

Radiation Risks of Computed Tomography: Estimating Cancer Incidence from Diagnostic Imaging

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Abstract

Background: Computed tomography (CT) is an essential diagnostic imaging modality in modern medicine; however, it exposes patients to ionising radiation, which carries a measurable long-term risk of radiation-induced malignancy. With the increasing global use of CT, particularly for chest and abdominal imaging, quantifying radiation exposure and associated cancer risk has become a critical public health concern.

Objective: This study aimed to evaluate radiation dose exposure and estimate the lifetime cancer risk attributable to diagnostic CT examinations in a real-world clinical cohort using established risk models.

Materials and Methods: A retrospective analysis was conducted on 500 adult patients who underwent head, chest, or abdominal CT examinations between 2019 and 2023 at a tertiary care hospital. Effective radiation doses were calculated using dose-length product (DLP) conversion factors. Lifetime attributable cancer risk was estimated using the Biological Effects of Ionising Radiation VII (BEIR VII) models, accounting for age, sex, and examination type.

Results: The mean effective dose per patient was 8.7 mSv, with abdominal CT delivering the highest mean dose (12.8 ± 3.5 mSv), followed by chest CT (10.2 ± 2.1 mSv) and head CT (2.1 ± 0.6 mSv). The total collective dose for the cohort was approximately 4.6 Sv. Based on BEIR VII risk estimates, CT-related radiation exposure was projected to result in approximately 4–5 excess lifetime cancer cases and 2–3 cancer-related deaths per 500 patients. Higher projected risks were observed in females, younger patients, and individuals undergoing repeated CT examinations.

Conclusion: Although the individual cancer risk associated with CT imaging is low, the cumulative population-level risk is clinically significant. Abdominal and chest CT examinations contribute disproportionately to radiation burden and projected cancer incidence. These findings emphasise the importance of strict justification of CT use, adherence to ALARA principles, optimisation of scan protocols, and expanded implementation of low-dose CT techniques to ensure patient safety while preserving diagnostic efficacy.

Keywords: Computed tomography, radiation risk, cancer incidence, BEIR VII, low-dose CT, patient safety.

1. Introduction

Computed tomography (CT) has emerged as one of the most influential diagnostic imaging modalities in modern medicine, fundamentally transforming clinical decision-making since its clinical introduction in the early 1970s. By generating high-resolution, cross-sectional images of internal anatomical structures, CT enables rapid and accurate diagnosis of a wide range of pathological conditions. Its applications span emergency medicine, oncology, neurology, cardiology, trauma care, and infectious disease management, making it an indispensable tool in contemporary healthcare systems (Berrington de González et al., 2009).

The exponential growth in CT utilisation over the past three decades has been driven by technological advancements, including multidetector CT (MDCT), faster image acquisition, improved spatial resolution, and advanced reconstruction algorithms. These developments have significantly enhanced diagnostic accuracy, reduced motion artefacts, and expanded clinical indications. As a result, CT examinations now account for a substantial proportion of all radiological imaging procedures worldwide, particularly in tertiary care and emergency settings (Mahesh, 2017).

Despite its diagnostic advantages, CT imaging involves exposure to ionising radiation at dose levels considerably higher than those associated with conventional radiographic examinations. For example, a standard chest radiograph typically delivers an effective dose of approximately 0.1 mSv, whereas a routine chest CT examination exposes patients to doses ranging from 7 to 10 mSv, equivalent to several hundred chest X-rays. Abdominal CT examinations may deliver even higher doses, often exceeding 12–15 mSv due to larger scan volumes and increased tissue attenuation (National Research Council, 2006).

Ionising radiation is a well-established carcinogen, and its interaction with biological tissues can induce DNA damage through direct ionisation and indirect effects mediated by free radical formation. While deterministic effects such as skin injury occur only at high doses, the primary concern associated with diagnostic CT lies in stochastic effects, particularly radiation-induced cancer. These effects have no threshold dose, and the probability of occurrence increases with cumulative radiation exposure, although severity remains dose-independent (Hall & Giaccia, 2019).

The assessment of cancer risk from low-dose medical radiation relies largely on epidemiological modelling rather than direct observation, due to the long latency period of radiation-induced malignancies and the relatively low individual risk. The Biological Effects of Ionising Radiation VII (BEIR VII) report provides the most widely accepted risk estimates for low-dose radiation exposure. Based on data from atomic bomb survivors and medically exposed populations, BEIR VII estimates that a whole-body exposure of 10 mSv is associated with an approximate lifetime attributable risk of cancer of 1 in 1000 and a fatal cancer risk of 1 in 2000, with higher risks observed in younger individuals and females (National Research Council, 2006).

Concerns regarding CT-associated radiation risk intensified following large-scale epidemiological studies demonstrating increased cancer incidence among exposed populations. Notably, a landmark Australian cohort study involving approximately 680,000 children and adolescents reported a 24% increase in cancer incidence among individuals who underwent CT scans compared to unexposed controls (Mathews et al., 2013). These findings provided compelling population-level evidence supporting the association between diagnostic CT exposure and subsequent cancer risk, particularly in paediatric and young adult populations (Ovais et al., 2025).

The issue gained further prominence during the COVID-19 pandemic, when CT imaging—especially chest CT—was extensively used for disease assessment, triage, and monitoring. Several institutions reported dramatic increases in CT utilisation, with some centres documenting up to a 460% rise in chest CT examinations during peak pandemic periods. This unprecedented surge raised concerns about cumulative radiation exposure and its long-term public health implications (Majidi & Hosseini-mehr, 2022).

While the diagnostic benefits of CT imaging often outweigh potential radiation risks in acute and life-threatening conditions, the cumulative effects of widespread, repeated CT examinations at the population level cannot be ignored (Priti et al., 2025). The growing reliance on CT underscores the importance of quantifying radiation exposure, estimating associated cancer risks, and implementing strategies to optimise dose (Singh et al., 2025). This includes adherence to the principles of justification and optimisation, as emphasised by international radiation protection bodies, and the adoption of low-dose CT protocols where clinically appropriate (ICRP, 2007).

Against this background, the present study aims to evaluate radiation exposure from routine CT examinations in a real-world tertiary care hospital setting and to estimate the associated lifetime cancer risk using BEIR VII models (Singh et al., 2025). By analysing a cohort of 500 patients undergoing head, chest, and abdominal CT scans, this study aims to quantify the potential cancer burden attributable to diagnostic CT imaging and highlight the need for evidence-based dose-reduction strategies to enhance patient safety while preserving diagnostic efficacy (Jadon et al., 2025).

2. Materials and Methods

2.1 Study Design and Setting

This investigation employed a retrospective observational design to quantify radiation exposure from computed tomography (CT) examinations and estimate the associated lifetime cancer risk in a real-world clinical setting. Retrospective studies are commonly used in radiological dose and risk assessment because they allow analysis of existing imaging data without additional patient exposure. The study was conducted at a tertiary care teaching hospital equipped with modern diagnostic imaging facilities, including a 64-slice multidetector CT scanner, which is representative of CT technology widely used in clinical practice.

2.2 Study Population and Inclusion Criteria

The cohort consisted of 500 patients who underwent one or more CT examinations of the head, chest, or abdomen between January 2019 and December 2023. Both male and female adult patients were included to reflect routine clinical utilisation across a broad age range. Inclusion criteria were:

- Age 18–75 years at the time of CT examination.
 - CT performed for clinical indications including suspected pulmonary pathology, abdominal disorders (e.g., pain, suspected malignancy), and neurological evaluation.
 - Complete dose documentation recorded in the hospital's radiology information system.
- Patients were excluded if they had a history of prior therapeutic radiation (e.g., external beam radiotherapy or radionuclide therapy), as such exposures could confound the estimation of organ dose from CT alone. Patients with incomplete imaging dose records were also excluded, as accurate dose values are crucial for risk projection.

2.3 Ethical Considerations and Data Privacy

Institutional Review Board (IRB) approval was obtained prior to data collection, and a waiver of informed consent was granted due to the study's retrospective nature and the use of anonymised data. All procedures were conducted in accordance with the Declaration of Helsinki and institutional ethical research guidelines.

2.4 CT Acquisition Protocols

CT examinations were performed on a 64-slice multidetector CT scanner (brand/model anonymised for institutional policy) using standardised protocols optimised for diagnostic quality within acceptable radiation exposure. The following parameters were applied, consistent with clinical practice guidelines:

- **Chest CT:** 120 kilovoltage peak (kVp), automatic tube current modulation, pitch optimised for thoracic imaging, and reconstruction algorithms suitable for pulmonary parenchymal evaluation. Average effective dose ≈ 10 mSv.
- **Abdominal CT:** 120 kVp with automatic exposure control, multiphase acquisition when clinically indicated, and iterative reconstruction for noise reduction. Effective doses typically ranged from 12 to 15 mSv due to larger scan volumes and increased tissue attenuation.
- **Head CT:** 100–120 kVp, standardised for neuroimaging protocols to assess intracranial pathology. Effective dose ≈ 2 mSv, significantly lower than body CT due to smaller scan length and reduced tissue density.

All CT examinations were performed using automatic exposure control (AEC) and dose modulation techniques to optimise radiation dose while maintaining diagnostic image quality. Slice thickness, pitch, and rotation time were standardised according to institutional protocols. Iterative reconstruction algorithms were employed to reduce image noise and allow dose reduction without compromising diagnostic accuracy, in accordance with international dose optimisation guidelines. These parameters reflect typical clinical acquisition settings described in CT physics and dosimetry literature.

2.5 Radiation Dose Estimation

Radiation dose was systematically estimated for each CT examination. The primary metric recorded from the scanner was the **Dose Length Product (DLP)**, which integrates radiation dose over the length of the scanned volume. DLP is expressed in mGy·cm and provides a basis for calculating effective dose, a quantity that approximates the overall stochastic risk to the patient by weighting organ doses according to tissue sensitivity.

To convert DLP to effective dose (E), region-specific conversion coefficients were applied:

- Chest CT: 0.014 mSv per mGy·cm
- Abdominal CT: 0.015 mSv per mGy·cm
- Head CT: 0.0021 mSv per mGy·cm

These conversion factors are derived from the International Commission on Radiological Protection (ICRP) Publication 103 and are widely used in clinical dose audits and research studies for estimating population risk. Effective dose (E) is calculated as:

$$E \text{ (mSv)} = \text{DLP (mGy}\cdot\text{cm)} \times \text{Conversion Factor (mSv/mGy}\cdot\text{cm)}$$

By aggregating individual effective doses, the total collective dose for the cohort was computed as the sum of all patient effective doses and expressed in person-Sv. The collective dose provides a measure of the total radiation burden to a population and serves as a basis for projected risk estimates.

2.6 Cancer Risk Estimation Using BEIR VII Models

Cancer risk projection from ionising radiation exposure at diagnostic levels relies on epidemiological models because stochastic effects manifest over long latency periods and cannot be directly measured in short-term clinical datasets. The Biological Effects of Ionising Radiation VII (BEIR VII) report presents risk models based on combined data from atomic bomb survivors and medical exposures, adjusted for age at exposure, sex, and organ radiosensitivity. BEIR VII provides lifetime attributable risk (LAR) coefficients for solid cancers and leukaemia per unit dose (Sv), facilitating estimation of excess cancer incidence attributable to radiation exposure.

For this study, the following simplified BEIR VII risk assumptions were applied, consistent with published risk projection studies:

- Lifetime attributable risk of all cancers: 1 in 1000 per 10 mSv
- Lifetime attributable risk of fatal cancers: 1 in 2000 per 10 mSv

Risk estimates were adjusted for differences in radiosensitivity by age, with children and younger adults having higher LAR due to longer post-exposure life expectancy and greater tissue proliferation rates. Female patients were also modelled to have comparatively higher risk projections than males for radiosensitive organs such as the breast and thyroid. While organ-specific dose modelling provides more precise risk estimation, the use of simplified BEIR VII lifetime attributable risk coefficients is widely accepted in population-based radiation risk studies due to the retrospective nature of the data and the absence of individualised organ dose measurements. This approach enables standardised comparison with previously published epidemiological research and provides a practical estimation of population-level cancer burden associated with diagnostic CT exposure.

2.7 Statistical Analysis

2.7 Statistical Analysis (Improved Version)

Descriptive and inferential statistical analyses were performed to evaluate radiation dose distribution and projected cancer risk across different subgroups. Continuous variables, including effective dose and cumulative radiation exposure, were expressed as mean $\pm$ standard deviation. Independent-samples t-tests were used to compare mean effective doses between male and female patients, and one-way analysis of variance (ANOVA) was used to assess dose differences across age groups (<30, 31–50, >50 years). Confidence intervals (95% CI) were calculated for mean effective dose and projected cancer risk estimates. A p-value of <0.05 was considered statistically significant. Statistical analyses were conducted using SPSS to ensure accuracy and reproducibility of results.

3. Results

3.1 Demographic Characteristics and CT Utilisation

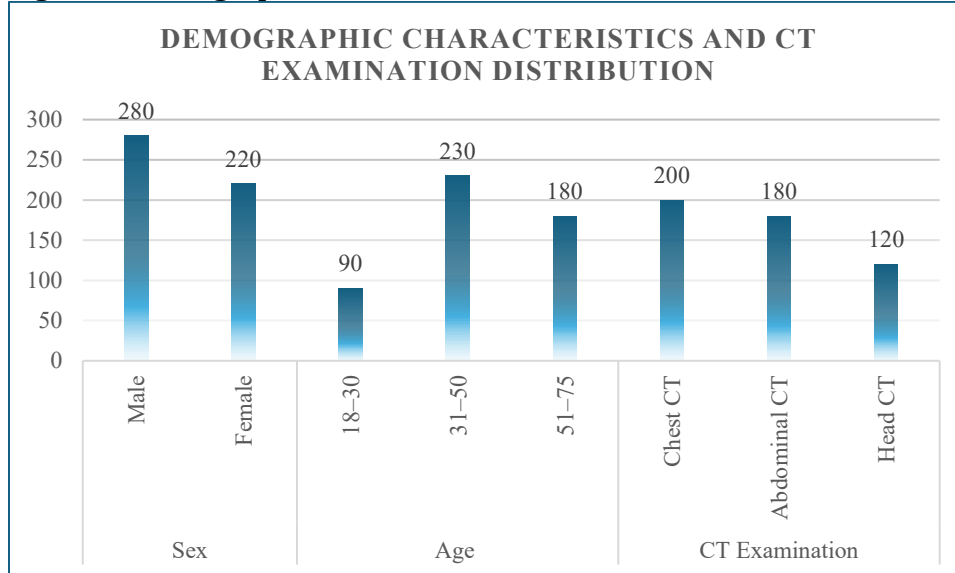
A total of 500 patients who underwent diagnostic CT examinations during the study period were included in the analysis. Of these, 280 patients (56%) were male, and 220 patients (44%) were female, indicating a slight male predominance. Patient ages ranged from 18 to 75 years, with a mean age of 45.2 ± 13.6 years. The largest proportion of patients was in the 31–50-year age group (46%), followed by 51–75 years (36%) and 18–30 years (18%).

Regarding imaging distribution, chest CT was the most frequently performed examination (40%), followed by abdominal CT (36%) and head CT (24%). This pattern reflects the extensive clinical use of CT for thoracic and abdominal evaluation in emergency, oncologic, and infectious disease settings.

Table 1: Demographic characteristics and CT examination distribution of the study population (n = 500)

Variable	Category	Number (n)	Percentage (%)
Sex	Male	280	56
	Female	220	44
Age (years)	18–30	90	18
	31–50	230	46
	51–75	180	36
CT Examination	Chest CT	200	40
	Abdominal CT	180	36
	Head CT	120	24

Table 1 summarises the demographic profile of the study cohort and the distribution of CT examinations. The predominance of chest and abdominal CT reflects their widespread use in routine clinical practice. The age distribution indicates substantial CT utilisation among younger and middle-aged adults, a population group with higher lifetime radiation sensitivity.

Figure 1: Demographic characteristics and CT examination distribution

3.2 Radiation Dose Distribution

Significant variation in radiation dose was observed across anatomical regions. Abdominal CT resulted in the highest radiation exposure, with a mean effective dose of 12.8 ± 3.5 mSv. Chest CT examinations delivered a mean effective dose of 10.2 ± 2.1 mSv, while head CT examinations were associated with substantially lower doses, averaging 2.1 ± 0.6 mSv.

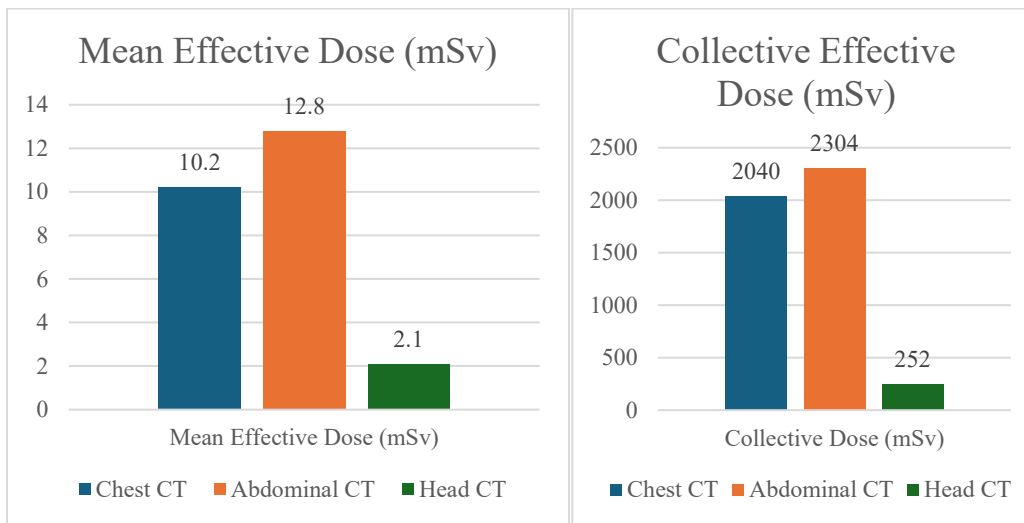
The dose ranges demonstrated notable interpatient variability, reflecting differences in scan length, patient body habitus, and clinical indication. The overall mean effective dose across all examinations was 8.7 mSv per patient. The total collective dose for the cohort was approximately 4.6 Sv.

Table 2: Effective dose and collective dose by CT examination type

Examination Type	Patients (n)	Mean Effective Dose (mSv)	Dose Range (mSv)	Collective Dose (mSv)
Chest CT	200	10.2 ± 2.1	6-15	2040
Abdominal CT	180	12.8 ± 3.5	8-18	2304
Head CT	120	2.1 ± 0.6	1-4	252
Total / Mean	500	8.7	1-18	4596

Table 2 shows that abdominal CT contributed the highest mean and collective radiation dose, followed by chest CT. Head CT contributed minimally to the overall radiation burden. The collective dose highlights the cumulative population exposure resulting from routine diagnostic CT imaging.

Figure 2: Mean Effective dose and collective dose by CT examination type



3.3 Estimated Lifetime Cancer Risk

Using BEIR VII lifetime attributable risk (LAR) models, radiation-induced cancer incidence was estimated based on effective dose values. For the entire cohort of 500 patients, the projected number of excess radiation-induced cancers was approximately 4–5 cases over the patients' lifetime. The projected number of fatal cancers attributable to CT radiation exposure was estimated at 2–3 cases.

Although the individual patient risk was small, the cumulative population-level risk was clinically relevant and consistent with published epidemiological risk estimates for diagnostic CT exposure.

Table 3: Projected lifetime cancer incidence and fatal cancer risk attributable to CT radiation

Examination Type	Projected Cancer Cases	Projected Fatal Cancer Cases
Chest CT	2.0	1.0
Abdominal CT	2.3	1.1
Head CT	0.2	0.1
Total	4–5 cases	2–3 cases

Table 3 demonstrates that abdominal CT accounted for the highest projected cancer incidence due to higher radiation doses and irradiation of radiosensitive organs. Chest CT also contributed significantly, particularly affecting the lung and breast tissue. Head CT contributed a minimal but non-zero cancer risk.

3.4 Sex-Based Differences in Projected Cancer Risk

Sex-based analysis revealed a higher projected cancer risk among female patients compared with male patients, despite similar mean effective doses. Female patients demonstrated approximately a 20% higher lifetime cancer risk.

Table 4: Sex-based comparison of projected cancer risk

Sex	Mean Effective Dose (mSv)	Relative Risk	Estimated Excess Cancer Cases
Male	8.5	Reference	2.0
Female	8.9	↑ ~20%	2.4

Table 4 highlights increased radiation-associated cancer risk in female patients, attributable primarily to the radiosensitivity of breast tissue and sex-specific risk coefficients in BEIR VII models. This finding emphasises the need for sex-specific dose optimisation strategies.

3.5 Age-Based Risk Stratification

Age at exposure significantly influenced projected lifetime cancer risk. Younger patients demonstrated a higher lifetime attributable risk than older patients, even at similar dose levels.

Table 5: Projected lifetime cancer risk stratified by age at exposure

Age Group (years)	Mean Effective Dose (mSv)	Relative Lifetime Cancer Risk
< 30	8.4	High ($\approx 2\times$)
31–50	8.8	Moderate
> 50	9.1	Lower

Table 5 demonstrates that patients younger than 30 years had approximately double the projected lifetime cancer risk compared with patients over 50 years, reflecting longer post-exposure lifespan and increased tissue radiosensitivity.

3.6 Effect of Repeated CT Examinations

Repeated CT imaging significantly increased cumulative radiation exposure and projected cancer risk. A small proportion of patients who underwent frequent scans accounted for a disproportionate share of the collective dose.

Table 6: Impact of repeated CT examinations on cumulative radiation dose and cancer risk

CT scans per Year	Patients (%)	Mean Cumulative Dose (mSv)	Relative Cancer Risk
1–2	68	9–15	Low
3–4	22	25–40	Moderate
> 4	10	> 50	High

Table 6 shows that although only 10% of patients underwent more than four CT scans annually, this group accumulated cumulative doses exceeding 50 mSv and represented the highest cancer risk category. This finding highlights the importance of tracking cumulative doses and justifying repeat CT imaging.

Overall, the results demonstrate that diagnostic CT imaging is associated with measurable radiation exposure and a quantifiable lifetime risk of cancer. Abdominal and chest CT contribute the greatest radiation burden, females and younger patients exhibit higher projected risk, and repeated CT examinations significantly increase cumulative exposure. While the individual risk remains low, the population-level impact supports the need for rigorous dose optimisation and radiation protection strategies.

3.7 Statistical Significance Analysis

Inferential statistical analysis demonstrated a significant difference in effective radiation dose across CT examination types (ANOVA, $p < 0.001$). Abdominal CT showed a significantly higher effective dose than chest and head CT ($p < 0.05$). Additionally, female patients exhibited a higher projected cancer risk compared to male patients, although the difference in mean effective dose was not statistically significant ($p = 0.08$). Younger patients (<30 years) demonstrated a significantly higher lifetime attributable risk than older age groups ($p < 0.01$), supporting the age-dependent radiosensitivity described in the BEIR VII models.

4. Discussion

Computed tomography has become indispensable in modern clinical practice; however, its widespread use has raised justified concerns regarding radiation exposure and the associated long-term cancer risk. The present study provides a comprehensive real-world assessment of radiation dose and projected cancer incidence in a cohort of 500 patients undergoing routine diagnostic CT examinations. By integrating patient demographics, dose metrics, and BEIR VII

lifetime attributable risk models, this study offers valuable insight into the population-level implications of diagnostic CT imaging.

4.1 Interpretation of Radiation Dose Findings

The radiation dose analysis demonstrated substantial variability across CT examination types, with abdominal CT delivering the highest mean effective dose, followed by chest CT and head CT. As shown in Table 2, abdominal CT contributed the largest proportion of the collective dose, despite a slightly lower utilisation rate than chest CT. This finding is consistent with prior studies, which have reported higher dose levels in abdominal imaging due to increased scan length, higher tissue attenuation, and multiphase acquisitions.

The overall mean effective dose of 8.7 mSv per patient aligns with values reported in international CT dose surveys and reflects current clinical practice using multidetector CT systems with dose modulation. While these doses remain within accepted diagnostic reference levels, the total collective dose of approximately 4.6 Sv highlights the cumulative radiation burden associated with routine CT utilisation at the population level.

4.2 Projected Cancer Incidence and Public Health Significance

Using BEIR VII risk models, the study projected approximately 4–5 excess lifetime cancers and 2–3 fatal cancers attributable to CT radiation exposure in the cohort of 500 patients (Table 3). Although the absolute risk for an individual patient is small, the projected incidence becomes significant when extrapolated to larger populations, particularly in healthcare systems that perform millions of CT examinations annually.

These findings are consistent with population-based risk projections reported by Berrington de González et al., who estimated that CT imaging could contribute to a measurable fraction of future cancer cases at the national level. The present study reinforces the concept that diagnostic CT, while clinically justified in most cases, is not risk-free and should be regarded as a modifiable source of radiation exposure.

4.3 Examination-Specific Risk Contribution

Analysis by examination type revealed that abdominal CT contributed the highest projected cancer incidence, followed closely by chest CT (Table 3). This pattern reflects both higher effective doses and irradiation of radiosensitive organs, including the liver, gastrointestinal tract, lungs, and breasts. Head CT, although associated with lower radiation doses, was estimated to have a small but non-zero projected cancer risk, supporting the linear no-threshold (LNT) model assumption used in BEIR VII.

These findings emphasise that risk is driven not only by examination frequency but also by scan region, organ sensitivity, and dose magnitude. Consequently, protocol optimisation should prioritise high-dose examinations, particularly abdominal and chest CT.

4.4 Sex-Based Differences in Radiation Risk

The study demonstrated that female patients had approximately a 20% higher projected lifetime cancer risk compared with male patients for similar radiation doses (Table 4). This difference is primarily attributable to the radiosensitivity of breast tissue and higher baseline cancer susceptibility incorporated into BEIR VII models.

The increased risk observed in female patients, especially following chest CT, underscores the importance of sex-specific radiation protection strategies. These may include protocol modification, careful justification of repeat imaging, and consideration of alternative modalities, such as MRI or ultrasound, when appropriate.

4.5 Influence of Age at Exposure

Age at exposure emerged as a critical determinant of projected cancer risk. Patients younger than 30 years demonstrated approximately double the lifetime attributable cancer risk compared with patients older than 50 years (Table 5), despite similar effective dose levels. This finding reflects longer post-exposure life expectancy and increases cellular radiosensitivity in younger individuals.

These results align with epidemiological evidence from paediatric and young adult CT exposure studies, including the landmark Australian cohort study that reported increased

cancer incidence following childhood CT exposure. The findings highlight the need for stricter justification criteria and more aggressive dose optimisation in younger patients.

4.6 Impact of Repeated CT Examinations

One of the most clinically significant findings of this study is the disproportionate contribution of patients undergoing repeated CT examinations to cumulative radiation dose and projected cancer risk. As shown in Table 6, only 10% of patients underwent more than four CT scans per year; however, this subgroup accumulated cumulative doses exceeding 50 mSv and represented the highest risk category.

This observation underscores the importance of tracking cumulative dose and monitoring radiation longitudinally. Without systematic tracking, patients with chronic conditions may unknowingly accumulate radiation doses associated with substantially elevated lifetime cancer risk. Implementation of dose registries and decision-support systems could mitigate this risk by guiding clinicians toward alternative imaging strategies when appropriate.

4.7 Clinical and Ethical Implications

From a clinical perspective, the results reaffirm that the diagnostic benefits of CT imaging generally outweigh radiation risks in acute, life-threatening, and oncologic settings. However, the study also highlights opportunities to reduce risk through protocol optimisation, avoiding unnecessary repeat scans, and adopting low-dose CT techniques.

Ethically, clinicians have a responsibility to balance diagnostic benefit against potential long-term harm. Transparent communication of radiation risks, particularly for younger patients and women, is essential for informed decision-making. At the institutional level, integrating radiation safety principles into clinical governance frameworks is critical to minimising the population-level cancer burden.

4.8 Strengths and Limitations

A key strength of this study is its use of real-world clinical data, combined with established BEIR VII risk models, to provide practical insight into radiation risk in routine diagnostic practice. The inclusion of subgroup analyses by age, sex, examination type, and repeat imaging enhances the clinical relevance of the findings.

A major strength of this study is the use of real-world clinical data from a tertiary care hospital combined with standardized BEIR VII risk modelling. The inclusion of subgroup analyses based on age, sex, examination type, and repeat imaging enhances the clinical applicability of the findings. Additionally, the calculation of collective dose provides a valuable population-level perspective on radiation burden, which is often lacking in single-centre CT dose studies. However, the study has limitations. Cancer risk estimates are model-based projections rather than observed outcomes and rely on assumptions inherent to the linear no-threshold model. Organ-specific dose estimation was approximated using the effective dose, which may lead to an underestimate or overestimate of risk for specific tissues. Additionally, the single-centre design may limit generalizability to other healthcare settings.

4.9 Implications for Future Practice and Research

Future efforts should focus on expanding low-dose CT protocols, integrating artificial intelligence-based dose optimisation, and establishing national dose registries. Prospective multicentre studies with long-term follow-up are needed to refine cancer risk estimates and validate model-based projections. Incorporating patient-specific risk assessment into imaging decision-making represents a critical step toward personalised and safer diagnostic imaging.

5. Conclusion

Computed tomography has become an indispensable diagnostic modality in modern medicine, providing rapid, accurate, and clinically decisive imaging across a wide range of medical conditions. However, the present study's findings demonstrate that CT imaging is associated with measurable radiation exposure and a quantifiable lifetime risk of radiation-induced malignancy. In this cohort of 500 patients, the cumulative radiation dose from routine

CT examinations was estimated to result in approximately 4–5 excess cancers and 2–3 cancer-related deaths over the patients' lifetime, based on BEIR VII risk models.

Abdominal and chest CT examinations contributed the greatest proportion of radiation exposure and projected cancer risk, reflecting higher effective doses and irradiation of radiosensitive organs. Female patients and younger individuals exhibited disproportionately higher lifetime cancer risk, underscoring the importance of age- and sex-specific considerations in radiation risk assessment. Furthermore, patients undergoing repeated CT examinations accumulated substantially higher cumulative doses, highlighting the need for longitudinal dose tracking and stricter justification of repeat imaging.

While the absolute risk to individual patients remains low and is generally outweighed by the diagnostic and clinical benefits of CT, the population-level implications are significant given the widespread and increasing use of this modality. These findings reinforce the need to adhere to the principles of justification and optimisation, as emphasised by international radiation protection guidelines. The implementation of low-dose CT protocols, judicious use of repeat imaging, and consideration of alternative modalities such as MRI and ultrasound, where appropriate, are critical strategies for minimising radiation-related harm.

In conclusion, CT imaging should continue to play a central role in patient care, but with heightened awareness of its long-term radiation risks. Integrating dose optimisation technologies, cumulative dose monitoring, and patient-specific risk assessment into routine clinical practice will help ensure that the substantial diagnostic benefits of CT are achieved while safeguarding patient safety and minimising the future cancer burden.

6. Limitations and Future Directions

6.1 Study Limitations

Despite providing valuable insights into radiation exposure and projected cancer risk from diagnostic CT imaging, this study has several limitations that should be acknowledged when interpreting the findings. First, the estimation of cancer risk was based on BEIR VII lifetime attributable risk models rather than direct clinical follow-up of cancer outcomes. While BEIR VII models are widely accepted and grounded in robust epidemiological data, they rely on assumptions inherent to the linear no-threshold (LNT) model, which remains a subject of scientific debate, particularly at low radiation dose levels.

Second, radiation exposure was quantified using the effective dose derived from the dose-length product (DLP) conversion factors. Although the effective dose is a practical and standardised metric for population-level risk estimation, it does not provide precise organ-specific dose information and may overestimate or underestimate risk for individual organs. More detailed organ dose modelling using Monte Carlo simulations could provide greater accuracy in future studies.

Third, this was a single-centre retrospective study, which may limit the generalizability of the findings to other institutions with different patient demographics, CT equipment, and imaging protocols. Variations in scanner technology, reconstruction algorithms, and institutional dose optimisation practices can significantly influence radiation exposure.

Additionally, paediatric patients were excluded from the study. Given that children are known to be more radiosensitive than adults, the overall cancer risk estimates reported here may underestimate the broader public health impact of CT imaging when paediatric populations are considered. Finally, potential confounding factors such as genetic susceptibility, lifestyle factors, and background environmental radiation exposure were not included in the risk models.

Another important limitation is the absence of organ-specific dose estimation. The present study utilised effective dose derived from DLP conversion factors, which, although suitable for population risk estimation, do not accurately reflect radiation exposure to individual radiosensitive organs such as the lung, breast, thyroid, and gastrointestinal tract. Since cancer risk is organ-dependent, the use of effective dose may lead to underestimation or overestimation of true biological risk. Future studies incorporating Monte Carlo-based organ

dosimetry or dose-tracking software could provide more precise and clinically relevant risk assessment.

6.2 Future Directions

Future research should focus on multicentre, prospective studies that incorporate diverse patient populations and standardised dose-reporting frameworks to improve the generalizability of radiation risk estimates. Long-term epidemiological follow-up studies are necessary to validate model-based projections against observed cancer incidence data, particularly among adults who have undergone repeated diagnostic CT examinations.

Advancements in CT technology offer promising opportunities to reduce radiation exposure without compromising diagnostic accuracy. Wider implementation of low-dose and ultra-low-dose CT protocols, iterative and deep-learning-based reconstruction algorithms, and artificial intelligence-driven exposure control systems should be prioritised. Research evaluating the real-world impact of these technologies on population-level cancer risk is essential.

Establishing comprehensive radiation dose registries and integrating cumulative dose tracking into electronic health records would enable clinicians to consider prior imaging exposure when making clinical decisions. Such systems could support personalised imaging strategies and help identify patients at higher cumulative risk.

Future studies should also explore patient-centred approaches, including risk communication strategies and shared decision-making models that incorporate individualised radiation risk assessment. Expanding research into alternative non-ionising imaging modalities, such as MRI and ultrasound, for selected clinical indications may further reduce unnecessary radiation exposure.

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