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Original Article

Radiology Section

Comparison of Radiation Doses of Computed Tomography Brain and Pulmonary Angiography with International Commission on Radiological Protection Guidelines: A Descriptive Study

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ABSTRACT

Introduction: Computed Tomography Angiography (CTA) is useful for evaluating and diagnosing conditions related to blood vessels, such as aneurysms, stenosis (narrowing of vessels), vascular malformations, and blockages. It provides valuable information for planning and guiding interventions or surgeries. It is also important to measure patient doses during CTA operations to evaluate and optimise the technique and balance the benefits compared to radiation hazards.

Aim: To calculate the CT Dose Index (CTDI), Dose Length Product (DLP), and effective dose for CT brain angiography and CT pulmonary angiography, and also to compare whether the measured values are within the International Commission on Radiological Protection (ICRP) recommended levels.

Materials and Methods: A retrospective descriptive study was conducted in the Department of Radiodiagnosis at Yenepoya Medical College Hospital Mangaluru, Karnataka, India, from September 2022 to September 2023. A total of 52 data points were collected for CT brain and CT pulmonary angiography examinations, which were acquired before October 2022. Information on CTDI and DLP was collected, and the effective dose was calculated using the conversion factor. The values were then compared with the ICRP reference level. Descriptive statistics, mean, and standard deviation for continuous variables, and frequency and percentage for categorical variables were used.

Results: There was a significantly lower value of CTDI, DLP, and effective dose for CT brain angiography and CT pulmonary angiography compared to the ICRP recommended reference levels. The mean CTDI and DLP for CT brain angiography were 111.56 mGy and 1153.31 mGy·cm, and the mean CTDI and DLP for CT pulmonary angiography were 24.56 mGy and 713.74 mGy·cm, respectively. The mean effective dose for CT brain and CT pulmonary angiography was 2.46 mSv and 9.94 mSv, respectively.

Conclusion: The measured values were within the recommended values of ICRP regulations. It is recommended that CT brain angiography and CT pulmonary angiography examinations are safer for diagnostic purposes. Optimising scanning protocols, utilising low-dose techniques, and implementing dose monitoring and control are important clinical aspects. Compliance with the guidelines helps to enhance patient care and reduce the risk of radiation-related complications.

Keywords: Brain angiography, Computed tomography dose index, Dose-length-product, Effective dose

INTRODUCTION

Computed Tomography (CT) is an imaging technology that generates cross-sectional images depicting the X-ray attenuation characteristics of anatomical structures [1]. CT is currently one of the most significant radiological techniques in the world, and due to its increasing usage in clinical practice, the radiation dosage from CT is rising as a component of the overall radiation dose received by patients and the general public [2]. Compared to other radiological treatments, CT has been extremely significant in identifying illnesses, even though it exposes patients to high radiation doses. Despite the well-established advantages of CT, the radiation danger should be far outweighed by these advantages in diagnosing illnesses [3]. The literature states that the Weighted CTDI (CTDIw) and DLP are acceptable dose-related quantities for establishing Diagnostic Reference Levels (DRLs) to optimise radiation exposure for patients [4]. The Volumetric CTDI and Weighted CTDI quantify the amount of exposure per tissue slice, while the DLP calculates the overall exposure for a sequence of scans [5,6]. The most accurate way to determine a patient's radiation exposure during any radiographic examination is to use the effective dose, which is correlated with the risk of carcinogenesis and the production of genetic consequences.

CT Angiography (CTA) is a non invasive procedure using an intravenous injection of contrast media to investigate vascular anatomy-related diseases and illnesses [5]. CT Brain angiography is a non invasive technique for detecting cerebral aneurysms [7], and the diagnosis of pulmonary embolism increasingly uses Computed Tomographic Pulmonary Angiography (CTPA). The advantage of CTPA is its ability to image the entire thorax, making it an easier and non invasive technique for diagnosing pulmonary embolisms [8].

The IRCP has recommended DRLs as a means of dose optimisation [9]. ICRP recommends an effective dose of 3.2 mSv for CT brain angiography and 12.1 mSv for CTPA, respectively [10]. The effective dose for radiological procedures varies depending on the patient's size and the type of procedure [10,11]. Hence, the study aims to calculate the CTDI, DLP, and effective dose and to check whether the measured dose is within the reference level of the ICRP recommendation.

MATERIALS AND METHODS

A retrospective descriptive study was conducted in the Department of Radiodiagnosis at Yenepoya Medical College Hospital, Mangaluru, Karnataka, India, from September 2022 to September 2023. The study was approved by the Yenepoya Ethical Committee after approval from the scientific review board (YEC2/1174), and a permission letter was obtained from the head of the department to collect data from the CT console. A total of 52 data points were collected for CT brain angiography and CT pulmonary angiography, with each examination consisting of 26 samples.

Inclusion criteria: CT brain angiography and CT pulmonary angiography studies with individuals aged 18 years and above were included in the study.

Exclusion criteria: Incomplete CT data, such as missing images or information, were excluded from the study.

Data collection and analysis: The cases of CT brain angiography and pulmonary angiography were selected from the CT console, which had been examined by the 128-slice GE Revolution CT [Table/Fig-1]. The dose was calculated for each CT brain angiography and CT pulmonary angiography examination (dose report obtained from the screen saver of the CT console, [Table/Fig-2,3]. Information on volume-averaged CTDI and DLP was collected, and the Effective dose was then calculated from DLP using conversion factors, termed k-coefficients. K-coefficients represent the relationship between the absorbed dose in a specific organ or tissue and the resulting effective dose to the whole body. The measured effective dose of CT brain and pulmonary angiography was compared with the ICRP recommended dose.

Machine	GE Revolution Evo Multidetector CT
Brand Name	GE Healthcare
No. of slices	128 slice

[Table/Fig-1]: Machine information.

S. no.	CTDI (mGy)	DLP (mGy.cm)	Effective dose (mSv)
1	129.37	1393.74	2.92
2	206.7	1081.8	2.27
3	144.69	786.53	1.65
4	119.79	1408	2.957
5	96.48	1422.83	2.988
6	67.39	1184.52	2.488
7	123.51	1421.64	2.986
8	135.48	898.71	1.888
9	112	746.07	1.566
10	125.02	1239.24	2.602
11	136.1	1423.43	2.988
12	144.19	1156.89	2.43
13	119.24	885.87	1.861
14	112.23	1354.66	2.846
15	95.16	1352.44	2.839
16	112.49	895.22	1.88
17	68.05	1146.74	2.409
18	80.72	1181.43	2.48
19	123.63	1243	2.61
20	109.48	1390.56	2.919
21	80.53	1346.74	2.829
22	82.49	895.22	1.88
23	84.23	1054.66	2.216
24	107.52	987	2.073
25	96.5	1103	2.316
26	87.6	986.2	2.071

[Table/Fig-2]: Protocol information-CT brain angiography.

S. no.	CTDI (mGy)	DLP (mGy.cm)	Effective dose (mSv)
1	24.08	575.04	8
2	18.27	485.52	6.79
3	29.83	856.55	11.98
4	26.61	841.97	11.7
5	22.83	603.88	8.4
6	22.5	771	10.7
7	30.8	860	12
8	22.12	506.5	7
9	23.96	602.2	8.4
10	25.41	444.46	6.22
11	24.83	845.06	11.8
12	26.76	803.19	11.2
13	37.16	839	11.7
14	21.21	701.14	9.8
15	22.78	834	11.6
16	20.48	534.23	7.47
17	16.98	839.63	11.75
18	22.71	702.16	9.8
19	21.89	548.94	7.6
20	26.15	862	12
21	28.55	799	11.1
22	26.15	786	11
23	30	705.83	9.8
24	21.91	548.94	7.6
25	21.41	806	11.2
26	23.1	855	11.9

[Table/Fig-3]: Protocol information- CT Pulmonary angiography.

1. Brain angiography:
    - The mean CTDI and DLP were calculated.
    - Effective dose=k value×DLP.
    - k value for the brain: 0.0021.
2. Pulmonary angiography:
    - The mean CTDI and DLP were calculated.
    - Effective dose=k value×DLP.
    - k value for the chest: 0.014.

STATISTICAL ANALYSIS

For statistical analysis, the data were analysed in Statistical Package for Social Sciences (SPSS) version 21.0. In descriptive statistics, mean and standard deviation were used for continuous variables, and frequency and percentage were used for categorical variables.

RESULTS

In CT brain angiography, the mean $CTDI_{vol}$ was found to be 111.56±29.65 mGy, with a minimum of 67.39 mGy and a maximum of 206.70 mGy. The mean DLP was 1153.31±216.73 mGy.cm, with a minimum of 746.07 mGy.cm and a maximum of 1423.43 mGy.cm. The mean effective dose was 2.46±0.42 mSv, with a minimum of 1.6 mSv and a maximum of 2.9 mSv [Table/Fig-4].

Descriptive statistics	N	Minimum	Maximum	Mean±SD
CTDIvol (mGy)	26	67.39	206.70	111.56±29.64
DLP (mGy.cm)	26	746.07	1423.43	1153.31±216.73
Effective dose (mSv)	26	1.650	2.988	2.46±0.42

[Table/Fig-4]: CT brain angiography.
CTDI: Computed tomography dose index; DLP: Dose length product

[Table/Fig-5] shows that in CT pulmonary angiography, the mean $CTDI_{vol}$ was found to be 24.55±4.27 mGy, with a minimum of 16.98 mGy and a maximum of 37.16 mGy. The mean effective dose was 9.94±1.96 mSv, with a minimum of 6.22 mSv and a maximum of 12 mSv.

[Table/Fig-6] shows the comparison between the observed values and the ICRP recommended values of effective dose. The results

Descriptive statistics	N	Minimum	Maximum	M±SD
$CTDI_{vol}$ (mGy)	26	16.98	37.16	24.56±4.27
DLP (mGy.cm)	26	444.46	862.00	713.74±140.55
Effective dose (mSv)	26	6.22	12.00	9.94±1.96

[Table/Fig-5]: CT pulmonary angiography.

	ICRP recommendation	Observed value
CT Brain angiography	3.2 mSv	2.46 mSv
CT Pulmonary angiography	12.1 mSv	9.94 mSv

[Table/Fig-6]: Comparison of observed effective dose with ICRP recommendations.

show a lower value for CT brain angiography (2.46 mSv) and CT pulmonary angiography (9.94 mSv) compared to the ICRP regulations of 3.2 mSv and 12.1 mSv, respectively.

DISCUSSION

Computed Tomography (CT) is currently one of the most significant radiological techniques globally, and due to its increasing utilisation in clinical practice, the radiation dosage from CT is becoming a larger component of the overall radiation dose received by patients and the general public. Present study revealed that the mean effective dose for CT brain angiography was 2.46 mSv, which was lower than the ICRP reference value of 3.2 mSv. Additionally, a lower mean effective dose of 9.94 mSv for CT pulmonary angiography compared to the ICRP recommendation of 12.1 mSv was observed.

Netwong Y and Krisanachinda A measured the effective dose from CTA of the brain, which ranged from 2.82 to 5.19 mSv, with an average of 3.7 mSv. This average value was twice the result of present study. They revealed that the higher dose was attributed to factors such as effective mAs, kVp, and scan length. They also correlated patient characteristics with the effective dose and found that an increase in effective dose is associated with an increase in patient height and weight [12]. The present study demonstrates a lower radiation dose of 2.46 mSv for CT brain angiography examination compared to the reference recommended levels of ICRP, which were performed using a 128-slice CT scanner. A study by Cohnen M et al., found that the average effective dose in brain CT following an acute stroke was 3.6 mSv, using four different protocols, including a standard head CT and intracranial and cervical vessels CTA, with a Somatom Sensation Cardiac 64 machine, which was higher compared to the ICRP recommendation [13]. Chen GZ et al., measured the radiation dose and image quality of cerebral CTA at 70 kVp with Sinogram-Affirmed Iterative Reconstruction (SAFIRE) and at 120 kVp prospectively. They compared both groups and concluded that the effective dose was 0.2 mSv at 70 kVp, resulting in an 85% reduction in radiation dose compared to the 120 kVp acquisition [14].

In present study, a lower effective dose was observed in CT pulmonary angiography. A retrospective study similar to present study was conducted by Takahashi EA and Yoon HC over a four-year period, which concluded that the average effective radiation dose provided by pulmonary CTA was 10.7 mSv, with a 6.3% incidence of pulmonary embolism [15]. Another study by Noël PB et al., reported a similar range of effective dose of 9.7 mSv for CTPA and also indicated that the use of iterative reconstruction significantly reduces the radiation dose [16].

Sauter A et al., conducted a prospective study on 19 patients (7 males, 9 females) for the detection of pulmonary embolism in ultra-low dose CTPA with the evaluation of an iterative reconstruction algorithm and procedure, including Body Mass Index (BMI) changes in tube current. This study enables the detection of pulmonary embolism in images with ultra-low doses, with a suggested mean effective dose of about 0.9 mSv. In present study, a retrospective method was used to collect data from the CT console of 26 patients who underwent pulmonary angiography, without consideration of gender comparison and BMI [17]. Deevband MR et al., conducted a study on BMI-based effective dose determination in a total of 550 adult patients who underwent abdomen-pelvis and chest CT examinations. They found a higher radiation dose with higher values of BMI [18].

The study recommends the use of an iterative reconstruction technique, which in the future can significantly reduce the radiation dose to patients without compromising image quality.

Limitation(s)

The small number of samples included in the current study was one potential limitation. Additionally, in the present study, information regarding age, sex, height, weight, and BMI was not included as it was a retrospective study. Therefore, further studies should be conducted using such parameters to evaluate the changes.

CONCLUSION(S)

As patients are exposed to substantial radiation doses during CTA examinations, it is important to keep the radiation dose as low as reasonably achievable. The present study concluded that the radiation doses for CT brain angiography and CT pulmonary angiography are lower than the ICRP reference levels, which makes it safer and reduces the radiation risk to patients.

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