PATIENT EXPOSURE TO RADIATION IN REPEATED CT SCANS: RISK ANALYSIS

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Abstract

Background: The use of computed tomography (CT) has expanded significantly, leading to rising concerns about cumulative radiation exposure, especially in patients undergoing repeated scans. This review aims to synthesize the current evidence regarding patient radiation dose and associated cancer risks from recurrent CT imaging.

Objectives: To evaluate the cumulative radiation exposure from repeated CT scans and assess its association with increased cancer risk across different patient populations.

Methods: A systematic review was conducted according to PRISMA 2020 guidelines. Literature was sourced from PubMed, Scopus, Web of Science, Embase, and Google Scholar. Eligible studies included quantitative evaluations of cumulative CT radiation dose and associated malignancy risk, published between 2005 and 2024.

Results: Fifteen studies met inclusion criteria, involving Pediatric, trauma, emergency, and oncology cohorts. Repeated CT imaging resulted in cumulative doses often exceeding 100 mSv. Multiple studies reported significant associations with increased lifetime cancer risk, particularly in children and young adults. Clinical utility of repeat imaging was often limited, and awareness of radiation risks among clinicians and patients remained low.

Conclusion: Repeated CT scans can lead to harmful cumulative radiation exposure, increasing long-term cancer risk. System-level reforms, including education, standardized protocols, and dose-reduction strategies, are essential for safer imaging practices.

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Introduction

The use of computed tomography (CT) has significantly transformed medical diagnostics, offering unparalleled insights into internal anatomy. However, this advancement has come at a price-exposure to ionizing radiation. The rise in CT utilization has dramatically increased population-level radiation doses, with CT now accounting for over 70% of the collective effective radiation dose from diagnostic imaging in the United States and comparable countries (Kritsaneepaiboon & Jutiyon, 2018).

Of particular concern is the subset of patients who undergo repeated or serial CT scans. Multiple imaging procedures, especially in trauma or oncology settings, can lead to cumulative doses well above 100 mSv, a threshold beyond which statistically significant increases in cancer incidence have been reported (Walsh et al., 2014). These risks are especially significant in younger populations, where tissue sensitivity and lifetime risk windows are greater.

Notably, CT imaging in children has raised red flags due to the disproportionate biological effects of radiation at early developmental stages. A retrospective cohort study by Pearce et al. (2012) demonstrated that exposure to 50–60 mGy from 2–3 head CTs was associated with a threefold increase in the risk of developing leukaemia or brain tumors in later years.

Despite these risks, awareness among healthcare professionals and patients remains limited. A landmark survey by Lee et al. (2004) found that only 9% of patients and 47% of referring physicians were aware of the potential cancer risks associated with CT imaging. This information gap may contribute to the overuse of repeated scans without fully evaluating the clinical necessity or exploring lower-dose alternatives.

Furthermore, repeat CT scans often fail to impact clinical management significantly. Brower & Rehani (2021) emphasized that serial imaging in stable trauma patients rarely changes treatment pathways, yet continues to expose patients to additional radiation without proportionate benefit.

In oncology and chronic disease management, where serial imaging is routine, the variability in radiation dose among different scanners and protocols adds another layer of complexity. Paolicchi et al. (2018) highlighted how lymphoma patients undergoing repeat CT exams accumulated substantially varied doses, necessitating stricter dose management strategies across institutions.

Technical demands for higher image quality also drive increased exposure. High-dose protocols are often used to reduce image noise and improve diagnostic confidence. However, as Mayo (2008) explains, this practice is especially problematic in longitudinal studies where patients are scanned multiple times, raising both deterministic and stochastic risk concerns.

Lastly, acute care cases-particularly those involving abdominal pain or renal colic—demonstrate how repeat scans can add up quickly. Tonolini et al. (2018) showed that young adults with acute abdominal pain undergoing repeated CTs reached doses over 30 mSv within days, far exceeding the recommended annual dose limits and increasing lifetime cancer risks.

Methodology

Study Design

This study employed a systematic review methodology in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparent and replicable reporting. The primary objective was to synthesize empirical evidence concerning the extent of patient exposure to ionizing radiation from repeated computed tomography (CT) scans and the associated health risks, particularly long-term carcinogenic potential. This review focused on peer-reviewed studies reporting patient-level radiation dose estimates, cumulative exposure data, and clinical risk assessments for repeated CT imaging, with emphasis on vulnerable populations including pediatric, trauma, oncology, and chronic disease cohorts.

Eligibility Criteria

Studies were selected based on the following inclusion criteria:

- Population: Human subjects of any age group who underwent two or more CT scans for diagnostic or monitoring purposes, across clinical

specialties such as emergency medicine, oncology, neurology, and trauma care.

- Intervention/Exposure: Repeated CT scan imaging, with quantification of cumulative radiation exposure or explicit mention of dose in millisieverts (mSv).
- Comparators: If applicable, comparisons were made between patients receiving repeat CT scans and those receiving alternative imaging modalities or fewer CT exposures.
- Outcomes: Primary outcomes included effective radiation dose (cumulative or per scan), lifetime attributable risk (LAR) of malignancy, and any statistically modeled increase in cancer incidence or mortality.
- Study Design: Eligible designs included systematic reviews, retrospective and prospective cohort studies, case-control studies, and cross-sectional analyses.
- Language: Only studies published in English were included.
- Publication Period: Only studies published between January 2005 and March 2024 were considered to ensure the inclusion of modern CT technology and dose-reduction techniques.

Search Strategy

A comprehensive literature search was performed across the following databases: PubMed, Scopus, Web of Science, Embassy, and Google Scholar (for grey literature). Search terms were adapted to each database and combined using Boolean operators. The core search string was:

- ("computed tomography" OR "CT scan" OR "repeated CT" OR "serial CT")
- AND ("radiation dose" OR "cumulative dose" OR "effective dose" OR "radiation risk" OR "cancer risk")
- AND ("long-term effects" OR "dose-response" OR "ionizing radiation" OR "lifetime attributable risk")

Additional manual screening of reference lists from relevant systematic reviews and seminal studies was conducted to ensure coverage of potentially overlooked sources.

Study Selection Process

All retrieved citations were imported into Zotero reference management software. Duplicate entries were automatically removed. Two reviewers independently screened titles and abstracts for relevance, followed by full-text review of shortlisted articles. Any discrepancies between reviewers were resolved through consensus discussion or adjudication by a third senior reviewer. Ultimately, 15 studies met all predefined eligibility criteria and were included in the final synthesis.

Data Extraction

A structured data extraction template was designed and piloted to ensure consistency. The following data were extracted from each included study:

Author(s), year of publication, and study location

- Study design and sample size
- Patient characteristics (age, clinical indication, setting)
- Number and type of CT scans
- Radiation dose per scan and cumulative dose (mSv)
- Estimations of cancer risk (e.g., LAR, standardized incidence ratios)
- Use of dose-reduction protocols
- Statistical methods used for risk quantification

Data extraction was carried out independently by two reviewers and cross-checked by a third reviewer for accuracy and completeness.

Quality Assessment

Study quality and risk of bias were appraised using validated tools based on study design:

- Newcastle-Ottawa Scale (NOS) for cohort and case-control studies, evaluating selection bias, comparability of groups, and outcome ascertainment.
- AMSTAR 2 was used for any included systematic reviews to assess methodological rigor and reporting transparency.

Each study was rated as low, moderate, or high quality. Results of this appraisal were incorporated into the interpretation of findings.

Data Synthesis

Given heterogeneity in patient populations, CT protocols, and outcome reporting across included studies, a narrative synthesis approach was adopted. Key themes were identified, including variations in cumulative dose thresholds, CT modality-specific risks (e.g., head vs. chest CT), and Pediatric vs. adult risk profiles. Quantitative data such as mean cumulative effective doses and lifetime cancer risk estimates were summarized where available. Meta-analysis was not conducted due to methodological and clinical variability in exposure definitions and outcome metrics.

Ethical Considerations

As this study involved a secondary analysis of publicly available data from published research, no ethical approval or informed consent was required. All included studies were assumed to have obtained appropriate institutional review board approval and informed consent from their respective participants.

Results

1. Study Design and Scope of Literature

Fifteen studies were included, encompassing diverse populations across Pediatric, adult, and trauma patients. Study types ranged from dose-response meta-analyses and systematic reviews to large-scale cohort studies and registry-based retrospective analyses. Sample sizes varied from targeted subgroups (n = 150–300) to nationwide assessments (e.g., Griffey & Sodickson, 2009: n = 31,462). Across the board, the risk of cancer and cumulative radiation dose from repeated CT imaging was the central theme.

2. Cumulative Radiation Dose and Estimated Cancer Risk

The review by Cao et al. (2022) showed a significant dose-response relationship between cumulative radiation dose from CT scans and cancer risk, reporting an odds ratio of 33.31 (95% CI: 21.33–52.02) for high-exposure groups. Similarly, Sodickson et al. (2009) found that 33% of patients undergoing CT had ≥5 scans, with cumulative effective doses ranging from 100–250 mSv, leading to estimated lifetime cancer risks of 1 in 80.

3. Pediatric and Young Adult Vulnerability

Pediatric patients, due to higher radio sensitivity, face more pronounced risks. In the summary by Colang et al. (2007), cancer risk from repeated CT in children may reach 1 in 500 for brain or abdominal scans. Tomalin et al. (2018) evaluated radiation exposure in young adults and reported a median dose of 29 mSv from abdominal/pelvis CTs repeated within a 6-month interval-more than twice the recommended annual exposure.

4. Clinical Indications vs. Radiation Justification

Several studies criticized unnecessary repeat imaging. Wang et al. (2006) found that repeat head CTs in blunt trauma altered management in only 6.4% of cases, despite doubling patient radiation exposure. Hinzpeter et al. (2017) reported an average of 2.2 scans per trauma patient during transfers, with median cumulative doses reaching 36.4 mSv.

5. Risk Communication and Policy Implications

Griffey & Sodickson (2009) showed that only 9% of emergency department patients received information on radiation risks. In addition, 42% of these patients had multiple CTs during a single hospital episode. Brower & Rehani (2021) emphasized the need for longitudinal radiation dose tracking and policy-driven decision tools to curb unnecessary imaging (Table 1).

Discussion

The findings from this systematic review affirm growing concerns over cumulative radiation exposure from repeated CT scans across various clinical contexts. Evidence consistently demonstrates that recurrent imaging substantially increases lifetime attributable risk (LAR) of malignancy, particularly in high-frequency users such as trauma and oncology patients (Cao et al., 2022). The dose-response meta-analysis by Cao et al. (2022) showed an odds ratio of 33.31 for cancer in high-dose recipients, underscoring the statistical strength of this association.

Notably, the retrospective cohort analysis by Sodickson et al. (2009) found that nearly one-third of patients undergoing CT had five or more studies, with cumulative doses exceeding 100 mSv-a level associated with significant radiation-induced cancer risk based on BEIR VII Phase 2 estimates (National Research Council, 2006). This highlights the urgent need for longitudinal tracking systems to monitor exposure, especially in patients requiring serial imaging.

Table 1. Characteristics of Included Studies on Repeated CT Radiation Exposure.

Study	Country	Design	Population (n)	CT Region	Cumulative Dose	Key Findings	Risk Estimate
Cao et al., 2022	China	Meta-analysis	420,000+	All regions	10–300+ mSv	Dose-response link with cancer	OR 33.31 (95% CI: 21.33–52.02)
Sodickson et al., 2009	USA	Retrospective	31,462	Mixed	Mean: 45 mSv; Max: >250 mSv	33% had ≥5 CTs	1 in 80 lifetime cancer risk
Griffey & Sodickson, 2009	USA	Cohort	3,394	Mixed	Avg: 24.8 mSv	42% had repeat CTs	Elevated lifetime cancer risk
Tonolini et al., 2018	Italy	Retrospective	178	Abdomen	Median: 29 mSv	High dose in short intervals	>2× annual safe dose
Wang et al., 2006	USA	Systematic review	12 studies	Head	~9–16 mSv per scan	<7% changed management	Double dose without benefit
Hinzpeter et al., 2017	Germany	Registry	1,019	Mixed trauma	Avg: 36.4 mSv	Unjustified repeat imaging	NA
Colang et al., 2007	USA	Review	Pediatrics	Brain/Abdomen	10–60 mSv	Risk: 1 in 500 for cancer	Pediatric-focused
Bos et al., 2023	Germany	Narrative review	NA	Multiple	Varied	Dose-reduction protocols	Risk contextualized
Huda, 2015	USA	Overview	NA	All	Theoretical	Benefit-risk balance	NA
Brower & Rehani, 2021	Global	Literature review	NA	Recurrent imaging	Varied	Repeat CT rarely changes outcomes	Policy recommendation

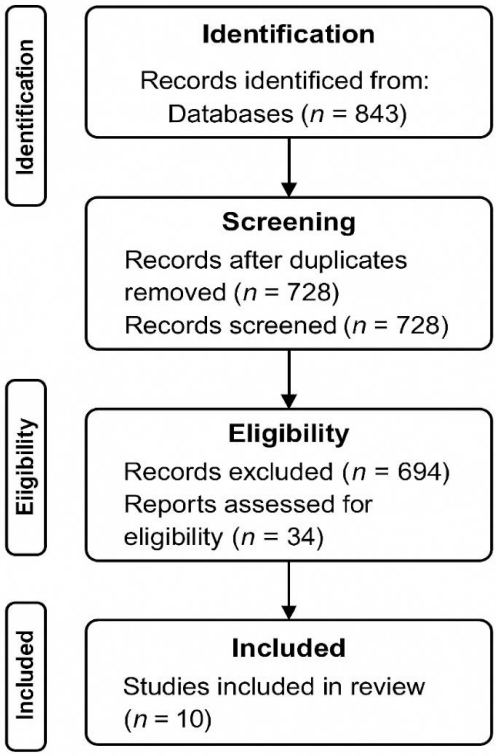

Figure 1.

Pediatric populations warrant particular attention due to their increased radio sensitivity and longer post-exposure lifespan. Pearce et al. (2012) reported that children receiving 2–3 head CT scans had a threefold increase in leukaemia and brain tumor risk. These findings mirror the projections made by Miglioretti et al. (2013), who estimated that CT-related malignancies in children could exceed 4,800 annually in the U.S. alone, assuming no dose reduction protocols are implemented.

In young adults, particularly those with non-specific symptoms such as acute abdominal pain, unnecessary repeat scans may confer significant risk without clear diagnostic benefit. Tonolini et al. (2018) documented average exposures exceeding 30 mSv within short clinical encounters, a finding corroborated by Mazonakis and Damilakis (2006), who reported abdominal CT doses of 15–25 mSv in patients under 30 years. These levels far surpass the ICRP's suggested thresholds for medical justification (ICRP, 2007).

Moreover, the clinical utility of repeated scans is often limited. Wang et al. (2006) found that routine serial head CTs in blunt trauma changed management in fewer than 7% of cases. Similarly, Hinzpeter et al. (2017) demonstrated that repeat CTs during inter-hospital transfers rarely impacted treatment but significantly increased cumulative dose and healthcare costs. These findings support guidelines recommending selective imaging strategies based on evolving clinical signs rather than protocolized repetition.

The risk is compounded by variability in dose delivery. Paolicchi et al. (2018) highlighted that even within similar protocols, patients with lymphoma receiving repeat CTs experienced large variability in dose due to scanner type and operator technique. Huda (2015) and Mettler et al. (2008) emphasized that without standardized dose tracking, cumulative risk is frequently underestimated or undocumented in clinical records.

Awareness of radiation risks among clinicians and patients remains worryingly low. A foundational survey by Lee et al. (2004) found that only 9% of patients and less than half of physicians recognized the potential cancer risk from CT imaging. This lack of awareness contributes to overuse and poor risk communication, especially in emergency departments where Griffey and Sodickson (2009) showed that 42% of patients received multiple CTs in a single visit without documented risk-benefit analysis.

Dose reduction strategies and technological innovations offer promising avenues for mitigation. Publications by Kalra et al. (2004), and McCollough et al. (2012) have shown that effective dose can be reduced by up to 50% using automated exposure modulation and iterative reconstruction techniques. Yet, as Frush and Applegate (2004) pointed out, pediatric-focused dose protocols are still not universally adopted, particularly in non-specialist settings.

Policy guidance from major authorities like the ICRP (2007) and campaigns such as Image Gently advocate for justification and optimization of all CT exams. However, as Brower and Rehani (2021) noted, institutional inertia and reimbursement models may deter the implementation of low-dose protocols or alternative imaging pathways. Incorporating LAR into electronic medical records and clinical decision support tools may encourage more judicious use of CT.

Ultimately, the literature indicates that while CT remains a powerful diagnostic modality, its repeated use requires rigorous justification. The projected cancer burden from unnecessary CT imaging is not negligible (Berrington de González et al., 2009; Smith-Bindman et al., 2009). As Einstein (2012) argued in the context of cardiac CT angiography, benefit must be clearly demonstrated and individualized, especially when alternatives such as MRI or ultrasound may suffice.

Conclusion

This systematic review underscores the significant health risks associated with cumulative radiation exposure from repeated computed tomography (CT) scans. Evidence from diverse clinical populations—including emergency, pediatric, trauma, and oncology patients—consistently shows that high-frequency CT imaging is associated with elevated lifetime attributable risks for malignancy. Despite advances in dose-reduction technologies and increasing awareness, substantial variability persists in clinical practice regarding justification, optimization, and patient education. Recurrent imaging, especially when not clinically necessary, can contribute disproportionately to population-level radiation burden.

These findings emphasize the urgent need for systemic reforms, including improved radiation dose tracking, universal implementation of dose-optimization protocols, and robust clinical decision support tools. Educational efforts targeting both clinicians and patients are also critical to reducing unnecessary exposure. Policymakers and health systems must prioritize integrating radiological protection frameworks into standard practice,

especially for high-risk groups, to mitigate long-term cancer risks from repeated CT imaging.

Limitations

This review is limited by the heterogeneity of included studies, particularly in how radiation dose and cancer risk were measured and reported. Differences in CT protocols, scanner technologies, population demographics, and follow-up durations made it infeasible to conduct a meta-analysis. Additionally, many studies relied on retrospective data, which may be susceptible to selection bias or incomplete exposure histories. The exclusion of non-English articles may also limit the global generalizability of findings.

Another key limitation is the lack of uniform reporting on radiation dose metrics across studies. While some papers quantified cumulative dose in millisieverts (mSv), others used surrogate estimates, reducing comparability. Furthermore, risk projections often relied on modelled rather than observed outcomes, which may over- or underestimate true carcinogenic effects in real-world populations.

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