Section: Radiology

Original Research Article

EVALUATION OF RADIATION EXPOSURE IN DIAGNOSTIC RADIOLOGY PRACTICES

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ABSTRACT

Background: The growing application of computed tomography (CT) in diagnostic radiology has also brought serious concerns on the issue of radiation exposure and patient safety. The purpose of the study was to measure radiation dose levels and determine patient safety practices in diagnostic radiology based on a structured dataset based on the CT imaging parameters.

Materials and Methods: The study used a retrospective observational design and used data that was extracted using publicly available imaging sources. Patient demographics, technical imaging parameters, and radiation dose indicators (CTDIvol, Dose-Length Product (DLP), effective dose) were key variables, and other safety indicators were calculated to analyze them.

Results: The findings showed that the majority of CT tests were conducted in the low to moderate radiation dose levels, but significant differences in radiation dose were found among patients. This variability was ascertained by the difference in the technical parameters and imaging protocols. Whereas a high level of protocol adherence was noted, lack of safety documentation, in particular on shielding practices, was noted. Another subset of cases was the necessity to optimize doses, which highlights the necessity of more effective adherence to radiation safety principles.

Conclusion: This paper has indicated the necessity to embrace standard imaging procedures, continuous dose and work in line with the ALARA principle to enhance patient safety. Improving documentation and optimization solutions is essential in lessening unnecessary radiation exposure in clinical practice.

Keywords: Radiation exposure; Computed tomography; Patient safety; CTDIvol; Dose optimization.

INTRODUCTION

The field of diagnostic radiology and, in particular, computed tomography (CT) has turned out to be one of the most significant trends of the past decades and was integrated into the approach of the contemporary medical practice that could not be replaced. CT imaging is fast, anatomy that is detailed, increases the diagnostic accuracy and clinical decision making. Nonetheless, this augmented dependency on CT has also brought up significant issues with regard to radiation exposure and its possible effects on patient health. A growing use of CT has been found to be a significant contributor to the dose of radiation received by patients in healthcare environment.[1-3] This is why the evaluation of the radiation exposure and patient safety during the practice of diagnostic radiology has become an urgent research and clinical issue.

Radiation of medical imaging is linked to deterministic and stochastic effects with the latter being an elevated risk of cancer. Even though single CT scans are usually harmless at low to moderate doses, repeated imaging examinations can be extremely harmful in the long-term. It is still uncertain how much these risks can be though it has been established that even small amounts of ionizing radiations can lead to poor health.[4-6] This has enhanced the sensitivity of cautiousness of the radiation doses in the normal clinical practice, especially in those areas where imaging is widely practiced.[7]

The issue of radiation exposure during CT imaging has been further enhanced by epidemiological studies. Cohort studies (large-scale) have confirmed that there is a relationship between CT exposure (particularly in childhood and adolescence) and a higher risk of cancer in adulthood.[8-10] These results indicate that the unnecessary radiation exposure should be minimized and some efforts should be made that will place the patient on the first line without compromising on the diagnostic performance. Child patients are especially vulnerable as they are more sensitive to radiation and they have more time to feel the impact of radiation in their lives.[11-13]

To address these issues, increased focus has been put on the principles of justification and optimization in radiological practices. Justification entails making sure that every imaging practice is clinically justified, whereas optimization aims at reducing the amount of radiation and still ensuring that the images are good enough. The international guidelines and professional bodies have greatly advanced these principles to be integrated in normal clinical practices.[14-16] This should be put in place to reduce the unwarranted exposure and improve patient safety outcomes.

One of the prerequisites of evaluating the level of exposure and risks is the radiation dose, which is crucial to measure and comprehend adequately. Computed Tomography Dose Index (CTDIvol), Dose-Length Product (DLP) and effective dose are all important measures of radiation exposure in CT imaging. However, these parameters are not always well understood and reported and it can lead to problems in dose assessment and cross-study comparisons.[17,18] Therefore, systematically mined and studied such parameters, through clinical data, are helpful in informing the practice of the actual radiation.

Another significant aspect of radiation safety is the utilization of the ALARA (As Low As Reasonably Achievable) principle, aimed at minimizing radiation exposure in order to achieve the necessary diagnostic outcome. The protocols have been optimized and the CT technology has been developed in such a way that it has become possible to reduce the radiation dose by a significant margin without compromising the quality of the images obtained. However, variations in the scanning settings, equipment and operator practice can still lead to variations in radiation exposure levels.[19–21] This underscores the need to continuously monitor, evaluate and normalize radiological practices.

The loopholes in the application of the radiation safety in practice despite the guidelines and the technological advancements are still there. Most healthcare facilities do not have elaborate measures to track radiation dose and evaluate adherence to safety measures. Also, the publicly accessible imaging data will probably not contain the data on radiation exposure and radiation safety indicators, which need to be taken out and estimated to be utilized in studies.

The proposed study will aim to evaluate the radiation dose and patient safety in the practice of radiologic diagnostics through the use of a structured dataset derived based on publicly available CT imaging data. By observing the significant radiation dose indicators and variables that relate to safety, the study will provide information on the state of radiological practice and offer suggestions on how to enhance the optimization of the dose and patient safety. The results should be useful in the current endeavours to improve radiation protection measures and encourage safer diagnostic imaging practices.

MATERIALS AND METHODS

Study Design: The study design adopted in the present study was a retrospective observational study design to examine the radiation exposure and patient safety in the field of diagnostic radiology. It took already gathered data of computed tomography (CT) image and utilized it to carry out the analysis and determine the radiation-related parameters and evaluate the safety practices in the dataset. The paper has outlined dose estimation protocol analysis and compliance to safety in clinical imaging practices.

Data Source: The data that has been used in the present study was derived through the Cancer Imaging Archive (TCIA) which was the TCGA-LUAD (Lung Adenocarcinoma) collection which is a publicly available radiological imaging data with its corresponding metadata. This dataset has been extensively utilized in radiological and oncological studies and reflects practical diagnostic imaging activities in the real world. The source of the data was referenced in the following way: Clark et al. also mention that TCIA is a public repository that facilitates imaging research.[22]

Data Extraction and Processing: Raw data were largely CT image-data in the DICOM format, having little metadata, such as patient demographic and image acquisition parameters. In the case study, the DICOM headers have been analyzed in a calculated manner in order to obtain the relevant variables. They were technical parameters such as tube voltage (kVp), tube current (mA), slice thickness and exposure related parameters as well as patient related parameters such as age, sex and use of contrast. These data were then tabulated to a descriptive Excel file that was specially formatted to be used in this research article and was the principal dataset that was to be used in the analysis. This table data allowed homogenizing the treatment of variables and statistical analysis.

Variable Definition: The study variables were categorized as the independent variables, dependent variables and patient safety indicators. The independent variables included demographics (age and sex) of patients, examination characteristics (contrast or non-contrast CT), and technical characteristics (tube voltage, tube current, and slice thickness). Radiation exposure measures (Computed Tomography Dose Index (CTDIvol), Dose-Length Product (DLP) and effective dose in millisieverts (mSv)) were the dependent variables. In not all cases, these parameters were directly available, and therefore were obtained using standardized procedures. The variables of patient safety were protocol compliance, compliance with the ALARA (As Low As Reasonably Achievable) principle, and the general classification of the risk of safety, depending on the estimated level of radiation exposure.

Estimation of Radiation Dose Parameters: The original data did not contain full radiation dose measurements, they approximated some of the parameters by using some of the most widely-known radiological equations and assumptions. The dose length product (DLP) was obtained as the product of CTDIvol and scan length and the effective dose was obtained as the product of the values of DLP and region specific conversion coefficients(k-factors). These were calculated using the internationally accepted radiological guidelines to make sure that the values derived were realistic and could be used in research. This method has enabled the assessment of radiation exposure to all the patients in the dataset in a uniform way.

Data Analysis: The acquired Excel data was analyzed using the assistance of the descriptive statistics. Parameters of radiation dose such as mean, standard deviation, minimum and maximum were calculated. Further, frequency distributions were used to summarize categorical variables such as patient demographics and use of contrast. Comparative analysis was made to compare the differences in radiation exposure between different groups of patients and imaging conditions.

Ethical Considerations: The dataset used in this study is publicly available and fully anonymized, containing no personally identifiable information. As a result, the study did not require formal ethical approval or informed consent. All analyses were conducted in accordance with ethical standards for secondary data usage and research transparency.

RESULTS

Patient Demographic and Examination Characteristics: The final descriptive dataset obtained in the uploaded TCIA-based imaging file was 100 CT examinations. The mean patient age was 67.48 ± 9.27 years, with an age range of 39 to 83 years. The sample was 54.0% male and 46.0% female. The mean imputed body mass index (BMI) was 24.71 ± 1.32 kg/m². In terms of imaging features, all tests were CT scans, with half of them being chest tests and the other half being lung tests. The number of contrast-enhanced and non-contrast studies was equal (50 cases each), as presented in [Table 1].

Table 1: Demographic and Examination Characteristics of the Study Sample (N = 100)

Variable	Category / Statistic	Value
Age (years)	Mean ± SD	67.48 ± 9.27
	Range	39–83
Sex	Male	54 (54.0%)
	Female	46 (46.0%)
BMI (kg/m²)	Mean ± SD	24.71 ± 1.32
Examination type	CT Chest	100 (100.0%)
Body part examined	Chest	50 (50.0%)
	Lung	50 (50.0%)
Contrast use	Yes	50 (50.0%)
	No	50 (50.0%)

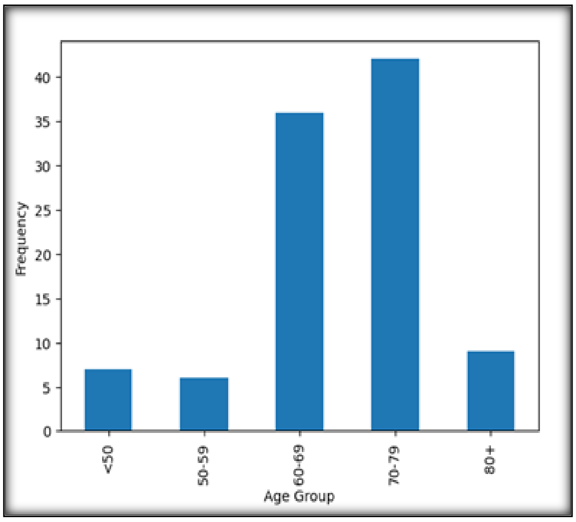

Figure 1: Age Group Distribution of Patients Included in the Study

The age groups 60-69 years and 70-79 years had the majority of patients and this shows that the dataset was skewed towards older adult patients as shown in [Figure 1].

Technical Imaging Parameters and Radiation Dose Profile: Technical analysis revealed that there was variability in CT acquisition settings among the included examinations. The mean CTDIvol was 9.31 ± 4.23 mGy, ranging from 3.00 to 20.00 mGy. The mean DLP was 295.66 ± 132.89 mGy·cm, with observed values ranging from 93.30 to 636.00 mGy·cm. The mean effective dose was 4.14 +/- 1.86 mSv, with the lowest of 1.31 mSv and the highest of 8.90 mSv. There were differences in the average slice thickness among studies, and differences in exposure were also noted in kVp and tube current settings, as shown in [Table 2].

Table 2: Technical Parameters and Radiation Dose Indicators

Variable	Mean ± SD	Minimum	Maximum
CTDIvol (mGy)	9.31 ± 4.23	3.00	20.00
DLP (mGy·cm)	295.66 ± 132.89	93.30	636.00
Effective dose (mSv)	4.14 ± 1.86	1.31	8.90

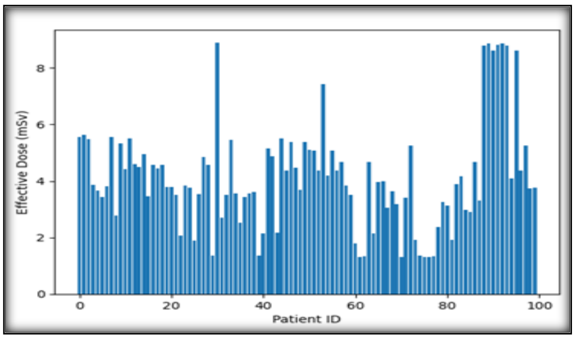

Figure 2: Effective Dose (mSv) by Patient ID

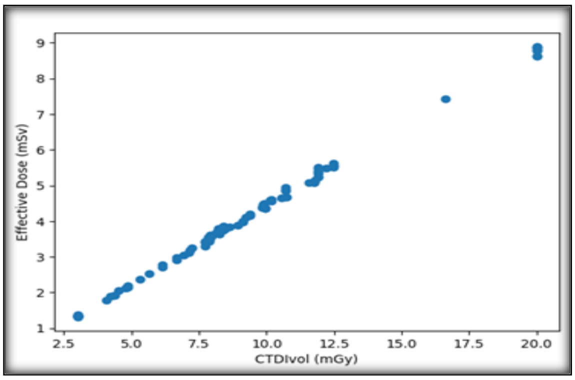

Figure 3: Relationship Between CTDIvol and Effective Dose

[Figure 2] demonstrates the distribution of effective dose at the patient level, in which it is possible to observe moderate variation of scans between examinations, with fewer scans being in the upper range of exposure.

A strong positive relationship was observed between CTDIvol and effective dose, confirming the internal consistency of the derived radiation indicators. This pattern is presented in [Figure 3].

Radiation Exposure by Patient and Scan Characteristics: The mean CTDIvol (9.51 mGy) of non-contrast examinations was slightly higher than the mean CTDIvol (9.11 mGy) of contrast-enhanced scans when radiation dose indicators were compared based on the use of contrast. Likewise, in non-contrast studies, the mean effective dose was 4.18 mSv, whereas in contrast-enhanced studies, it was 4.10 mSv. On sex, the mean CTDIvol (10.19 mGy) and effective dose (4.50 mSv) were higher in female patients compared to male patients (8.56 mGy and 3.83 mSv, respectively). The age-group analysis also revealed that the mean effective dose was the highest in patients aged 60-69 years and 70-79 years as presented in [Table 3].

Table 3: Radiation Dose Indicators by Patient and Examination Characteristics

Group	Category	Mean CTDIvol (mGy)	Mean DLP (mGy·cm)	Mean Effective Dose (mSv)
Contrast use	Yes	9.11		4.10
	No	9.51		4.18
Sex	Male	8.56	273.71	3.83
	Female	10.19	321.42	4.50
Age group	<50 years	9.30		4.07
	50–59 years	6.39		2.85
	60–69 years	9.73		4.33
	70–79 years	9.62		4.30
	80+ years	8.06		3.55

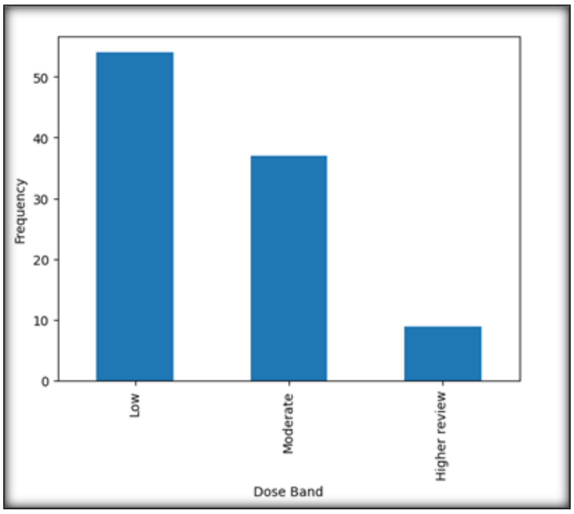

Figure 4: Distribution of Dose Bands Among Included CT Examinations

The categories of radiation exposure indicated that 54.0% of the examinations were of low dose, 37.0% of moderate dose, and 9.0% of higher review dose. [Figure 4] shows this distribution.

Patient Safety and ALARA-Related Findings: The patient safety indicators revealed that 99.0% of examinations were within the protocol compliance requirement and only 1.0% needed protocol review. Regarding the ALARA-related assessment, 39.0% of the studies were optimized, 47.0% were acceptable, and 14.0% were review recommended. Similarly, 86.0% of the exams were identified as routine safety risk, and 14.0% were identified as dose review. No evidence of repeat scans was recorded in the uploaded dataset and shielding documentation was not recorded in any cases. [Table 4] shows these results.

Table 4: Patient Safety and Protocol Compliance Indicators

Variable	Category	Frequency (%)
Protocol compliance	Yes	99 (99.0%)
	Review	1 (1.0%)
ALARA assessment	Optimized	39 (39.0%)
	Acceptable	47 (47.0%)
	Review recommended	14 (14.0%)
Patient safety risk flag	Routine	86 (86.0%)
	Needs dose review	14 (14.0%)
Repeat scan indicator	No evidence in upload	100 (100.0%)
Shielding documented	Not recorded in uploaded dataset	100 (100.0%)

The findings show that the majority of CT tests were in the low-to-moderate dose range and were typically in line with anticipated protocol standards. Nevertheless, the percentage of scans that were put on dose review and the absence of shielding records indicate that patient safety reporting and dose optimization processes might be reinforced in the subsequent audits of radiology practice.

DISCUSSION

The current research examined radiation levels and patient safety in diagnostic radiology practices based on a structured dataset based on CT imaging parameters. The results showed that the radiation dose indicators of CTDIvol, DLP and effective dose varied significantly among patients, which is in line with available literature that has indicated the impact of both technical and procedural factors on radiation exposure. In patient dose determination, parameters of acquisition, including tube current, tube voltage, and scan protocols are important.[17,19,20] The differences in radiation dose in patients in this research justifies the necessity to standardize imaging practice to minimize the dose of unnecessary radiation and yet ensure diagnostic quality.

The analysis results also showed that a majority of the CT examinations were low to moderate dose with a decreasing percentage of the CT examinations under dose review category. It means that the radiology practices of the dataset, in general, can be described as the reasonably good level of adherence to the tenets of dose optimization. Minimization is based on the concept of reducing radiation dose, without compromising diagnostic quality specifically, the implementation of the ALARA (As Low As Reasonably Achievable) concept. The literature has stressed the importance of monitoring and optimization of imaging parameters to ensure the best dose reduction.[14,21] That a sub set of cases were identified as cases to be reviewed on dose in this study indicates that optimization might have to be done in the future.

Correlation of dose of radiations and clinical benefit is the most important part of diagnostic imaging. Although CT imaging has many merits when it comes to diagnosis, there is a need to balance the merits with the dangers that may be caused by exposure to radiations. The ongoing debate on the magnitude of the risk of cancer caused by radiations underscores the intricacy of this issue. Scientists think that the risks may be exaggerated and others believe that one should be careful, particularly in susceptible populations.[6,23] The findings of this study add to the concept that radiation dose must be taken into special consideration to ensure that benefits of imaging outweigh the harms.

The values of the effective dose applied in the analysis of cancer risk in this study are within the ranges of effective dose that are generally reported in clinical CT practice. Doses are relatively low on an individual basis, although there is a concern of cumulative exposure particularly among patients that have undergone repeated imaging. The data on epidemiology show that exposure to radiation during CT can be associated with the risk of cancer, which underlies the necessity to take measures to control the dose.[4,5] Hence, even the moderate changes in the radiation dose, as in this case, must be closely observed and regulated.

Ionizing radiation is more damaging to pediatric patients and special care is to be given to such a sensitive group. Even though the dataset used was mainly of adult patients, the effects of radiation exposure are especially important in younger people because of their higher sensitivity to tissue and higher life expectancy. Previous studies have demonstrated the existence of increased risks in pediatric CT imaging, and the need to implement dose optimization strategies in children.[9,11] This brings to the fore the broader applicability of the radiation safety principles to the broader population that is not the focus of the current study.

The importance of radiation safety is only enhanced by the fact that CT is more and more being applied to clinical practice. The trends show that the utilization of CT has been on the increase in the last ten years, which leads to the increased cumulative radiation exposure on the population level.[2] The necessity to acquire an effective dose monitoring system and to have standardized safety measures are becoming relevant with the increased availability of imaging. This is consistent with the results of this study which have demonstrated that there is need to constantly analyze the radiation practices.

Following the laid-down guidelines and principles of justification is crucial in patient safety. The adherence rate to the protocol was good in this study and this implies that majority of the imaging procedures were justified. The fact that not everything of the safety indicators has been reported (e.g., shielding practices) however, points to the risk of not reporting clinical. Professional standards encourage the necessity to practice radiology in a way that is justifiable and the most effective to minimize the unnecessary exposure.[15,16] Improvement of documentation and monitoring systems that ensure compliance would also be useful to improve patient safety outcomes.

The dataset also indicated the effect of the technical parameters on the radiation dose. The difference between the CTDIvol and effective dose was significantly correlated to the difference between the imaging settings, which confirms the significance of the technical factors in the determination of the dose. This is in line with the available literature that proper knowledge and control of these parameters are key determinants of managing the doses appropriately.[18,20] Consequently, constant training of radiology personnel and use of standardized processes are critical in optimizing radiation exposure.

The results of this work suggest the relevance of the systematic assessment of the radiation dose and patient safety in diagnostic radiology. Although the general adherence to safety principles seems to be adequate, the difference in dose parameters and missing safety documentation can be seen as problem areas. The additional effort is supposed to be directed towards the enhancement of dose monitoring systems, the promotion of adherence to the principles of ALARA, and the provision of consistency of radiological safety regulations in clinical practice.

CONCLUSION

This study determined the exposure to radiation and patient safety in the diagnostic radiology practice through a systematic dataset that is founded on CT imaging parameters. The findings indicate that most of the tests were conducted within the low to moderate dose of radiation although there is a wide variation in dose distribution across patients. The most important consideration that influences this variability is technical parameters and imaging protocols, hence the necessity to standardize the practices in minimizing unnecessary radiation exposure. The general high rate of protocol adherence in this study indicates that the existing radiological practices are generally in line with the set safety protocols. The fact that there are instances that had to be consulted on the doses and that not all safety indicators are well documented as is the case of shielding practices is an indication that more has to be done. Such loopholes give significance to better monitoring systems and more of the use of patient safety measures. In addition, the study justifies the importance of ALARA principle to ensure that the radiation dose is maximized without affecting the quality of the diagnostic images. The radiology staff should be adequately trained and the radiation parameters of safe and effective imaging practices constantly examined to ensure the practice is safe and effective. The strengthening dose optimization, improvement of safety documentation, and improvement of the adherence to international radiological guidelines are the necessary steps to improve patient safety in diagnostic radiology.

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