REVIEW ARTICLE

Assessment and optimization of scattered radiation in computed tomography: A review of measurement techniques, dosimetry tools, and radiation protection strategies

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Abstract

Background: Off-target patient doses and occupational personnel exposure are caused by Computed Tomography (CT) induced dispersed radiation. Even with improvements in CT equipment and dosage reduction techniques, routine scatter field measurement and reporting are still inconsistent. In this article, we present publications from 2020–2025 that highlight radiation protection techniques that can be used in intra chamber/room scatters, dosage evaluation techniques, and measuring techniques of scatters of importance to Thermoluminescent Dosimeters (TLDs). *Methods:* Keywords such as "scattered radiation," "computed tomology," "dosimetry," "thermoluminescent dosimeter," "TLD," "OSLD," "MOSFET," "operator dose," and "radiation protection" were used in systematic searches conducted in Scopus, PubMed, and Google Scholar between 2020 and 2025. Relevance for CT scatter measurement, dosimeter characterisation by CT spectrum beams, occupational exposure in CT/CT-fluoroscopy, and experiments examining shielding or optimization methods were taken into consideration while choosing records. Following screening and eligibility assessment according to PRISMA guidelines, 18 studies were included in the qualitative synthesis. *Results:* The most popular passive dosimeters [TLDs, Optically Stimulated Luminescence Dosimeter (OSLDs)] and active dosimeters (ion chambers, metal-oxide-semiconductor field-effect transistor) for scatter mapping were employed in phantom and *in vivo* investigations. Although there are now various OSLDs and electronic dosimeters with reading and reusability benefits, TLDs remain the gold standard for integrating low-dose measurement because of their sensitivity, stability, and traceable calibration. The degree of the resulting level of dispersion is primarily determined by the following factors: patient size, scan duration, tube voltage, Tube Current Modulation (TCM), and in room personnel presence. Unexpected outcomes from contact shielding with automatic exposure control followed by increases in the resulting patient dose have been reported in recent studies. *Conclusions:* Standard practices, such as phantom matching, dosimeter batch calibration, and thorough documentation of scanner settings, are necessary for accurate scatter measurement. Dosimeter calibration and geometry must be balanced in twin center comparisons. Use of TLDs for proof of principle research and cumulative charting, as well as further use of dosimeters in real-time mode for interventions. As low as reasonably achievable principles must serve as the foundation for radiation protection, with an emphasis on administrative and distance management as well as carefully managed technical and procedure optimizations.

Keywords: Computed Tomography, Scattered Radiation, Thermoluminescent Dosimeter, Dosimetry, Radiation Protection, CT Fluoroscopy

Introduction

The accurate cross-sectional representation of illness and anatomy made possible by Computed Tomography (CT), which has revolutionized diagnostic imaging, is essential for diagnosis, therapy planning, and image-guided therapies [1]. The rise in CT guided interventional procedures, expanding clinical reasons, and the expanding availability of Multi-Detector CT (MDCT) have all contributed to a steady increase in CT use world-wide over the past few decades [2-3]. Even while CT has clear clinical advantages, it is still one of the main reasons why patients and medical professionals are exposed to the scanner during certain operations [4]. A significant amount of secondary exposure in the CT environment and the primary beam that produces the diagnostic image are caused by scattered radiation, which is produced by interactions between photons and the patient's tissues and surrounding structures [5-6]. Particularly during CT-fluoroscopy-guided procedures and in room imaging, scattered photons may reach personnel, travel in different directions, and contribute to doses to organs that are not the intended targets [7-8].

In the past, the main focus of CT dosimetry has been on patient-oriented measurements [volume Computed Tomography Dose Index (CTDI vol), dose length product (DLP), Size-Specific Dose Estimate (SSDE)] that estimate dosage in the primary beam and to directly irradiated organs [9]. These measurements do not estimate the room scatter field, which is essential for workplace safety and off-target patient dose calculation caused by scatter and leakage [10]. During interventional procedures like CT fluoroscopy, ablations, and CT guided biopsies, operators typically stand close to the gantry and patient [11]. This exposes them to scatter fields that deliver quantifiable doses to the hands, eyes, and entire body [12, 13]. The height of the patient table is very important for figuring out how scatter radiation is spread out vertically. When the table is higher, scatter radiation tends to move toward the upper body, which could mean more exposure for the operator's head, neck, and lens [14]. The rising awareness of occupational risk has led to a rise in regulatory interest in eye lens dose limits, real-time surveillance, and optimal shielding operations [15,16].

Scatter measurements are technically challenging. The scanner's automatic exposure management algorithms, beam filtration, collimation, patient size, and tube potential all affect the scatter intensity, which diminishes with distance [17,18]. The energy spectrum of scattered photons, which is different from the original beam's spectrum, determines the energy-dependent response of different dosimeters. Reproducible experimental geometries, careful selection of dosimetry instruments, and calibration of CT relevant energy spectra are necessary for practical measurement. Measuring scattered radiation in CT scans is critical to ensure staff safety and patient dose optimization. Techniques combine the use of standardized physical phantoms, real-time area survey instruments, and passive personal dosimeters [19].

Thermoluminescent Dosimeters (TLD), Optically Stimulated Luminescence Dosimeters (OSLD), ionisation chambers, and electronic personal dosimeters are all types of dosimeters [20]. Dose monitoring systems play an important role in dose monitoring and optimization in radiology departments [21]. Radiation Dose Monitoring Systems (RDMSs), especially for CT, have been implemented in medical imaging departments aiming towards regulatory compliance while continuing to provide valuable information concerning the optimization and justification of radiological procedures [22].

For a long time, TLD have been widely used for phantom based and *in vivo* studies due to their excellent sensitivity, small size, and established calibration chains. Moreover recently, Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) dosimeters, electronic personal dosimeters, and OSLD have been employed as an extension to TLDs due to their benefits in readout and quasi-real-time feedback. Although numerous studies have identified statistically distributed fields close to CT scanners, it is challenging to compare them because of variations in methodology, dosimeter design, and reporting practices. High-end CT systems with intricate tube current modulation and iterative reconstruction techniques highlight the delicate relationships between the shielding that is used and autonomous exposure management. More tube output from Automatic Exposure Control (AEC) is produced by exterior patient-contact shields or patient-contact shields shown on localizer images, which paradoxically increases patient dose, according to recent research. The position of the shields at measurement needs to be meticulously documented, which has consequences for both patient shielding laws and measurement techniques intended to quantify dispersion. Furthermore, there is limited operational information regarding standardized scatter mapping processes in national [American Association of Physicists in Medicine (AAPM) and American College of Radiology (ACR)] and international [The International Commission on Radiological Protection (ICRP)] recommendations, which encourage a strong emphasis on as low as reasonably achievable (ALARA) principles and optimization. Standardized protocols, such as comparing the scatter between two CT facilities within a single center, are necessary in twin center research to ensure that observed variations are caused by true inter-center variability and not methodological errors. This study summarizes the literature on scatter measurement approaches from 2020–2025 with an emphasis on effective radiation protection strategies, dose calculation methodologies, and TLD-based dosimetry.

We planned to: study the current state of intra-chamber scatter measurement methods; assess the advantages and disadvantages of TLDs and associated dosimeters in CT scatter fields; assess radiation safety protocols and possible hazards (e.g., shielding-AEC interactions); and offer operational guidelines for standard form twin center comparison studies and continuous occupational monitoring in CT installations.

Methods

Study design and reporting guidelines: This review was conducted to evaluate recent evidence on scattered radiation measurement techniques, dose evaluation methods, dosimetry tools and radiation protection strategies in CT.

Search methodology: To find publications published between January 1, 2020, and July 31, 2025, a comprehensive literature search was performed in PubMed/MEDLINE, Scopus, and Google Scholar. Combinations of "(scattered radiation" OR "scatter radiation") AND ("computed tomography" OR "CT") AND ("CT fluoroscopy") ("dosimetry" OR "dosimeter") AND ("thermoluminescent" OR "TLD") AND ("OSLD") AND ("MOSFET)" AND ("ion chamber") AND ("occupational") AND ("radiation protection") were among the search terms. Citation chaining of pertinent articles was added to search techniques that were modified for each database.

Selection criteria

Inclusion criteria: Dosimeter tests in CT energy spectra; staff monitoring studies with published staff doses in CT/CT fluoroscopy facilities; evaluation studies of shielding and optimization methods with measured results; phantom or in vivo experiments that measure scatter radiation in CT rooms.

Exclusion criteria: Articles published outside of the designated time frame, studies that primarily addressed patient primary beam organ dosimetry without scatter mapping, and studies with inadequate room or phantom scatter measurements.

Data extraction and screening: Following database searching, duplicate exclusion was carried out. Prior to full-text assessment, titles and abstracts were vetted for relevancy. Study design, CT system model, scan protocol parameters (kVp, mA, pitch), phantom type, dosimeter type and calibration, measurement positions and distances, measured quantities (air kerma, dose rate, Hp(3), μSv/procedure), usage of shielding, and important findings were among the data that was retrieved. Clear reporting of geometry, dosimeter calibration, background subtraction, and statistical analysis of repeated measures were all emphasized by quality control.

Results

Literature search and study selection

The literature search identified 1553 records from PubMed, Scopus and Google scholar. After removal of duplicates and screening of titles and abstracts, 18 studies met the eligibility criteria and were included in the qualitative synthesis. The included studies investigated scattered radiation measurements, occupational radiation exposure, dosimetry tools, shielding effectiveness and radiation protection strategies in CT environments. The characteristics and principal findings of these studies are summarized in table 1.

Table 1: Characteristics, dosimetric techniques, study focus and principal findings of the 18 studies included in the qualitative synthesis of scattered radiation measurement, occupational exposure dosimetry and radiation protection in computed tomography

Author	Dosimeter technique	Study focus	Key findings
Larjava *et al*. (2024) [1]	CT shielding assessment	Patient shielding in CT	Shielding visible to AEC may increase patient dose and affect dose optimization.
Knott *et al*. (2024) [2]	CT fluoroscopy dosimetry	Physician scatter exposure	Quantified scatter radiation doses received by physicians during CT-guided procedures.
Moonkum *et al*. (2023) [3]	Scatter radiation measurements	Staff radiation exposure	Evaluated scatter radiation doses received by healthcare personnel.
Inaba *et al*. (2022) [4]	Eye lens dosimetry	Occupational eye exposure	Measured eye lens radiation dose during CT fluoroscopy-guided biopsy.
Arao *et al*. (2023) [5]	Scatter dose measurement	Tube voltage optimization	Lower tube voltage reduced scatter radiation exposure to healthcare workers

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Grunz *et al*. (2023) [6]	Thermoluminescent Dosimeters (TLDs)	CT dose optimization	Tin prefiltration significantly reduced radiation dose while maintaining image quality.
Biegała *et al*. (2024) [7]	Spatial dose mapping	Scatter dose distribution	Evaluated scatter radiation patterns around CT scanners.
Nakatani *et al*. (2022) [8]	Radiation protection techniques	CT fluoroscopy safety	Summarized radiation exposure risks and protection methods during CT fluoroscopy.
Hayashi *et al*. (2024) [9]	Shield attenuation measurements	Shielding evaluation	Demonstrated importance of X-ray tube position in shielding effectiveness measurements.
Chen *et al*. (2024) [11]	Contact shielding assessment	CT shielding practices	Investigated benefits and limitations of eliminating patient contact shielding.
Troville *et al*. (2024) [12]	Occupational dosimetry	CT vs C-arm fluoroscopy	Compared physician radiation doses between CT and C-arm fluoroscopy procedures
Koch et al. (2024) [13]	Real-time electronic dosimetry	Radiation protection	Real time dose visualization contributed to reduced operator exposure.
Noto *et al*. (2025) [16]	Dose Length Product (DLP)-based calculations	Shielding design	Proposed a cost-effective method for CT room shielding calculations.
Khoshhal *et al*. (2025) [17]	Organ dose measurements	Patient radiation exposure	Evaluated absorbed doses in radiosensitive head and neck organs during CT
Inaba *et al*. (2021) [18]	Eye lens dosimetry	CT guided interventions	Reported occupational eye lens doses among physicians performing CT guided procedures
Leong *et al*. (2025) [19]	Scatter radiation mapping	Scatter distribution	Investigated dispersion patterns of scattered radiation during CT fluoroscopy.
Jeyasugiththan *et al*. (2022) [23]	Thyroid dosimetry and shielding	Organ protection	Assessed thyroid dose and effectiveness of thyroid shielding during CT examinations.
Abdulhamid *et al*. (2022) [24]	Eye lens dose assessment	Dose reduction strategies	Evaluated CT protocol modifications to reduce radiation exposure to the eye lens.

CT – computed tomography; AEC – automatic exposure control

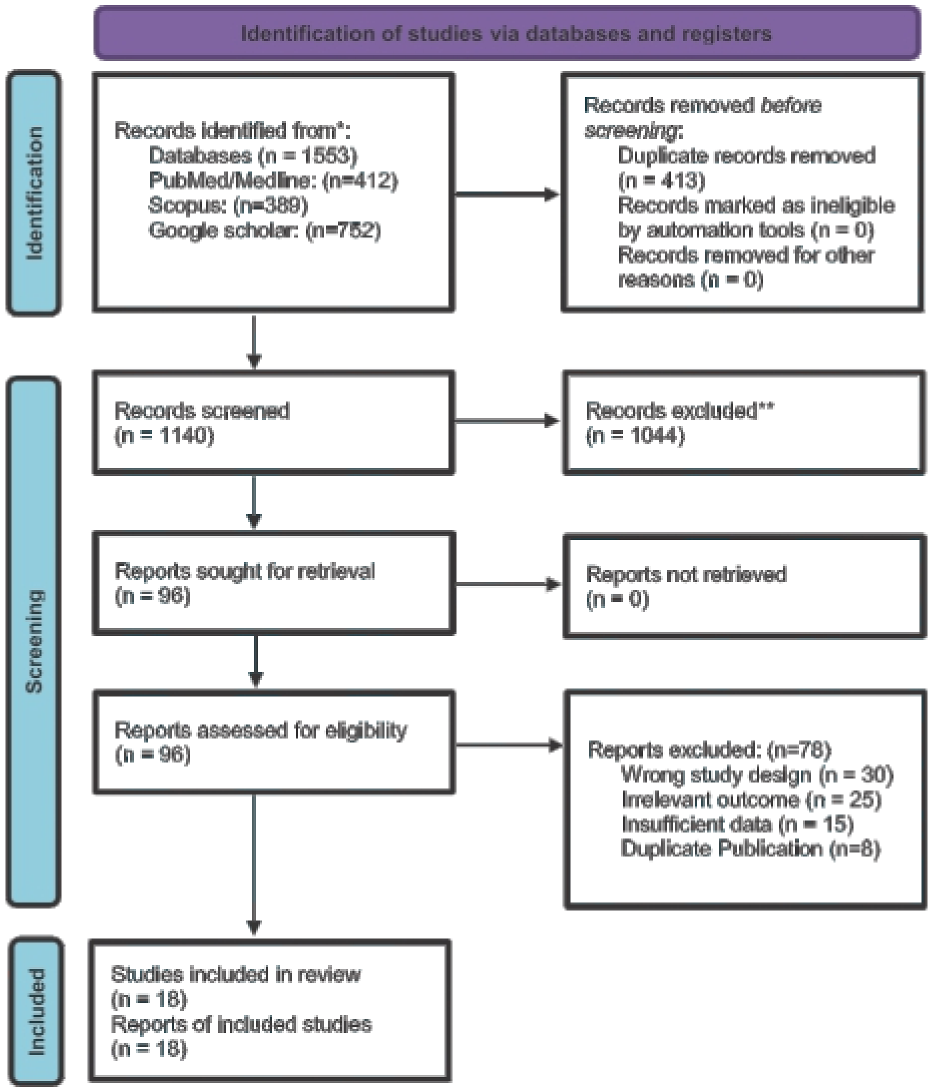

Figure 1: PRISMA chart

Measurement techniques and experimental setup

A combination of phantom based, in vivo (cadaver or patient), and occupational monitoring trial designs are used in studies evaluating scatter in CT facilities. Anthropomorphic phantoms (Alderson/RANDO, anthropomorphic pediatric replacements) or water-equivalent phantoms set on an isocentre to mimic patient attenuation are frequently used in phantom-based measurements. Typical measurement positions include operator positions next to the gantry, hand/eye positions during CT directed procedures, control room windows, and room peripheries (corners, doors).

Key considerations in experimental design

Avoid the primary beam: To measure scatter alone, dosimeters must be positioned outside of the primary beam; their locations must be accurately determined in Cartesian coordinates from the isocentre.

Background subtraction: In particular, for low-dose scatter measurements, the room background radiation needs to be assessed and removed from experimental data.

Statistical reporting and repeated measurements: Measurement uncertainty brought on by dosimeter read out noise and scanner output fluctuations is decreased by repeated measurements.

Energy correction and calibration: Dosimeters must be adjusted using the instrument's published energy response curves (e.g., TLD-100, LiF: Mg,Ti; OSLD nanoDot; MOSFET calibration parameters) or calibrated in CT-type energy spectra.

Dosimeters used for scatter measurement

TLDs (LiF: Mg,Ti, such as the widely used TLD-100) are tiny, tissue-equivalent, and the response is well characterized, they are frequently utilized for cumulative assessments. The continued use of TLD in CT scattered radiation studies can be attributed to their high sensitivity, stability and established clinical validation. Previous investigations have demonstrated their suitability for medical dosimetry applications and dose verification procedures [10,20,25-26]. TLDs need to be calibrated batch dependently against an ionization chamber or a primary standard, handled carefully to prevent fading, and subjected to regulated annealing processes. Low detection limits and well-established QA protocols are advantages; potential energy dependency at low photon energies, sluggish readout techniques, and the absence of real time readout are negatives.

OSLD: OSLDs, such as Al_2O_3:C nanoDots, are more practical due to their signal stability and readability. Calibration and orientation control are required for their energy response and angular dependency in scatter spectra. OSLDs have been effectively applied to in vivo dose assessments and phantom mapping.

Ionization chambers and survey meters: The gold standard for measuring absolute air kerma and dosage rate is a free-in-air ionization chamber. When interpreting measurements in CT scatter fields, solid-state survey meters offer quick mapping of the dose rate distribution with energy-dependent responses.

Electronic personal dosimeters and MOSFETs: When placed at strategic locations (e.g., eye, hand), MOSFETs offer spatial resolution and quasi-real-time dosage measurements. They are especially helpful for monitoring radiation accumulation and providing immediate protection during interventional CT fluoroscopy. Energy/angular dependence and sensitivity drift are warning signs that need to be checked for calibration on a regular basis.

TLD: Extended comparison

Overview and guiding concepts: When exposed to ionizing radiation, TLDs work by trapping energy in crystal defect states. The stored electrons are released when heated, producing light in proportion to the dose that was absorbed. Lithium fluoride (LiF) TLDs (TLD-100, LiF: Mg,Ti) are widely used because of their linearity over a wide range of dosages and quasi-tissue equivalency.

Quality assurance and calibration: It is recommended that calibration be done using reference beam quality that is similar to CT beam spectra (usually 80–140 kVp). Labs use diagnostic X-ray beams or filtered beams to generate calibration factors for dispersed CT fields. Annealing cycles, control dosimeters, and batch homogeneity testing are necessary for traceability and accuracy. Dosimetric accuracy for absolute air kerma estimates is increased by cross-calibration with ionization chamber measurements under free-in-air conditions.

Practical use for scatter mapping

Badge/Chip locations: To measure spatial gradients, use numerous TLD chips on small plates; install them at operator stations (chest, eye level), hand locations, and at predetermined radial distances from the isocentre (e.g., 0.5 m, 1.0 m, 1.5 m). To estimate the per-process dosages in CT-guided procedures, TLDs may be employed per procedure and with standard intervals read. For regular diagnostic CT scans for mapping, add together a few images to obtain a reproducible signal over background. Adjust the data as needed by applying fading adjustments, energy response corrections, and background subtraction. Uncertainty analysis should incorporate dosimeter reproducibility, calibration uncertainty, and placement geometrical uncertainty.

Performance in comparison to OSLD/MOSFET: Because of their well-understood behavior and reduced vulnerability to instantaneous drift, TLDs are still chosen for long-term cumulative monitoring, even though OSLDs offer quick re-readability and MOSFETs offer real-time data. For both cumulative and procedural peak exposure measurements, TLD mapping with spot-checking by MOSFETs is used in most recent studies.

Dose evaluation: Metrics and practical findings

Concerns regarding occupational radiation exposure extend beyond radiology departments and have also been reported among surgical trainees and other healthcare professionals exposed to ionising radiation [27]. In occupational and scatter dosimetry, the most often reported metrics are effective dose estimates (μSv), dose equivalent at 10 mm or 3 mm depth (Hp(10), Hp(3)), and air kerma (μGy). In occupational dosimetry, hp(3) is used for eye-lens doses and hp(0.07) for skin doses (hands). Studies most frequently report μSv per procedure or μSv per hour per operator position, which makes comparisons by process type and scanner technology easier.

Main empirical findings (2020–2025)

In CT guided surgeries and CT fluoroscopy, operator doses vary somewhat: depending on proximity, shielding, and process duration, per-procedure eye doses can range from sub-μSv levels to many tens of μSv. The size of the patient, the gantry/table materials, and the room layout all affect the scatter level, which roughly drops with the square of the distance from the isocentre. **Tube voltage and filtration:** Studies indicate that the effect of reduced kVp on scatter dose varies based on the method of scanner filtration and patient habitus. It boosts contrast but alters the scatter spectrum. Tube Current Modulation (TCM) and AEC depending on the imaging job and exterior objects (shields) in the localizer picture, TCM can either enhance or decrease scatter; Significant patient dose spikes were observed in a number of recent studies when exterior shields were apparent to AEC algorithms [1].

Barriers and shielding: Well-thought-out structural shielding and movable barriers minimize personnel dispersal; however, patient-contact shields need to be used carefully due to possible AEC interactions.

Strategies for radiation protection

Control hierarchy: Personal protective equipment (PPE), engineering controls, administrative controls, and elimination/substitution (to the greatest extent feasible) are the conventional controls for radiation protection in CT facilities.

Engineering controls: Structural shielding, design drawing based on workload and estimated scatter;

post-installation measurements using OSLDs or ion chambers should validate pre-installation estimates. The evidence now available indicates that DLP-based shielding estimations should be sufficient if they are compared to in-room measurements. Gantry-based controls and remote operation: reduce the amount of time spent in the control room and on the intercom while minimizing exposure levels in the room. Lead glass and mobile barriers offer targeted protection for the hands and upper body during treatments.

Administrative and procedural controls: Staff rotation and procedural work flows that cut down on time spent close to the gantry gradually lower occupational dosage. Taking distance is a practical and affordable mitigation strategy that involves defining safe zones and adhering to minimum distances while exposing.

Training: Instruction on shield placement, AEC behaviour, and procedural ergonomics to prevent inadvertent patient dosage increases.

Devices and equipment for personal protection: Thyroid shields and lead aprons limit scatter exposure to the neck and chest; when worn on patients, they should be positioned such they don't obscure AEC localizer pictures. Leaded glasses and protective eyewear are worn for extended periods of time away from scattering sources; operator acceptance and attenuation are determined by fit and thickness. Hands: if using radioprotective gloves won't impair procedural dexterity or increase dosage through dispersed interactions, use forceps and needle holders to get as far away from the central beam as possible.

Real-time monitoring and feedback: Electronic dosimeters and real-time dose displays have been demonstrated to lower operator exposures when used in workflows because they enable prompt remedial actions (e.g., moving shields, stepping back).

Comparative twin-center study considerations

Design harmonization: To enable equitable comparison between twin centers, harmonize the phantom type, dosimeter batches and calibration, scanner protocols (kVp, mA/pitch, rotation time), and grid measurement. Use the same number and placement of TLDs and OSLDs, and record any variations in the software version or scanner make and model.

Suggested measuring grid: 0.5, 1.0, 1.5, and 2.0 meters on the front, posterior, left, and right axes are the radial isocentre distances. Operator stations: hand positions for standard operations, chest level, and eye level. External measurements of the control room and doorway are used to determine whether the shielding is adequate.

Analyse data: Show uncertainty ranges, normalized doses per DLP or CTDIvol (to account for protocol variation), and per-procedure doses. If the data is skewed, compare using non-parametric statistical tests; show the median and interquartile range for the doses used during the operation.

Discussion

Studies in mammography, dentistry and phantom based radiographic examinations have similarly emphasized the importance of organ specific dose assessment and optimization strategies, supporting the broader need for radiation protection across imaging modalities [28-30]. These findings reinforce the significance of accurate and reliable dosimetry methods for evaluating radiation exposure and guiding dose reduction measures. A comparative study by Srikanth *et al*. (2024) demonstrated that although minimally invasive surgical techniques offered several clinical advantages, they were associated with increased radiation exposure compared with conventional procedures, emphasizing the need for effective radiation monitoring and protection strategies [31].

The review notes that because of their sensitivity and established calibration procedures, TLDs continue to be the most popular for scatter mapping, even though many more modern dosimetry techniques are being developed. However, the lack of uniform reporting makes it impossible to compile results from different centers in an easy way. The need for protocol specific testing of any shielding policy is highlighted by the unexpected interplay between AEC and shielding. Options for additional scatter exposure reduction are provided by ongoing innovation, such as real-time dosimetry, enhanced scanner filtration (such asmodification. tin filtering), and AI-assisted protocol

Research requirements and recommendations

Professional societies are required to provide consensus measurement techniques for scatter mapping, including calibration methods, placement distances, and dosimeter types.

Harmonized multi-center research: Extensive twin- or multi-center investigations will enhance shielding recommendations for diverse scanner fleets and establish typical scatter dosage levels. The best-practice dosimeter selection for a particular application (cumulative monitoring versus real-time feedback) would be informed by systematic TLD, OSLD, and MOSFET intercomparisons in typical CT scatter fields.

AEC Transparency: To avoid inadvertent dosage escalation, scanner makers should provide more thorough documentation of the external attenuator's AEC response.

Conclusion

A combination of good protocol design for the measurement, careful dosimeter selection (of which TLDs are an excellent choice for cumulative mapping), and protection strategies based on distance and administrative controls with well-applied engineering and shielding countermeasures are necessary for the successful measurement and reduction of scattered radiation in CT. Standardized dose reporting, common dosimeter calibration, and harmonized protocols are necessary for twin-center investigations. Future research will need to focus on intercomparison studies of dosimetry devices in CT scatter fields, manufacturer reporting on AEC, and consensus protocols.

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References

1. Larjava HRS, Eneh CTM, Niiniviita HM. To shield or not to shield: shielding may have unintended effects on patient dose in CT. *Eur Radiol* 2024; 34(4):2480-2486.
2. Knott EA, Troville JL, Reynoso CA, Rose SD, Wagner MG, Lee FT Jr, *et al*. Physician scatter dose in interventional CT fluoroscopy. *J Appl Clin Med Phys* 2024; 25(6):e14355.
3. Moonkum N, Jitchom S, Sukaram S, Nimtrakool N, Boonrat P, Tochaikul G. Determination of scattered radiation dose for radiological staff during portable chest examinations of COVID-19 patients. *Radiol Phys Technol* 2023; 16(1):85-93.

4. Inaba Y, Hitachi S, Watanuki M, Chida K. Radiation eye dose for physicians in CT fluoroscopy-guided biopsy. *Tomography* 2022; 8(1):438-446.
5. Arao S, Masuda T, Oku T, Ono A, Okura Y. Utility of lower tube voltage scans in reducing exposure of healthcare workers within computed tomography room to scattered radiation. *Radiat Prot Dosimetry* 2023; 199(19):2338-2343.
6. Grunz JP, Halt D, Schüle S, Beer M, Hackenbroch C. Thermoluminescence dosimetry in abdominal CT for urinary stone detection: effective radiation dose reduction with tin prefiltration at 100 kVp. *Invest Radiol* 2023; 58(3):231-238.
7. Biegała M, Brodecki M, Skoczylas K, Jakubowska T, Domienik-Andrzejewska J. Analysis of dose distribution around a computed tomography scanner in terms of exposure to scattered ionizing radiation of caregivers of pediatric patients. *Int J Occup Med Environ Health* 2024; 37(3):326-334.
8. Nakatani M, Kariya S, Ono Y, Maruyama T, Ueno Y, Komemushi A, *et al*. Radiation exposure and protection in computed tomography fluoroscopy. *Interv Radiol* 2022; 7(2):49-53.
9. Hayashi H, Maeda T, Takegami K, Nishigami R, Kobayashi D, Asahara T, *et al*. A suitable procedure of dose reduction factor measurements of X-ray shields during computed tomography examination: the importance of considering positional changes of an X-ray tube. *Radiat Phys Chem* 2024; 222:111880.
10. Adam DP, Hammer C, Malyshev JZ, Culberson WS, Bradshaw TJ, Grudzinski JJ, *et al*. Creation of waterproof TLD probes for dose measurements to validate image-based radiopharmaceutical therapy dosimetry workflow. *Biomed Phys Eng Express* 2023; 9(4).
11. Chen J, Tu J, Huang S, Zhu Z, Tu Y. Is it appropriate to completely eliminate contact shielding during CT examination? A discourse based on experimental findings. *Health Phys* 2024; 126(1):46-55.
12. Troville J, Knott E, Reynoso-Mejia CA, Wagner M, Lee FT, Szczykutowicz TP. Technical note: a comparison of physician doses in C-arm and CT fluoroscopy procedures. *J Appl Clin Med Phys* 2024; 25(5):e14335.
13. Koch A, Gruber-Rouh T, Zangos S, Eichler K, Vogl T, Basten L. Radiation protection in CT-guided interventions: does real-time dose visualisation lead to a reduction in radiation dose to participating radiologists? A single-centre evaluation. *Clin Radiol* 2024; 79(6):e785-e790.
14. Utsugi K, Takigawa T, Suwa K, Igarashi M, Komatsuzaki Y, Funaki A, *et al*. Proposal for reducing the operator radiation exposure dose during 3D DSA imaging under carotid artery occlusion tests (Matas and Alcock test). *J Neuroendovasc Ther* 2025; 19(1):2025-0024.
15. Mansouri Z, Salimi Y, Wolf NB, Mainta I, Zaidi H. CT-free attenuation and Monte-Carlo based scatter correction-guided quantitative 90Y-SPECT imaging for improved dose calculation using deep learning. *Eur J Nucl Med Mol Imaging* 2025; 52(9):3484-3499.
16. Noto K, Mitsui W, Takata T, Kojima H, Matsubara K, Yamaguchi I. Cost-effective shielding design based on the dose length product method for shielding calculations in X-ray computed tomography systems. *Radiat Prot Dosimetry* 2025; 201(11):795-801.
17. Khoshhal AR, Torshabi AE, Zehtabian M. A dosimetry measurement on head and neck sensitive organs during CT scan: a comprehensive study. *Appl Radiat Isot* 2025; 225:111949.
18. Inaba Y, Hitachi S, Watanuki M, Chida K. Occupational radiation dose to eye lenses in CT-guided interventions using MDCT-fluoroscopy. *Diagnostics (Basel)* 2021; 11(4):646.
19. Leong SS, Azman N, Vijayananthan A, Wong JHD. Dispersion patterns of scattered radiation exposure on phantom in CT fluoroscopy. *Radiat Phys Chem* 2025; 228:112810.
20. Kry SF, Alvarez P, Cygler JE, DeWerd LA, Howell RM, Meeks S, *et al*. AAPM TG 191: Clinical use of luminescent dosimeters: TLDs and OSLDs. *Med Phys* 2020; 47:e19-e51.
21. Milano MT, Mahesh M, Mettler FA, Elee J, Vetter RJ. Patient radiation exposure: imaging during radiation oncology procedures: executive summary of NCRP report no. 184. *J Am Coll Radiol* 2020; 17(9):1176-1182.
22. Ria F, D'Ercole L, Origgi D, Paruccini N, Pierotti L, Rampado O, *et al*. Association of Medical Physics Task Group statement of the Italian Association of Medical Physics (AIFM) task group on radiation dose monitoring systems. *Insights Imaging* 2022; 13:23.
23. Jeyasugiththan J, Kumarihami AMC, Satharasinghe D, Mahakumara P, Senanayaka G, Jayakody I. Evaluation of thyroid radiation dose during abdominal Computed Tomography procedures and dose reduction effectiveness of thyroid shielding. *Radiography* 2022; 28(3): 704-710.

24. Abdulhamid M, Ibrahim U, Zira JD, Yusuf SD, Abdulhamid A. Assessment of head CT protocol to reduce the radiation dose in eye lens in some selected hospital in Kaduna State, Nigeria. *Appl Radiat Isot* 2022; 190:110469.
25. Ginzburg D, Eliyahu I, Spooner N, Sterenberg M, Reshes G, Shapiro A, *et al*. Search for experimental evidence of dose-rate and wall scattering effects in the thermoluminescence response of LiF: Mg, Ti (TLD-100). *Radiat Prot Dosimetry* 2022; 198(4):222-228.
26. El-Faramawy N, Chopra V, Rawash S, El-Hafez AA, Dhoble SJ. Response of TLD-600/TLD-700 and CR-39 to neutrons for medical dosimetry. *Luminescence* 2021; 36(5):1257-1264.
27. Sierra LAM, Katsnelson JY, Pineda DM. Occupational radiation exposure among general surgery residents: should we be concerned? *J Surg Educ* 2022; 79(2):463-468.
28. Ali RMK, Hogg P. Eye radiation dose from breast cancer screening using full field digital mammography and digital breast tomosynthesis: a phantom study. *Radiography (Lond)* 2024; 30(1):141-144.
29. Khafaji M, Albadawi GH. Assessment of scattered dose to the eye in dentistry: a systematic review. *Cureus* 2023; 15(8):e43113.
30. Peiro A, Chegeni N, Danyaei A, Fatahiasl J, Tahmasbi M. Pelvic radiation dose measurement for trauma patients in multifield radiographic examinations: a phantom-based TLD dosimetry study. *Health Sci Rep* 2023; 6(7): e1424.
31. Srikanth T, Thota S, Venkat K, Ramesh Chandra VV, Prasad BCM. Comparative study of open Transforaminal Lumbar Interbody Fusion (TLIF) and Minimally Invasive Transforaminal Lumbar Interbody Fusion (MISTLIF) based on clinical outcome, radiological outcome, tissue injury markers and radiation exposure. *J Krishna Inst Med Sci Univ* 2024; 13(4):107-114.

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