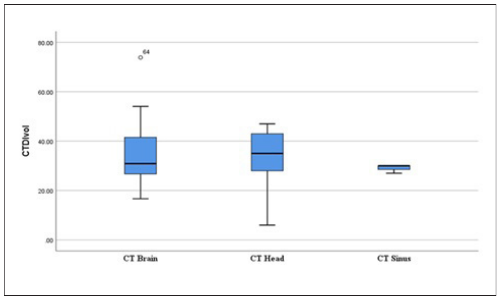

Fig. 2. *Box plot illustrating the CTDIvol levels for the different test sites.*

Unlike variations in CTDIvol with age, the median DLP across age groups continued to rise with increasing age (Figure 3).

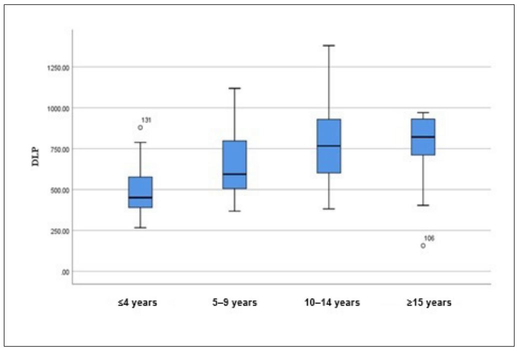

Fig. 3. *Box plot illustrating the DLP levels for the different age groups.*

As for CTDIvol, the median DLP for the different test sites was highest for head CT, followed by brain and then sinus CT (Figure 4).

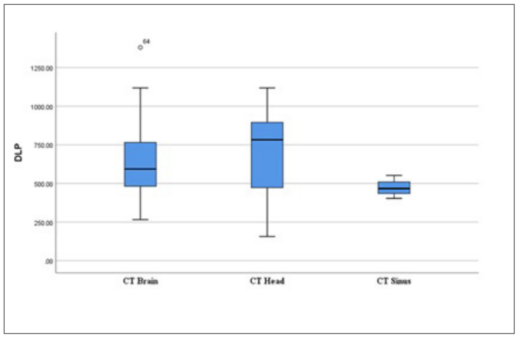

Fig. 4. *Box plot illustrating the levels of DLP for the different test sites.*

Correlation of Age with the Radiation Dose-Dependent Indices

The descriptive statistics for the demographic factor patient age and the image acquisition variables are presented in tables and illustrative figures to reflect the depth of the data. To better visualize the relationships between the variables, a correlation test was performed to investigate how the radiation dose indices (CTDIvol and DLP) varied with changes in age and a deterministic dose factor (milliamperage). The results are shown in Tables 5–6 and illustrated in the scatter diagrams with their associated regression lines (Figs. 5–6).

Table 5.

Correlation of CTDIvol with age and tube current.

Variables	*r* (Correlation Coefficient)	*P*-value
Age	0 .325	0.000
Tube current (mA)	−0.127	0.127

Table 6.

Correlation of DPL with age and tube current.

Variables	*r* (Correlation Coefficient)	*P*-value
Age	0.455	0.000
Tube current (mA)	−0.109	0.190

As for CTDIvol, the median DLP for the different test sites was highest for head CT, followed by brain and then sinus CT (Figure 4).

The highly significant, but moderately positive, linear relationship between patient age and CTDIvol (Table 5 and Figure 5) indicates that radiation dose tended to increase with increasing patient age. The same trend applied to the highly significant, moderately positive relationship (r=0.455) between patient age and DLP (Table 6 and Figure 6).

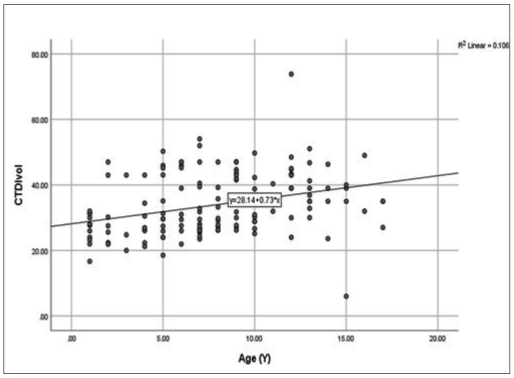

Fig. 5. *Scatter plot showing the correlation of CTDIvol with age.*

However, no significant correlations were observed between tube current (mA), a deterministic radiation dose factor, and radiation dose as measured by CTDIvol and DLP (Table 5 and Table 6, respectively). In both cases, the correlation was weakly negative, which indicated an inverse relationship between radiation dose and tube current. This inverse relationship was weak and insignificant, so increasing tube current would not reduce radiation dose. Accordingly, the regression was meaningless, and the scatter plots are not shown.

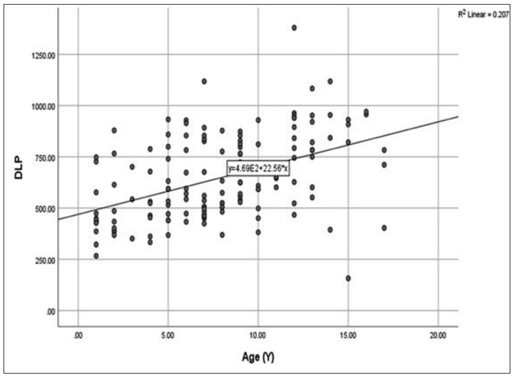

Fig. 6. *Scatter plot showing correlation of DPL with age.*

Impact of Technical Factors on Radiation Dose

We aimed to determine the impact of the technical radiation dose determinants, milliamperage, kVp, and FOV, on radiation dose in terms of the radiation-dose indices (CTDIvol and DLP).

Correlations between CTDIvol and the technical predictors mA, kVp, and FOV:

- The correlation between the X-ray tube current and CTDIvol was found to be insignificant (Table 5).
- In the scatter plot showing the correlation between kVp and CTDIvol, the upward-sloping trend line indicates a moderately positive relationship between kVp and CTDIvol.
- In the scatter plot showing the correlation between the FOV and CTDIvol, the moderate upward trend line indicates a moderately positive relationship between FOV and CTDIvol.

Correlations between DLP and the technical predictors mA, kVp, and FOV:

- The correlation between the X-ray tube current and DLP was found to be insignificant (Table 6).
- In the scatter plot showing the correlation between kVp and DLP, the upward-sloping trend line indicates a moderately positive relationship between kVp and DLP.
- In the scatter plot showing the correlation between the FOV and DLP, the moderate upward trend line indicates a moderately positive relationship between FOV and DLP.

Multiple Linear Regression Analysis

To check the effect of the deterministic technical variables identified (kVp, tube current, and FOV) on CT dose index and DPL, multiple linear regression analysis was performed.

Multiple linear regression for the dependent variable was formulated as a regression line equation comprising an intercept and a set of independent variables, each associated with a specific coefficient (slope). Models were constructed—analogous to a line of best fit—to forecast future values based on existing data.

CT Dose Index Volume

To obtain the regression coefficient for a CTDIvol regression line, standard linear regression methods were used to estimate the slope and intercept that best fit a dataset of CT imaging parameters and corresponding dose values.

The regression coefficient table showed that the independent variables named kVp and tube current have a statistically significant impact on CTDIvol ($P<0.05$), but FOV did not ($P=0.559$) (Table 7).

Table 7.

Regression Coefficients Base Model for the dependent variable CTDIvol.

Coefficients[a]							
Model	Unstandardized Coefficients		Standard. Coeffic.	T	*P.*	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-65.744	11.855		-5.546	<.001		
Peak kilovoltage applied during CT	.758	.128	.774	5.919	<.001	.221	4.526
Tube current (mA) used during CT	.051	.011	.394	4.775	<.001	.555	1.801
FOV the size of the scanned area	.100	.171	.082	.586	.559	.193	5.188
a. Dependent Variable: CTDIvol							

The variance inflation factor (VIF) for FOV was 5.188, exceeding 5, indicating multicollinearity among the independent variables. Thus, it was removed from the regression model due to its insignificant effect and multicollinearity. After removing the FOV, the regression coefficients of the optimal model for the dependent variable, CTDIvol, were obtained (Table 7).

The optimal model showed (Table 8) that the p-values of kVp and tube current are less than 0.05. At the 5% significance level, it can be concluded that the two variables have a statistically significant impact on CTDIvol. Furthermore, the VIF values are below 5, providing further evidence that there is no multicollinearity among the independent variables.

Next, we examined the regression coefficients to discuss the direction and magnitude of their effect on the dependent variable, CTDIvol.

- The kVp regression coefficient is 0.818, which means that CTDIvol will go up by 0.818 units for every kilovoltage increase, assuming that all other factors stay the same.
- The tube current regression coefficient is 0.049, meaning that CTDIvol increases by 0.049 units for every milliampere increase, assuming all other factors remain constant.

The model summary table showed an adjusted R^2 of 0.454, indicating that 45.4% of the total variation in CTDIvol is explained by the independent variables (Table 9).

The ANOVA table showed that the *P*-value for the F statistic is <0.001. At the 5% significance level, we can say that the fitted model is statistically significant and provides a good fit (Table 10).

Table 8.

Regression Coefficients Optimal Model for the dependent variable CTDIvol.

Coefficients[a]							
Model	Unstandardized Coefficients		Standard. Coeff.	T	*P*	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-69.438	10.013		-6.935	<.001		
Peak kilovoltage applied during CT	.818	.075	.836	10.884	<.001	.638	1.569
Tube current (mA) used during CT	.049	.010	.377	4.902	<.001	.638	1.569
a. Dependent variable: CTDIvol							

Table 9.

Model Summary.

Model Summary				
Model	R	R^2	Adjusted R^2	Std. Error of the estimate
1	.680	.462	.454	7.00308

Table 10.

Analysis of Variance (ANOVA).

Model	Sum of Squares	Df	Mean Square	F	*P*-value
Regression	6019.760	2	3009.880	61.372	<.001
Residual	7013.162	143	49.043		
Total	13032.921	145			

Fitted Equation

CTDIvol = -69.438 + 0.818 × Peak Kilovoltage Applied + 0.049 × Tube Current (in mA)

Therefore, the above CTDIvol best-fitting equation can be solved to obtain the peak kilovoltage to be applied for any tube current and vice versa.

Dose-Length Product

The research aims to assess the impact of peak voltage, tube current, and FOV on DLP. Here, DLP is the dependent variable, and peak voltage, tube current, and FOV are the independent variables. As the dependent variable is continuous, we can perform multiple linear regressions to check the impact. Table 11 presents the regression coefficients for the base model of the dependent variable DLP.

The regression coefficients indicated that the independent variables, peak kilovoltage and tube current, have a statistically significant impact on DLP ($P<0.05$).

But FOV does not have a significant impact on DLP (*P*=0.399).

Table 11.

Regression Coefficients Base Model for the dependent variable DLP.

Coefficients[a]							
Model	Unstandardized Coefficients		Standard. Coeff.	T	*P*	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-1421.676	268.944		-5.286	<.001		
Peak kilovoltage applied during CT	15.277	2.904	.711	5.261	<.001	.221	4.526
Tube current (mA) used during CT	1.137	.242	.401	4.699	<.001	.555	1.801
FOV the size of the scanned area	3.286	3.886	.122	.846	.399	.193	5.188
a. Dependent Variable: DLP							

The variance inflation factor (VIF) for FOV was 5.188, exceeding 5, indicating multicollinearity among the independent variables. Thus, it was removed from the regression model due to its insignificant effect and multicollinearity. After removal of the FOV, the regression coefficients of the optimal model for the dependent variable, DLP, were obtained (Table 12).

Table 12.

Regression Coefficients Optimal Model for the dependent variable DLP.

Coefficients[a]							
Model	Unstandardized Coefficients		Standard. Coeff.	T	*P*	Collinearity Statistics	
	Std. Error	Beta	B			Tolerance	VIF
(Constant)	-1542.729	227.456		-6.783	<.001		
Peak kilovoltage applied during CT	17.262	1.708	.804	10.108	<.001	.638	1.569
Tube current (mA) used during CT	1.063	.226	.375	4.713	<.001	.638	1.569
a. Dependent Variable: DLP							

The optimal model showed (Table 12) that the *P*-values of kVp and tube current are less than 0.05. At the 5% significance level, it can be concluded that the two variables have a statistically significant impact on DLP. Furthermore, the VIF values are below 5, providing further evidence that there is no multicollinearity among the independent variables.

The obtained regression coefficient values indicate the direction and magnitude of the influence on the dependent variable DLP.

- The kVp regression coefficient is 17.262, which means that DLP will go up by 17.262 units for every kilovoltage increase, assuming that all other factors stay the same.
- The tube current regression coefficient is 1.063, meaning that DLP will increase by 1.063 units for every milliamperage increase, assuming all other factors remain constant.

The model summary table shows that the adjusted R^2 is 0.416, indicating that 41.6% of the total variation in DLP is explained by the independent variables (Table 13).

Table 13.

Model summary.

Model summary				
Model	R	R^2	Adjusted R^2	Std. Error of the estimate
1	.651	.424	.416	159.08418

The ANOVA table showed that the *P*-value for the F statistic is <0.001. At the 5% significance level, we can say that the fitted model is statistically significant and provides a good fit (Table 14).

Table 14.

Analysis of Variance (ANOVA).

Model	Sum of Squares	Df	Mean Square	F	*P*
Regression	2660389.611	2	1330194.805	52.561	<.001
Residual	3619012.235	143	25307.778		
Total	6279401.845	145			

Fitted Equation

DLP = -1542.729 + 17.262 × Peak Kilovoltage Applied + 1.063 × Tube Current (in mA)

Therefore, the DLP best-fit equation can be solved to obtain the kVp to apply for any tube current, and vice versa. Coefficients can be calculated using statistical software (for example, Excel, Python, etc) or manually.

Discussion

Given that the objective of this study was to identify and quantify the impact of key technical and demographic factors on radiation dose during CT of the brain and head in children, this task was addressed by quantitatively assessing the influence of these determining factors on CTDIvol and DLP. Any factor affecting these indices will, in turn, influence the overall radiation dose. It follows, therefore, that the precise adjustment of key parameters affecting these indices will enable the optimization of radiation dose.

In this study, we identified several key variables that significantly impacted radiation dose in pediatric brain and head CT scans: age, kVp, and scan type. From the regression coefficients (Tables 7 and 11), we observed clearly that the independent variables kVp and mA had a statistically significant impact on dependent variables, CTDIvol and DLP, $P<0.05$ in both cases. However, FOV did not have a significant impact on the CT dose index ($P=0.559$). Accordingly, FOV was excluded from the best-fit equations for CTDIvol and DLP.

The best-fit equations for CTDIvol and DLP in this study were derived from multiple linear regression analysis, which facilitated the determination of mA and kVp values corresponding to the manual CTDIvol settings.

Our findings suggest that as pediatric patients grow older, their exposure to radiation increases due to larger head size, underscoring the importance of age-adjusted protocols. In our study, radiation exposure was significantly dependent on scan type, with brain CT scans generally yielding lower exposure than head CT scans. This finding has direct implications for clinical practice, underscoring the importance of pediatric-specific protocols to minimize radiation exposure during head and brain scans. For instance, reducing the milliamperage and adjusting the scan parameters based on patient size and age can significantly reduce the radiation dose, as shown by the best-fit equation in our study and by previous studies.[15] The findings of this study agree with those of previous studies that used targeted brain scan protocols (which restrict the scan range to the brain) rather than broader adult head scan protocols (which may include the skull base and upper neck) and significantly reduced radiation exposure. Accordingly, we recommend that pediatric institutions establish specific protocols tailored to individual characteristics to improve patient care and safety. Additionally, automatic exposure control systems can minimize radiation exposure by automatically adjusting the milliamperage based on the patient's size.[16]

According to previous studies, pediatric patients are readily affected by radiation-induced effects and may receive up to three times more radiation per unit of body weight than adults.[17] This calls for urgent measures that utilize existing protocols to reduce radiation exposure while other accurate diagnostic tools are being developed. In the present study, we examined the various technical and demographic parameters that affect radiation dose levels in head and brain CT scans in children by analyzing CTDIvol and DLP. We found that brain scan procedures developed for children reduced their radiation exposure more effectively than those for the head alone, demonstrating the relevance of these procedures through appropriate naming and standardization. Statistical analyses have shown that applying age-adjusted dose changes can reduce the overall radiation exposure to young patients by up to 30% when automated exposure control systems are used.[18]

One important consideration in this study was selecting reference points to establish DRLs that fell within the 75th percentile at our hospital. The 75th percentile values of our local dose distribution were determined in accordance with the European guidelines on diagnostic reference levels for pediatric imaging (ACR, 2015). The third quartiles of the local CTDIvol and DLP values for both pediatric brain and head CT scans will be continuously refined and incorporated into the national diagnostic reference levels for pediatric CT imaging, once developed.

The pediatric diagnostic reference levels in this study were established for children grouped by age (e.g., 1–4-year-olds); however, groupings should preferably be based on body weight (e.g., 5–15 kg group),[19,5] as weight better reflects body size than age. Weight-based groupings are therefore recommended to establish diagnostic reference levels in body CT. Nevertheless, age-based groupings are recommended for brain CT scans because weight does not reflect head size.

Study Limitations

This study had several limitations. Its retrospective design introduced the potential for selection bias and unmeasured confounding. Furthermore, the single-center design may have limited the generalizability of the findings to other institutions with different CT equipment and patient demographics. Consequently, these results should be interpreted in the context of the present study, and future multicenter, prospective studies are warranted to validate and extend our findings. Finally, the influence of certain technical parameters, such as scan time and contrast use, warrants further investigation to build a more comprehensive model for dose optimization. The application of advanced imaging techniques, such as iterative reconstruction algorithms, should be considered to reduce radiation exposure without compromising image quality.[20]

This study underscores the need for patient-specific dose adjustment, particularly with respect to age, and affirms the value of automated exposure control in minimizing radiation exposure. By aligning with global safety initiatives, such as the Image Gently campaign, our findings provide an evidence-based strategy to enhance safety in pediatric neuroimaging and support the dual development of standardized low-dose CT protocols and individualized procedures based on patient age and clinical indications. To translate these findings into practice, future research should prioritize validating these protocols, and policymakers are urged to integrate this evidence into formal guidelines and regulations for pediatric imaging.

Conclusions

In this study, age, milliamperage, peak kilovoltage, field of view, and scan type emerged as the key determinants of radiation dose in pediatric brain CT scans, as shown by their effects on CTDIvol and DLP. The positive relationships among age, milliamperage, and field of view with radiation dose underscore the importance of strict pediatric optimization protocols. While the patient data revealed key CT measurement parameters, the regression analysis showed that patient age, peak kilovoltage, and mA readings significantly impacted the CTDIvol levels (*P*-values <0.05). Our results affirm the need for effective reforms in CT protocol standardization, personnel training, and national dose regulations, especially in regions where pediatric diagnostic reference levels do not exist. The necessity of a diagnostic test should be weighed repeatedly against the associated radiation risk in the pursuit of safer imaging. As Salah et al.[21] noted, "Optimizing CT techniques is important, primarily for pediatrics, being more radiosensitive to radiation than adults." This study contributes to that optimization by highlighting the levels at which doses can be applied scientifically and safely and thus controlled effectively.

Institutional Review Board Statement

The study was approved by the Standing Committee for Scientific Research at Jazan University, reference No: REC-46/07/1357.

Informed Consent Statement

Patient consent was waived due to the retrospective nature of this study, which involved no direct interaction with human subjects or new data collection; the research used existing deidentified patient data from hospital records, qualifying for a waiver under minimal risk and retrospective data criteria.

Data Availability Statement

The datasets used in this study are available on request from the corresponding author.

Author Contribution Statement

Nouf Abuhadi confirms sole responsibility for all aspects of the research.

Conflicts of Interest

The author has declared no conflict of interest.

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