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MEDICAL PHYSICS INTERNATIONAL
The Journal of the International Organization for Medical Physics

Aims and Coverage:

Medical Physics International (MPI) is the official IOMP journal. The MPI Proceedings provides a platform for medical physicists to share their experience, ideas and new information generated from conference abstracts/proceedings, and dissertation abstracts for recent graduates in medical physics or closely related fields. The e- journal is available free of charge to IOMP members.

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REM2026

Enhanced patient care through effective data management

INTERNATIONAL SYMPOSIUM ON RADIATION EXPOSURE MONITORING IN MEDICAL IMAGING

11-13 June 2026 | Sofia, Bulgaria

Under the auspices of the Ministry of Health of Republic of Bulgaria

Organised by:

Roentgen Foundation

BAR Bulgarian Association of Radiology

Supported by:

ICRP

ISR International Society of Radiology

International Organization for Medical Physics

ISRRT International Society of Radiographers & Radiological Technologists

IFMBE

ESR European Society of Radiology

EFOMP

EFRS European Federation of Radiographer Societies

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WELCOME BY THE CHAIR OF THE REM 2026 ORGANISING COMMITTEE

Dear colleagues,

Welcome to this special issue of the journal containing the abstracts of papers and invited presentations from the International Symposium on Radiation Exposure Monitoring in Medical Imaging (REM2026). The Symposium, held under the auspices of the Ministry of Health of the Republic of Bulgaria, is co-organised by several Bulgarian governmental and professional bodies and supported by nine international organizations representing the diverse professional communities involved in medical imaging.

This broad multidisciplinary collaboration makes REM2026 a platform for dialogue and exchange among experts working to optimize radiation exposure monitoring and promote its effective use in support of patient safety and high-quality healthcare.

The overarching goal of REM2026 is reflected in its motto: “Enhanced patient care through effective data management.” The scientific programme highlights the latest developments and future directions in radiation exposure monitoring in medical imaging, with particular emphasis on automation, interoperability, connectivity, and the integration of digital exposure monitoring systems with wider healthcare information infrastructures. The Symposium also explores analytical applications of exposure data and innovative IT solutions for effective data management at the level of individual patients, healthcare institutions, and national or international healthcare systems. The growing role of artificial intelligence in these processes is also an important topic of discussion.

The programme includes plenary lectures, topical sessions featuring invited talks and scientific papers, round-table discussions, two workshops, and poster session. In addition, the Symposium provides opportunities for interaction with industry through company presentations and discussions with vendors of medical imaging and radiation exposure monitoring solutions.

REM2026 is designed for a broad multidisciplinary audience, including radiologists and other imaging physicians, medical physicists, radiographers, IT specialists, engineers, healthcare and radiation protection authorities, manufacturers, patient organizations, and experts in risk communication.

We hope that this collection of abstracts will inspire further discussion, collaboration, and innovation in this important field of radiation protection in medicine, ultimately contributing to safer and more effective patient care.

Jenia Vassileva

Chair of the Organising Committee

REM2026

INTERNATIONAL SYMPOSIUM
ON RADIATION EXPOSURE MONITORING IN MEDICAL IMAGING

11-13 June 2026 | Sofia, Bulgaria

SCIENTIFIC PROGRAM

CONFERENCE VENUE

Convention Centre, Grand Hotel Millennium Sofia

Floor 4, Shakespeare Hall and Mozart Hall

REGISTRATION DESK

Convention Centre, Grand Hotel Millennium Sofia

Floor 4, Shakespeare Hall and Mozart Hall

REGISTRATION HOURS

THURSDAY, 11th June 2026	8:00 – 18:00
FRIDAY, 12th June 2026	8:00 – 18:00
SATURDAY, 13th June 2026	8:00 – 12:00

THURSDAY, 11th JUNE 2026

10:00 – 11:00 **Shakespeare Hall**	**OPENING SESSION** Opening by Ms. Katya Ivkova, Minister of Health Welcome Addresses by the Local Organisers: J. Vassileva (Roentgen Foundation, Chair), J. Djounova (NCRRP, Co-chair), D. Kostova-Lefterova (BSBPE, Co-chair), N. Traykova (BAR), P. Bochev (BSNM), N. Dzhankova (BARMIRT) Opening Messages from the International Partners: M. Kortesniemi (ICRP), D. Frush (ISR), J. Damilakis (IOMP), N. Pongnapang (ISRRT), R. Magjarevic (IFMBE), M. Ludviksson (ESR), E. Koutsouveli (EFOMP), P. Cornacchione (EFRS), S. E. McKenney (Image Gently)	
11:00 – 12:30 **Shakespeare Hall**	**PLENARY SESSION: SETTING A SCENE: FROM DATA TO CARE** *Moderators: M. Kortesniemi (Finland), J. Vassileva (Bulgaria)*	
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11:10 – 11:30	PL2. Radiation Exposure Data: Nurturing from the Numbers	D. Frush (*USA*)
11:30 – 11:50	PL3. Integrating Dose Monitoring into a Holistic Care System	E. Samei (*USA*)
11:50 – 12:10	PL4. From Generic to Individualised Dose in the Era of AI and Emerging Technologies	M. Rehani (*USA*)
12:10 – 12:30	PL5. Ethics and Patient Centred Care: Transformative Influences on Radiation Protection in Medicine	J. Malone *(Ireland*)
12:30 – 14:00 **Mozart Hall**	**LUNCH, TECHNICAL EXHIBITION, POSTER VIEWING**	
13:30 – 14:00 **Shakespeare Hall**	**COMPANY PRESENTATION: QAELUM NV: FROM DOSE DATA TO CLINICAL INSIGHT: SUPPORTING OPTIMIZATION IN MEDICAL IMAGING** *Speakers: N. Fitousi (Qaelum NV), J. Vignero (UZ Leuven)* *Moderator: P. Trindev (Bulgaria)*	
14:00 – 15:31 **Shakespeare Hall**	**SCIENTIFIC SESSION 1: METRICS BEHIND THE IMAGE: DOSE, RISK, AND QUALITY** *Moderators: M. Mahesh (USA), S. Avramova-Cholakova (UK)*	
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14:20 – 14:40	SS1.2. Precision or Practicality: Fit-for-Purpose Dose Assessment	M. Brambilla (*Italy*)
14:40 – 14:55	SS1.3. Advances in Patient-Specific Organ Dose Assessment and the Role of AI	J. Damilakis (*Greece*)
14:55– 15:10	SS1.4. Image Quality Quantification, Monitoring and Automation	E. Samei (*USA*)
15:10 – 15:17	SS1.5. Monte Carlo Methods Coupled with Machine Learning Algorithms in Support of Patient-Dependent Organ Dose Assessment in CT	D. Madaleno, C. Borges, J. Santos, P. Vaz, C. Lee (*Portugal, USA*)
15:17 – 15:24	SS1.6. Dose Evaluation of Head and Neck Organs Using ICRP Mesh-Type Reference Computational Phantoms in Dental CT	C.H. Min, K. H. Sung, H. Choi, S. Sung, S.M. Lee, D. Kim, D. Kim, H. M. Yang (*Republic of Korea*)
15:24 – 15:31	SS1.7. Fetal Radiation Exposure from Cone-Beam Computed Tomography in Photon and Proton Breast Radiotherapy: Dosimetric Measurements and Monte Carlo Dose Assessment	A. C. Sá, et al. (*Portugal, Sweden, Belgium, Croatia*)

15:31 – 16:00 **Mozart Hall**	**COFFEE, TECHNICAL EXHIBITION, POSTER VIEWING**	
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16:15 – 16:30	SS2.2. Safe Data Sharing in Medical Imaging: Regulatory and Ethical Perspectives for AI and Dosimetry	J. Damilakis (*Greece*)
16:30 – 16:45	SS2.3. Dose Management System: From Setting Up to Quality Assurance	R. M. Sánchez, I. Tsalafoutas, L. Arlany, R. Ruggeri, I. Reiser, V. Tsapaki (*IAEA*)
16:45 – 16:55	SS2.4. Lessons Learned from Dose Monitoring System Implementation	N. Pongnapang (*Thailand*)
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FRIDAY, 12th JUNE 2026

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9:15 – 9:30	SS3.2. Data Quality as the Foundation of Effective Exposure Monitoring	H. Bosmans (*Belgium*)
9:30 – 9:45	SS3.3. Quantifying and Managing Imaging Dose in Radiotherapy	S. Gros (*USA*)
9:45 – 10:00	SS3.4. Data for Population Radiation Dose Estimation	M. Mahesh *(USA*)
10:00 – 10:07	SS3.5. Comparison of Peak Skin Dose Calculations in Qaelum DOSE to Existing Manual Method for Interventional Cardiology Procedures	I. Turner (*UK*)
10:07 – 10:14	SS3.6. Characterizing Global Noise Level Outliers in CT Abdomen Dose Monitoring	J. Vignero, N. Fitousi, H. Bosmans *(Belgium)*
10:14 – 10:21	SS3.7. Generalized Conversion Coefficients for Collective Dose Estimation: A Methodological Approach for a National Data Collection System	O. Rampado, et al. (*Italy*)
10:30 – 11:00 ***Mozart Hall***	**COFFEE, TECHNICAL EXHIBITION, POSTER VIEWING**	
11:00– 12:32 ***Shakespeare Hall***	**SCIENTIFIC SESSION 4: FROM DRLs TO OPTIMISATION: CLINICAL USE OF EXPOSURE DATA** *Moderators: P. Cornacchione (Italy), A. Zagorska (Bulgaria)*	
11:00 – 11:15	SS4.1. DRL Establishment and Use: Errors and Solutions	G. Paulo (*Portugal*)
11:15 – 11:30	SS4.2. Data-Driven Optimisation: Integrating Dose and Image Quality	M. Kortesniemi (*Finland*)
11:30 – 11:45	SS4.3. Using Exposure Monitoring in Cancer Screening	H. Bosmans (*Belgium*)
11:45 – 11:57	SS4.4. Right Data, Right Care: Managing Radiation Exposure for Pediatric Patients	S. E. McKenney (*Image Gently, USA)*
11:57 – 12:04	SS4.5. Use of Interventional Cardiology Datamine for Quality Improvement	A. Rogers, S. Heath (*UK*)
12:04 – 12:11	SS4.6. Cardiology Dose Comparison for Procedures with Small Sample Sizes Using Precision-Weighted Pooling	J. Cole, C. Baker, S. Fisher, S. Jackson *(UK*)
12:11 – 12:18	SS4.7. Using Exposure Monitoring to Standardize CT Quality Across Diverse Facilities	P. Boxx (*USA*)
12:18 – 12:25	SS4.8. An Integrative Approach for Optimizing CT Scan Protocols Regarding Low Contrast Detectability and Radiation Exposure	S. Scheidegger, et al (*Switzerland*)
12:25 – 12:32	SS4.9. Variability of Cone Beam Dose Index in Cone Beam Computed Tomography Protocols: A Multicenter Assessment and National Survey	A. Sá, at al (*Portugal*)

12:32 – 14:00 ***Mozart Hall***	**LUNCH, TECHNICAL EXHIBITION, POSTER VIEWING**	
13:30 – 14:00 ***Shakespeare Hall***	**COMPANY PRESENTATION: PACSHealth LTD** *Speaker: S. Massey* *Moderator: P. Trindev (Bulgaria)*	
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14:15 – 14:30	SS5.2. Cumulative Radiation Dose Monitoring and Patient Care: Relevance to the Blind Men and Elephant Parable	D. Frush (*USA*)
14:30 – 14:45	SS5.3. Metrics and Tools to Quantify and Benchmark Recurrent Imaging	M. Brambilla (*Italy*)
14:45 – 14:53	SS5.4. Behind the Images: Unmasking Cumulative Radiation Load	S. Avramova-Cholakova (*UK*)
14:53 – 15:01	SS5.5. Catch Me If You Can: How We Can Track Individual Patients	N. Saltybaeva (*Switzerland*)
15:01 – 15:09	SS5.6. Radiation Exposure Monitoring in Recurrent Imaging: A Single Center Clinical Audit	I. Dyakov, G. Georgieva, V. Stoynova, D. Kostova-Lefterova (*Bulgaria*)
15:09 – 15:17	SS5.7. Radiation Exposure Monitoring and Early Detection of Deterministic Skin Injury in Paediatric Interventional Cardiology: A Local Workflow Experience	D. Kostova-Lefterova, P. Parashkevova, L Dimitrov, D. Georgiev (*Bulgaria*)
15:17 – 15:24	SS5.8. An Investigation of High-Dose CT Examinations Performed on Five CT Systems	D. Ivanova, I. Dyakov, K. Romanova *(Bulgaria)*
15:24 – 15:30	Q&A: Who Owns the Dose? Tracking, Access, and Use of Individual Exposure Data	
15:30 – 16:00 ***Mozart Hall***	**COFFEE, TECHNICAL EXHIBITION, POSTER VIEWING**	
16:00 – 17:30 ***Shakespeare Hall***	**SCIENTIFIC SESSION 6: FROM SILOS TO SYSTEMS: INTER-FACILITY EXPOSURE REGISTRIES, AI AND E-HEALTH INTEGRATION** *Moderators: H. Bosmans (Belgium), E. Georgiev (Bulgaria)*	
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16:15 – 16:30	SS6.2. National E-Health Integration of Imaging Exposure Data	M. Kortesniemi (Finland)
16:30 – 16:40	SS6.3. Managing Imaging Data in the Bulgarian E-Health System	Representative of the Bulgarian Ministry of Health
16:40 – 16:50	SS6.4. Radiation Exposure Monitoring and Dose Surveys: The Bulgarian Experience with a Multi-Layer Software Ecosystem	F. Simeonov *(Bulgaria)*
16:50 – 16:59	SS6.5. Radiation Dose Monitoring in Complex Coronary Interventions: Establishment of a National Registry in Bulgaria	H. Mateev, D. Kostova-Lefterova. A. Aleksandrov, D. Sidjimova (*Bulgaria)*

16:59 – 17:08	SS6.6. National Electrophysiology Registries as a Framework for Radiation Dose Monitoring, Optimization, and Establishment of Diagnostic Reference Levels for Electrophysiology Procedures	K. Dzhinsov, D. Kostova-Lefterova, T. Shalganov *(Bulgaria*)
17:08 – 17:17	SS6.7. Combining Dose Monitoring Data and Clinical Records to Identify Systematic Issues in Interventional Radiology and Cardiology Practices	J. Vignero, K. Lemmens, D. Petrov, H. Bosmans (*Belgium*)
17:17 -17:27	SS.6.8. Bridging Occupational and Patient Dose Data in Modern Radiation Monitoring	R. M. Sanchez (*Spain*)
17:27 – 17:35	SS6.9. Analysis of clinical practice for neuroradiological procedures for exposure optimization	E. Samara, A. Stüssi, G. Pamplona, J. Ekeberg, Z. Kulcsar (*Switzerland*)
17:35 – 18:30	**POSTER HIGHLIGHTS AND YOUNG TALENT SESSION**	
Shakespeare Hall	*Moderators: S. Gros (USA), N. Dzhankova (Bulgaria)*	
17:35 – 17:40	Overview of posters in Group 1	R. Borisova (*Bulgaria*)
17:40 – 17:45	Overview of posters in Group 2	I. Petrov (*Bulgaria*)
17:45 – 17:50	Overview of posters in Group 3	E. Georgiev (*Bulgaria*)
17:50 – 18:30	**Young Talent Award candidates:**	**3 minutes per poster**
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	P1.5. Iterative and Deep Learning reconstruction-based imaging dose reduction in Lung sparse-view computed tomography	Y. Adib (*Morocco*)
	P1.7. Monte Carlo–based Clinical Systems for CT Organ Dosimetry: A Comparative Study	D. Madaleno (*Portugal*)
	Poster highlights:	**3 minutes per poster**
	P1.6. Determination of size-specific dose estimates in PET/CT: A deep learning approach for anatomical classification and dosimetry	O. V. Vargas (*Mexico*)
	P1.8. Validation of a Dose Management System for PET/CT and SPECT/CT Examinations in Nuclear Medicine	A. Zagorska (*Bulgaria)*
	P2.1. Diagnostic Reference Levels from Sub-Saharan Africa	C. Trauernicht (*South Africa*)
	P2.13. Optimisation of Interventional Radiology and Cardiology Procedures Following the Publication of New National Diagnostic Reference Levels	S. Avramova-Cholakova (UK)
	P3.5. Evaluation of Population Exposure and DRLs and Calculation of Patient's Doses Using E-Health System Data in Lithuania	V. Grigoniene (Lithuania)
	P3.6. Characterisation of Ionising Radiation Exposure in Medical Procedures During 2025	C. Machado (*Portugal)*
	P3.9. Geographical Distribution and Technical Data Analysis of CT Scanners and Angiography Devices in Georgia	S. Kiparoidze (*Georgia)*

SATURDAY, 13th JUNE 2026

8:00 – 9:00 ***Shakespeare Hall***	**IFMBE WORKSHOP** *Lecturer: R. Magjarevic (IFMBE, Croatia)* *Moderator: M. Stoeva (Bulgaria)*	
9:00 – 10:00 ***Shakespeare Hall***	**ROUND TABLE 1: FROM TECHNOLOGY TO CLINIC** *Moderators: E. Samei (USA), A. Trianni (Italy)*	
9:00 – 9:08	RT1.1. We Need a Working Group - Recommendation - Regulation on Quality of Patient DICOM Dose Reporting	G. Lutters, O. Pusterla, A. Urben, F. Eichenberger, L. Jakober, D. Platten, E. McDonagh (*Switzerland, UK*)
9:08 – 9:16	RT1.2. Common Data Inconsistencies in Multi-vendor Clinical Environments: Lessons Learned from Real-world Dose Management	A. Romanyukha, N. Fitousi (*Belgium*)
9:16 – 10:00	**DEVELOPERS VISIONS FOR EXPOSURE MONITORING AND OPTIMISATION** Round Table with Representatives of Vendors and Users	Panelists: E. McDonagh, S. Boon, N. Fitousi, S. Massey, V. Tafradjiiksi, A. Legland
10:00 – 10:45 ***Shakespeare Hall***	**ROUND TABLE 2: FROM REGULATION TO PRACTICE** *Moderators: V. Gershan (IAEA, Austria), J. Djounova (Bulgaria)*	
10:00 – 10:10	RT2.1. Implementation of International Safety Standards in the Optimisation of Patient Radiation Protection – Based on an IAEA Assessment	V. Gershan (IAEA)
10:10 – 10:20	RT2.2. Support for Optimisation of Patient Protection through the European Union's Strategic Agenda for Medical Ionising Radiation Applications (SAMIRA)	G. Simeonov (EC)
10:20 – 10:45	**THE ROLE OF REGULATORS IN IMPLEMENTING DOSE OPTIMIZATION** Round table and discussion	Panelists: G. Simeonov (EC), E. Friberg (HERCA), I. Lasić (Bosnia and Herzegovina), I. Garba (Nigeria)
10:45 – 11:15 ***Mozart Hall***	**COFFEE, TECHNICAL EXHIBITION, POSTER VIEWING**	
11:15– 12:30 ***Shakespeare Hall***	**ROUND TABLE 3: EXPLAINING EXPOSURE: EDUCATING PATIENTS, EMPOWERING PROFESSIONALS** *Moderators: G. Paulo (Portugal), D. Frush (USA)*	
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11:23 – 12:00	**MAKING RADIATION EXPOSURE MEANINGFUL TO PATIENTS** Multidisciplinary Round Table	Panelists: J. Malone, M. Ludviksson, E. Koutsouveli, P. Cornacchione, S. E. McKenney, G. Bogdanova
12:00 – 12:30	Audience Q&A: Explaining Exposure in the Real World	

12:30 – 14:00 ***Mozart Hall***	**LUNCH, TECHNICAL EXHIBITION, POSTER VIEWING**	
13:30 – 14:00 ***Shakespeare Hall***	**COMPANY PRESENTATION: INTERMEDICA GROUP EOOD AND CANON MEDICAL SYSTEMS EUROPE** *Speaker: M. Caballo* *Moderator: I. Dyakov (Bulgaria)*	
14:00 – 15:00 ***Shakespeare Hall***	**PLENARY SESSION: FROM DATA TO CARE: LOOKING INTO FUTURE** *Moderators: M. Rehani (USA),* E. Samei (*USA*)	
14:00 – 14:20	Summary of the Sessions and Round Tables:	
	Metrics, Standardisation	A. Trianni (*Italy*)
	Analytics, AI, Integration	M. Kortesniemi *(Finland)*
	Regulation, Research and Communication	G. Paulo (*Portugal*)
14:20 – 15:00	Discussion: What future developments in exposure data monitoring are expected and receivable?	
15:00 – 16:00 ***Shakespeare Hall***	**CLOSING SESSION** Best Paper Award, Young Talent Award Closing remarks by the Chair	

POSTERS

GROUP 1

Rapporteur: R. Borisova (*Bulgaria*)

P1.1	Quality Assurance Framework for Deep Learning Models in Radiation Dose Prediction	M. Piksis (*Latvia*)
P1.2	Enhancing Diagnostic Accuracy in Digital Mammography Using an Integrated Deep Learning Framework	M. Mehrabi, S. Zolghadri, S. Vosoughi, N. Salek (*Iran*)
P1.3	Artificial Intelligence in Medical Exposures in Greece - Users' Perception, Awareness, Competence	S. Vogiatzi, C. J. Hourdakis, L. Astrakas (*Greece*)
P1.4	Bringing Monte Carlo to the Clinic: AI-Driven Real-Time Radiation Dosimetry in Medical Imaging	I. S. Karanisa (*Greece*)
P1.5	Iterative and Deep Learning Reconstruction-Based Imaging Dose Reduction in Lung Sparse-view Computed Tomography	Y. Adib, M. Driouch, M. A. Youssoufi, L. B. Drissi, M. M. Reda Mesradi (*Morocco*)
P1.6	Determination of Size-Specific Dose Estimates in PET/CT: A Deep Learning Approach for Anatomical Classification and Dosimetry	O. V. Vargas, E. T. García, J. R. Franco, Z. O. Arzate (*Mexico*)
P1.7	Monte Carlo–Based Clinical Systems for CT Organ Dosimetry: A Comparative Study	D. Madaleno, I. Pinto, S. Borges, C. Machado, N. Laia, P. Vaz (*Portugal*)
P1.8	Validation of a Dose Management System for PET/CT and SPECT/CT Examinations in Nuclear Medicine	A. Zagorska, P. Tonchev, V. Kostadinov, S. Masso (*Bulgaria*)
P1.9	Comparison of the Practice at Two Nuclear Medicine Departments with and without Dose Collection Software	I. Dyakov, A. Zagorska, S. Shalamanov (*Bulgaria*)
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P1.11	CBCT Dose Monitoring in Radiotherapy: Pediatric–Adult Comparison and National Pediatric Survey Results	D. Saraiva, A.C. Sá, F. Costa, G. Farinha, A. R. Figueira, A. Monteiro, D. Ribeiro, A. G. Dias, L. T. Cunha, L. Osório, G. Couto (*Portugal, Malta*)
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REM2026

INTERNATIONAL SYMPOSIUM
ON RADIATION EXPOSURE MONITORING IN MEDICAL IMAGING

11-13 June 2026 | Sofia, Bulgaria

PLENARY SESSION

Radiation Exposure Data: Nurturing from the Numbers

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Ionizing radiation used in medical imaging is requisite for these invaluable tools in providing medical care of the patient and, by extension, their personal and medical communities. Those in the practice of medicine are easily recognized as stewards of careful monitoring. Monitoring consists of the benefits that medical imaging provides. Radiation exposure is obligate in performing this imaging care and so, then, is the need to also monitor exposure due to the inherent real and potential risks which depend on the level of exposure. While there are both *measures* and derived *metrics*, the *manifestation (*and *meaning)* of this exposure numeracy through systems to gather, keep, and analyze these data is more opaque than the benefits that radiation modalities provide: specifically, what are the goals? In this presentation, the perspectives from a clinical imaging standpoint of those who are invested in the expanse of patient care such as the patients themselves, their families, referrers, the public, researchers (e.g., epidemiologists), regulatory authorities and policy makers, on the value of exposure information will be discussed. A nuanced way of acknowledging this expanded approach of impact is to rethink the phrase *patient care* (a direct recipient for advancing health) to *care of the patient*, arguably introducing a more systems and more corporate-oriented perspective. One must understand that the significance of care improvement depends on one of a variety of intended recipients of this information. For example, improved care can be embraced by an improved understanding of the impact on population exposure; adherence to standards, guidelines, and regulations (such as professional certification, practice accreditation, etc), public trust arising from practice reputation in part earned through accountability, patient agency (and other ethical considerations) and referrer and patient covenant. These are all salient in dialogues about how exposure data through informed use of radiation exposure metrics can improve the care of patients. And the prioritization of value depends on one’s role, such as in the clinical setting. With this investment in the relevancy of these numbers by those invested in and entrusted with radiation protection, there can be “nurturing with numbers”.

Integrating Dose Monitoring into a Holistic Care System

Ehsan Samei, Reed and Martha Rice Distinguished Professor Duke University, Durham, NC, USA

Dose, its assessment, reduction, management, and monitoring, has been an integral part of radiation care in the practice of medicine. That is appropriate, as for decades we have known the potential harm that can come from radiation exposure. Even so, radiation has a significant role in delivering effective healthcare. We use radiation in medicine despite its presumed potential harm because its overall benefit to the individual outweighs its likelihood of harm. That reality is central to the practice of radiation care. As such, caring for patients is not only about reducing their exposure to radiation, but rather appropriating the right amount of exposure to deliver the desired benefit. That is the very essence of holistic care, where both minimizing radiation harm and maximizing derived value are maintained in the context of care for the individual patient. Dose monitoring likewise needs to be oriented in the context of individual holistic care. This orientation means that, first, the intention of the procedure needs to be clearly known in advance, taking into consideration the exact context and preferences of the patient and their caregivers. Second, the procedure needs to include image quality assessment and targeting to ensure its benefits are maintained. Third, the radiation dose should generally align with good practice. Fourth, adequate flexibility needs to be built into the system to enable individualized accommodation of the patient's preferences and the application of aggregate-based analyses to individual conditions. Dose monitoring in the context of holistic care thus takes on a more encompassing, patient-centered, and multi-dimensional role, including image quality and the context of application.

From Generic to Individualized Dose in the Era of AI and Emerging Technologies

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Medical imaging has historically relied on population-based metrics and generalized dose indicators such as CTDIvol, DLP, and effective dose. While these metrics have served an important role in standardization and benchmarking, they are inherently limited in representing the true biological burden of radiation to individual patients. This limitation is increasingly critical in an era where imaging utilization continues to rise, patient populations are aging, and cumulative exposures are becoming more common.

REM 2026 highlights key themes such as patient exposure metrics, individual exposure tracking, and AI-driven developments, all of which converge on a central question: can we move from generic approximations to truly individualized dose assessment?

Emerging technologies such as photon-counting detectors and the development of monochromatic X-ray sources will not only improve dose efficiency but also redefine radiation monitoring and dosimetry. By narrowing or tailoring the energy spectrum, these approaches challenge the applicability of conventional dose descriptors derived from polychromatic beams, necessitating new models for organ dose estimation, calibration, and risk assessment. This transition further strengthens the case for individualized dosimetry frameworks that integrate energy-dependent interactions at the patient level.

A major focus will be on the transformative role of artificial intelligence. AI has the potential to enable automated organ segmentation, real-time dose reconstruction, and adaptive protocol optimization. Beyond dose calculation, AI-driven systems can identify outliers, detect protocol drift, and support decision-making by integrating cumulative exposure histories into clinical workflows. These developments shift radiation protection from retrospective auditing to prospective, patient-centered management.

However, significant challenges remain. These include the lack of standardized frameworks for individualized dose reporting, uncertainties in risk modeling at the individual level, integration with clinical systems, and the ethical implications of communicating personalized risk.

There is a need to have a roadmap toward clinically meaningful individualized dose metrics, emphasizing harmonization across modalities, incorporation into dose registries, and alignment with evolving recommendations from international bodies. It represents a paradigm shift toward truly personalized radiation protection where each imaging decision is informed by the patient’s unique characteristics, clinical context, and cumulative exposure history.

Ethics and Patient Centred Care: Transformative Influences on Radiation Protection in Medicine

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Professions generally aspire to a high moral standard. Those of us attending the Radiation Exposure Monitoring in Medicine Symposium (REM 2026) might reasonably be expected to have high expectations in helping ensure that our own work and that of other professionals is morally sound. On the other hand, it is useful to note that among the professionals involved including our own, familiarity with well developed systems of ethics mandated by relevant professional organisations is not widespread. Even among those with a well-developed, refined personal moral compass, there is often a deficit of knowledge and experience of systems of professionally mandated professional ethics.

Over the last 20 or so years, and particularly since the Fukushima accident, this deficit has been noted and been the subject of advocacy in radiation protection. Recently a system of ethics for radiation protection in medicine has come of age, is well described in the literature, and is underwritten by formal publications and/or positions adopted by the international organisations and professional bodies. For example in Malone et al (2016 and 2019), in formal publications from ICRP (2018 and 2025) and WHO (2022), and in the conclusions of the IAEA X-Ray Vision conference (IAEA, 2025).

These publications will be reviewed and concerns relevant to attendees at REM26 will be identified and presented. They include basic social/moral, ethics and human rights issues that arise, but are often missed when addressing Patient Centred Care and Patient Safety. They also include a set of six value pairs, identified by ICRP and others, how to apply them, and realistic examples of their application. As all Radiological and Radiation Oncological Procedures are Medical Acts, the approaches developed must be consistent with medical ethics.

In the words attributed to Victor Hugo *This is an Idea whose time has come.* Or to give the full quote: *Nothing Is More Powerful Than an Idea Whose Time Has Come***,** and with ethics for Medical Radiation Protection, this is now clearly so. Although, implementation in practice is likely to be slow and take some years.

For the most part, the publications involved are, or will be, available shortly on an Open Access basis as free downloads. The relevant references will be provided at the symposium.

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SCIENTIFIC SESSIONS

Modality-Specific Dose Metrics: From IEC and DICOM Standards to Clinical Displays

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Radiation dose in diagnostic imaging is not a single quantity. Each modality operates under different physical principles and clinical constraints, and the metrics used to characterise patient exposure reflect this diversity. CT relies on CTDIvol and DLP as primary output descriptors, with SSDE introduced to account for patient size variability that CTDIvol alone cannot capture. Fluoroscopy and interventional procedures require tracking of dose area product alongside cumulative air kerma at the interventional reference point, given the extended and often unpredictable nature of these examinations. Mammography dosimetry is built around mean glandular dose, derived from incident kerma through conversion coefficients that depend on breast composition and thickness. Digital radiography uses the exposure index as defined by IEC 62494-1, a standardised quantity that replaced the inconsistent vendor-specific indices previously in use. Nuclear medicine follows a different framework altogether, centred on administered activity and internal dose estimation.

The IEC 60601 standard series provides the regulatory basis for how these quantities must be measured, reported, and displayed by equipment manufacturers. Understanding what each part of the standard actually requires — and where it leaves room for interpretation — is relevant to anyone responsible for evaluating or implementing dose monitoring in a clinical setting.

On the data side, DICOM Radiation Dose Structured Reports are the established mechanism for encoding and transferring dose information. Not all RDSR implementations are equivalent, however, and the differences between RDSR, MPPS, and Secondary Capture objects have practical consequences for downstream data collection and completeness.

Dose indicators as recorded in the RDSRs might be different from how dose indicators are shown to users — at the acquisition console, in the PACS viewer, and in dose management dashboards. IEC requirements for real-time display are reviewed, along with threshold-based alert systems and layout guidance from ACR and AAPM. Open issues include the lack of uniform display standards across vendors.

Precision or Practicality: Fit-for-Purpose Dosimetry

Marco Brambilla, Medical Physics Department, Azienda Ospedaliero Universitaria "Maggiore della Carità, Novara, Italy

Effective dose (ED) is a radiological protection quantity created by the ICRP as a risk-adjusted dosimetric quantity for the management of protection against stochastic effects and may be considered as an approximate indicator of possible risk, with the additional consideration of variation in risk with age and sex.

Historically, ICRP has promoted the derivation of conversion coefficients that can be used to evaluate ED from measured quantities, such as the dose-length product (DLP) for CT. *DLP-based* effective dose (ED_k) is the ED calculated by multiplying the DLP for the conversion factors (k) of the scanned anatomical region as provided for adult patients in the ICRP publication 102.

Since then, there was a movement toward organ dosimetry and *organ dose-based* effective dose ED_{OD}. Software programs were introduced that use precomputed Monte Carlo dose libraries accommodating a range of CT scanner models, collimation settings, kV options. With time, the use of reference phantoms has evolved from geometric, stylized phantoms to the voxel phantoms in which organs are represented by geometrical shapes derived by models based on CT scans of real patients. The software programs such as VirtualDose CT, National Cancer Institute dosimetry system for CT (NCICT) and MIRD CT can calculate ED_{OD} with reference phantoms for both sexes and a set of tissue weighting factors (ICRP 60 or ICRP 103).

Finally, in recent years there has been a movement toward personalized dose estimation. Software programs like VirtualDose CT and NCICT incorporate an extensive library of ICRP mesh-type phantoms spanning various ages, body habitus, and both sexes to provide a quantity of similar character of ED but more related to the risk for individual patients, which could be named as patient-specific effective dose (EDp).

ED_{OD} and ED_P are generally viewed as more accurate and precise metrics than ED in patient dosimetry. As we will see, this assumption is partially undermined by the significant variability in the estimates obtained from different software programs. It is, in fact, common knowledge that before a metric can be proven accurate, it must be reproducible.

Furthermore, when it comes to population dose estimates, we will see that there are no significant differences in the epidemiological indicators obtained from the assessments

conducted by ED, ED_{OD}, and $ED_{p.}$ Therefore, the greater ease of calculation and practicality of ED leads us to believe that ED is still the best metric available, at least for population-based studies.

Advances in Patient-Specific Organ Dose Assessment and the Role of AI

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Recent advances in patient-specific organ dose assessment have been driven by the need for more accurate, rapid, and clinically practical dosimetry methods. Traditional approaches, particularly Monte Carlo simulations, remain the gold standard due to their high accuracy in modeling particle interactions and dose distributions within complex patient anatomies. However, their widespread adoption is limited by lengthy computation times, the need for manual organ segmentation, and significant demands on computational resources. These limitations have prevented personalized dosimetry from becoming routine in clinical practice, despite its clear benefits for optimizing radiation dose management and enhancing patient safety. Artificial intelligence, especially machine learning and deep learning models, has emerged as a transformative solution to these challenges. By training on extensive datasets derived from personalized Monte Carlo simulations, artificial intelligence models can rapidly and accurately predict organ-specific doses, automate organ segmentation, and generate three-dimensional dose distributions. Studies have demonstrated that deep neural networks, convolutional neural networks such as U-Net and V-Net architectures, and support vector regression models can achieve dose predictions with mean percentage differences below eight percent compared to Monte Carlo simulations, while reducing processing time by over ninety percent. Key advancements include the automation of organ segmentation, which eliminates a labor-intensive bottleneck, and the ability to incorporate patient-specific parameters such as water-equivalent diameter, scan length, and tube current without requiring extensive manual input. Emerging architectures like transformers, recurrent neural networks, transfer learning, and ensemble methods offer further promise by capturing complex spatial relationships and improving generalizability across diverse patient populations and imaging conditions. Despite these successes, several challenges remain. Artificial intelligence models are highly dependent on the quality and diversity of training data; biased or unrepresentative datasets can lead to inaccurate predictions for certain patient groups. Robust external validation across multiple institutions and imaging protocols is essential to ensure clinical reliability. Additionally, uncertainties inherent in Monte Carlo simulations, including segmentation variability and tissue composition assumptions, are inherited by artificial intelligence models. Addressing these limitations requires curated multi-institutional datasets, rigorous validation frameworks, and continuous model monitoring after deployment. In conclusion, artificial intelligence-driven dosimetry represents a paradigm shift from standardized, slow dose estimates toward real-time, patient-specific assessments that account for individual anatomy. This advancement has the potential to improve cumulative dose management for patients requiring multiple scans, support optimization of imaging protocols, and enable wider implementation of personalized dosimetry even in resource-limited settings.

Image Quality Quantification, Monitoring and Automation

Ehsan Samei, Reed and Martha Rice Distinguished Professor Duke University, Durham, NC, USA

Image quality is a primary aspect of delivering high-quality healthcare in medical imaging, as it dictates the usefulness of images for their intended clinical purpose. Main methods for assessing image quality are based on subjective observer preference and objective observer-based diagnostic statistics (e.g., ROC analyses across image collections). However, neither of these approaches is considered robust for individual images – they are both used in aggregate. Alternatively, image quality is quantified in terms of its representation of imaged idealized objects (i.e., phantoms) in terms of three key attributes of noise, contrast, and spatial resolution. However, while these image quality attributes are relevant to the radiologist's diagnostic tasks, phantom-based measures may not readily translate to clinical quality. Recent advances have shown that these measures can be extracted from clinical images and then combined, taking also into account the desired diagnostic task, thereby deriving an integrated assessment of task-specific image quality. The metrics can then be included in a monitoring system that surveys the practice, analyses results, and offers recommendations for practice adjustments to deliver the desired aggregate performance across the practice. This presentation offers a detailed description of these methods.

Monte Carlo methods coupled with Machine Learning algorithms in support of patient-dependent organ dose assessment in CT

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Computed tomography (CT) dosimetry is routinely reported using dose descriptors that do not reflect patient organ absorbed doses. Robust organ-dose estimation requires patient size information; however, basic anthropometric variables (namely height and weight) may not be systematically recorded or retrievable in many retrospective CT cohorts, compromising organ-dose assessment across heterogeneous populations. Biotype-based stratification of patients provides a practical pathway to incorporate patient habitus into organ-dose assessment while preserving compatibility with established CT dose monitoring and benchmarking frameworks, including diagnostic reference levels. This study proposes a Monte Carlo (MC) based approach coupled with a machine learning (ML) stratification of patients approach to characterize organ dose patterns across CT patient biotypes.

A retrospective cohort of 500 adult CT examinations was analyzed, including chest CT for pulmonary embolism, chest–abdomen–pelvis CT for staging, abdomen–pelvis CT for infection, and lumbar spine CT for trauma. Organ dose estimation was performed using a MC-based CT organ dosimetry software. Patients were stratified into four biotypes (small, medium, large, and extra-large) based on water-equivalent diameter (WED), using a k-means clustering algorithm. Organ doses were analyzed as $CTDI_{vol}$-normalized organ doses (nODT) to isolate biotype-dependent effects from scanner output.

Across all CT protocols, nODT showed a consistent decreasing trend across patient biotype categories (from small to extra-large) for organs within the primary scanned region, despite scanner dose descriptors generally increasing with patient size. Median nODT values decreased by 30–55% from small to extra-large biotypes, depending on the organ and the clinical protocol used. This pattern was consistently observed in both male and female subgroups and across chest, abdomen–pelvis, and spine examinations.

These findings show that stratification by biotype using ML and WED reveals consistent and clinically relevant trends in nODT that may be lost when patients are considered

collectively. This stratification-based analysis supports a more meaningful interpretation of organ dose patterns in heterogeneous CT patient populations and contributes to improved dose monitoring and comparison across clinical protocols.

Dose Evaluation of Head and Neck Organs Using ICRP Mesh-Type Reference Computational Phantoms in Dental Computed Tomography

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Although dental computed tomography (CT) provides high diagnostic image, accurate assessment of organ dose remains essential, as radiation-sensitive organs, such as the lens of the eye, could be directly exposed. Conventional device-based dosimetry, including the CT dose index and dose–area product, do not adequately account for patient-specific anatomy or the precise location of small anatomical structures, which may lead to over or underestimation of actual organ doses. Therefore, phantom-based Monte Carlo (MC) dose assessment that realistically reflects anatomical details and imaging conditions is crucial for patient-specific radiation safety and dose optimization.

In this study, organ dose assessment for dental CT was performed using MC simulations with ICRP mesh-type reference computational phantoms (MRCPs). The X-ray tube of the OPX/105 system was modeled using the GEometry ANd Tracking version 4 (GEANT4) toolkit, and the X-ray energy spectrum was generated by accelerating electrons to 95 kVp. Four field-of-view (FOV) conditions were defined to evaluate organ doses from dental CT scans, and photon phase-space (PHSP) data were acquired for each FOV case. Based on these PHSP data, organ doses in the head and neck region were calculated for both male and female MRCPs.

The simulated X-ray energy spectrum exhibited characteristic photon peaks at 60 keV and 67 keV. The simulation was validated by comparison with measurements obtained using an

SRS-78 spectrum analyzer, yielding a mean squared error of 0.0027%. Following validation, PHSP data containing photon position, direction, kinetic energy, and particle type were generated. To reproduce the rotational geometry of dental CT scanning, the source term was rotated over 360 degrees at 1-degree intervals.

The highest lens doses were calculated from MRCP-based MC simulations of sinus and TMJ CT scans, yielding maximum values of 8.19 mGy for females and 6.27 mGy for males. Among head and neck organs, the salivary glands received the highest absorbed doses, with maximum values of 14.58 mGy for females and 12.62 mGy for males, whereas brain doses were relatively low (0.72 mGy for females and 0.68 mGy for males). The largest gender-related dose difference was observed in the thyroid, with maximum doses of 2.20 mGy for females and 0.90 mGy for males.

These findings indicate that phantom-based MC dose assessment can support optimization of dental CT protocols to minimize unnecessary radiation exposure to radiosensitive head and neck organs.

Fetal Radiation Exposure from Cone-Beam Computed Tomography in Photon and Proton Breast Radiotherapy: Dosimetric Measurements and Monte Carlo Dose Assessment

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Purpose: Radiation therapy in pregnant patients with breast cancer raises concerns regarding fetal radiation exposure. Fetal absorbed dose from Cone-Beam Computed Tomography (CBCT) has been reported to range from approximately 0.2 to 1.4 mGy per acquisition, depending on imaging parameters and gestational age. This study aims at assessing and comparing, using measurements as Monte Carlo (MC) simulations, the fetal radiation dose per CBCT acquisition in a pregnant patient undergoing photon and proton radiotherapy.

Method: An anthropomorphic phantom representing an 18-week pregnant woman was used to measure fetal dose using a five-channel Metal Oxide Semiconductor Field Effect Transistor (MOSFET) system. Measurements were performed with a gantry-mounted CBCT system of a proton therapy unit using a thorax imaging protocol (110 kV, 1732 mAs) and with a photon therapy unit CBCT system operating at 125 kV and 270 mAs. In parallel, Monte Carlo (MC) simulations were conducted. GATE MC simulation was employed for

proton CBCT and TOPAS for photon CBCT. The MC models were validated against experimental measurements performed in Computed Tomography Dose Index (CTDI) phantoms using a 100 mm pencil ionization chamber for each imaging protocol.

Results: Validations, using the CTDI phantoms, of both proton and photon CBCT MC models showed average discrepancies below 9% and approximately 10%, respectively, between measured and simulated data. Measured fetal doses per CBCT acquisition were 0.2 mGy for the photon system and 0.46 mGy for the proton system. In contrast, preliminary MC simulations estimated fetal doses of 1.09 mGy for photon CBCT and approximately 0.55 mGy for proton CBCT per acquisition. The cumulative imaging dose over a full breast radiotherapy course is estimated to range from approximately 1.0–2.3 mGy for ultra-hypofractionated regimens (5 fractions), 3.0–6.9 mGy for moderate hypofractionation (15 fractions), and 5-11.5 mGy for conventional fractionation (25 fractions), with an additional 1.6–3.68 mGy when a tumor bed boost of 8 fractions is delivered. Lower cumulative dose values correspond to CBCT acquisitions performed on photon therapy systems, whereas higher values are associated with CBCT on proton therapy systems.

Conclusions: The findings of this study demonstrate that cumulative fetal exposure is strongly influenced by fractionation and imaging frequency and strengthen the role of MC simulations as a quantitative tool for CBCT dose assessment and optimization in radiation exposure monitoring.

Interoperable IT Infrastructure for Dose Monitoring: Systems, Standards, and Data Security

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Building a dose monitoring system that actually works across an institution is harder than it looks: the equipment is from different vendors, the DICOM Structured Reports produced are not identical; the PACS, RIS and HIS were installed at different times and speak different languages. Starting from scratch is rarely an option.

This presentation looks at the infrastructure needed to make dose monitoring function reliably in this kind of environment. The data path runs from RDSR generation at the modality through DICOM routing and parsing, normalisation, central storage, and integration with clinical systems. Each step has failure modes. Missing tags, inconsistent coding, incomplete RDSR generation — these are not edge cases, they are common findings in real installations. The talk identifies where problems typically arise and what can reasonably be done about them.

The IHE Radiation Exposure Monitoring profile provides the main integration framework. DICOM, HL7 and FHIR each play a role, and in practice all three are present in any reasonably complex installation. The gap between what these standards define and what vendors actually implement is worth discussing honestly.

On security: GDPR obligations for health data are familiar in outline but their practical consequences for infrastructure design are often worked out late, or not at all. Encryption, access control, pseudonymisation, audit logging — these are not optional features. NIS2 adds further requirements for institutions that qualify as essential or important entities. Cloud deployments and cross-institutional data sharing make the security picture more complicated, not less.

The broader point is that infrastructure is not a preliminary to the real work — it determines what the real work can be. Dose data fed into AI tools or organisational reporting is only useful if the collection layer is solid. That is the argument this presentation makes.

Safe Data Sharing in Medical Imaging: Regulatory and Ethical Perspectives for AI and Dosimetry

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AI has the power to improve medical imaging and radiation safety. However, reaching this goal depends on sharing large sets of patient data between hospitals and countries. This sharing must be done carefully to follow tough privacy laws and ethical standards. This presentation synthesizes foundational governance principles with practical implementation strategies derived from the RHYTHM project, an EU4Health initiative focused on radiation protection and quality in pediatric imaging across Europe. A main objective of RHYTHM is to develop a European CT image and dose repository for benchmarking through the DRL concept. Repository users will also be able to compare their scanner protocol settings, dose indices, and image quality with those of other institutions using the same CT scanner model. The biggest challenge in sharing medical images and metadata is balancing the need to use the data with the need to protect patient privacy. The RHYTHM Data Management Plan (DMP) solves this by creating a consistent set of rules for all participating countries, even though each country may interpret European privacy law (GDPR) slightly differently. It focuses especially on the important difference between data that is completely anonymous and data that is only coded (pseudonymized).The adopted architectural solution permits data providers to retain either anonymization or pseudonymization at the local level according to institutional policy, while ensuring the central repository never receives re-identification keys. This approach to governance aligns with GDPR, effectively rendering the data anonymized from the repository's perspective and mitigating the risk of singling out or linkability. However, traditional metadata removal is no longer sufficient to achieve this state of anonymization in the era of high-resolution volumetric imaging. Modern modalities, particularly in head CT and MRI, generate isotropic voxel data capable of rendering highly detailed three-dimensional facial reconstructions. To mitigate this specific re-identification vector, the integration of automated defacing tools, algorithms designed to strip or smooth identifiable facial features from the bone and soft tissue windows of cranial exams, is an essential prerequisite for any compliant sharing of head imaging data. The University of Crete team, developed a DICOM metadata de-identification tool as well as a de-facing tool to ensure full de-identification of studies. RHYTHM has also sets up strong rules for how data is managed and who can access it. A Data Management Board is in charge of making sure only approved people has access to the information, that proper agreements are signed before data is shared, and that only the minimum amount of data needed is collected and used for the right reasons. In conclusion, the RHYTHM DMP demonstrates that safe data sharing in medical imaging for AI and dosimetry is not solely a technical challenge but a harmonized legal and ethical exercise.

Dose Management Systems: From setting up to quality assurance.

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Dose monitoring systems (DMS), also called dose management systems, have emerged as essential tools for patient radiation dose auditing in modern diagnostic facilities performing imaging by use of ionising radiation. The capability of current technology to record and transmit information regarding patient radiation exposure allows for the tracking of every diagnostic study and enables retrospective analysis of optimization strategies.

Multiple DMS solutions are currently available on the market—including open-access options—offering various functionalities (supported modalities, types of data recorded, etc.) and scopes (local or regional). Consequently, professionals must make informed decisions regarding which system best suits their needs, the requirements for implementation, necessary human resources, and quality assurance protocols.

To address this need, the International Atomic Energy Agency (IAEA) organized a series of technical meetings between 2022 and 2023, resulting in the comprehensive guidance document: "Dose Management Systems: From Setting Up to Quality Assurance" [1]. Written for medical physicists, this document provides technical details on how DMS function, a detailed description of their features, including the results of a survey conducted among major providers. It also covers critical aspects of installation, commissioning, quality assurance and the professional roles required to fully leverage the systems' potential benefits. Additionally, a set of use-case scenarios is discussed to demonstrate the capabilities of these systems, from basic applications to the most complex implementations.

The survey results clearly demonstrate significant differences between DMS solutions. Therefore, potential users should carefully determine which features are essential for their specific requirements, prioritize desirable functionalities, and consider their existing infrastructure, required level of support, and budget before selecting a system.

This work was carried out in the context of the International Atomic Energy Agency (IAEA)

project: Preparation of guidelines for medical physicists on the content, analysis, and evaluation of dose management systems.

Lessons Learned from Dose Monitoring System Implementation

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The transition of radiation dose monitoring from manual, intermittent audits to automated, continuous surveillance represents a significant shift in patient safety. In Thailand, the implementation of a comprehensive Dose Management System (DMS) has served as the foundation for establishing a data-driven culture in radiology. This presentation shares the strategic experience of deploying a DMS and its subsequent evolution into a National Dose Index Registry (NDIR), highlighting the necessity of multidisciplinary synergy in translating digital data into clinical optimization.

The Thai experience demonstrates that successful DMS implementation requires a robust, interoperable IT infrastructure capable of aggregating data from diverse imaging modalities and vendors. By centralizing this information, Thailand has scaled local monitoring into a National Dose Index Registry, started with Computed Tomography, providing a benchmark for institutional performance and allowing for the harmonization of imaging practices across the country. A pivotal outcome of the NDIR is the practical application of Diagnostic Reference Levels (DRLs). Rather than treating DRLs as static regulatory limits, our implementation utilizes this data as a dynamic tool for optimization. By analyzing national trends, we pinpoint protocols requiring adjustment, ensuring radiation doses remain as low as reasonably achievable without compromising diagnostic utility.

Central to this success is the collaboration between radiologists, radiographers, and medical physicists. Medical physicists provide the technical validation and statistical rigor for data integrity, while radiographers implement technical adjustments at the point of care. Radiologists ensure that dose reduction strategies remain aligned with clinical requirements. In the AI era, this integration ensures that automated data is met with human expertise. The Thai model proves that while technology provides the data, the collaborative "human bridge" between physics and clinical practice is what truly drives radiation protection forward, turning a national database into a living system for continuous quality improvement.

Real-Time Dynamic Dashboard for CT DRL Monitoring and Dose Optimization Across Multi-Hospital Healthcare Networks

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Background:

Diagnostic Reference Levels (DRLs) are crucial for radiation protection and dose optimization in computed tomography (CT). Traditional DRL approaches, based on periodic national surveys, are updated infrequently and often fail to keep pace with advancements in clinical practice, technology, and varying protocols across large healthcare networks. This challenge is especially pronounced in multi-hospital and regional collaborations, where inconsistencies in protocols may persist unnoticed.

Methods:

An interactive dashboard was developed to enable real-time calculation and continuous assessment of CT DRLs for both adult and pediatric imaging. The system aggregates large-scale CT dose data from routine clinical practice and automatically determines protocol-specific DRLs using the 75th percentile of dose distributions. Users can instantly view institutional reference levels and local median dose values for individual hospitals across selected CT protocols, facilitating immediate benchmarking. Advanced filtering allows stratification by protocol, patient age, time period, vendor, and scanner model, supporting flexible and targeted analyses. Built using Microsoft Power BI, the platform ensures interactive data visualization, rapid query, and scalable deployment across networks.

Results:

Currently, the dashboard includes data from around 685,000 CT examinations performed on 22 scanners across 13 hospitals in Qatar, encompassing both general and specialized facilities. Its principal advantage is immediate, data-driven DRL evaluation, eliminating the need for manual extraction or offline analysis and enabling rapid identification of outlier protocols in need of optimization. Moreover, the system supports direct comparison of scanners from the same vendor and model at different hospitals, revealing substantial inter-hospital variability stemming from local protocol configurations and optimization practices. These insights underline significant opportunities for targeted harmonization. The dashboard also captures protocol-level median acquisition parameters—such as tube voltage

(kV), tube current–time product (mAs), scan length, CTDIvol, and DLP—offering a comprehensive view of technical contributors to dose variability.

Conclusion:

This interactive, scalable dashboard provides an effective, user-friendly solution for dynamic DRL management. Designed for easy expansion to additional institutions or international collaborations, the system maintains patient confidentiality by excluding identifying information and focusing exclusively on imaging, dose, age, weight, and scanner characteristics. By supporting real-time benchmarking, inter-hospital comparison, and harmonization of vendor-model protocols, the dashboard enables rapid, data-driven CT optimization and strengthens radiation exposure monitoring across diverse healthcare networks.

BulDose: A Platform for Radiation Exposure Monitoring and High-Risk Patient Tracking

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Introduction

Effective radiation exposure monitoring requires dedicated digital systems for tracking individual patients, identifying high-risk imaging pathways, and supporting clinical follow-up and optimisation. Patients undergoing complex interventional procedures, children requiring repeated examinations, and patients exposed to more than one high-dose study represent groups with increased radiation risk and require structured monitoring, trigger-based surveillance, and cumulative exposure assessment.

Purpose

To introduce the BulDose dose management platform, developed in Bulgaria under IAEA Project BUL9026, and to demonstrate its technical architecture and clinical monitoring capabilities for interventional procedures exceeding trigger levels, paediatric patients with repeated examinations, and patients undergoing multiple high-dose imaging procedures.

Methods

BulDose is a web-based ASP.NET MVC platform deployed within hospital networks and connected to PACS and imaging modalities via DICOM C-STORE SCP. The system ingests DICOM studies and Radiation Dose Structured Reports (RDSR) when available and extracts modality-specific exposure parameters from DICOM headers. Dose data are stored in a central relational database with modality-specific processing for CT, interventional radiology, fluoroscopy, radiography, mammography, PET/CT and SPECT/CT. Configurable trigger levels are implemented for interventional procedures enabling automated identification of high-dose events.

Dedicated patient filters enable tracking of interventional procedures exceeding predefined trigger levels, paediatric patients with more than one imaging examination, and patients undergoing more than one high-dose procedure across CT, interventional and hybrid

nuclear medicine. The platform provides analytical dashboards, dose distributions, threshold charts, cumulative exposure views, and structured exports for audit and quality assurance.

Results

BulDose enables systematic identification and follow-up of interventional procedures exceeding trigger levels, with visualisation of exceeded parameters and aggregation of repeated high-dose events at patient level. The platform allows identification of children undergoing repeated imaging examinations and supports representative typical dose assessment. For adult patients, dedicated filters enable detection of cumulative high-dose pathways, including combinations of CT, interventional, PET and SPECT studies. The system supports structured review of imaging histories and retrospective analysis of dose distributions by procedure type, protocol and equipment.

Conclusion

BulDose provides structured radiation exposure monitoring in high-risk imaging pathways. Its architecture supports trigger-based surveillance of interventional procedures, tracking of paediatric patients with repeated examinations, and identification of patients undergoing multiple high-dose studies. The platform demonstrates how integrated exposure data management can support institutional quality assurance, clinical follow-up of high-risk patients, and optimisation of imaging pathways.

Exposure Monitoring Toolbox for the physicist: creating a modern and secure open source software

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The Integrating the Healthcare Enterprise (IHE) Radiation Exposure Monitoring (REM) profile and European Society of Radiology (ESR) EuroSafe Imaging initiative list a recommendation for the implementation of radiation dose management systems. The authorities issue per country rules and numbers for diagnostic reference levels to be compared with local practice. The open source software OpenREM has been updated and upgraded to comply with the requirements to adhere to modern data and software security rules, to be able to filter patient data using advanced filters, and to estimate patient effective dose.

The Python packages and associated software for OpenREM - the dose management solution for medical physicists and radiation protection experts - have been updated to the most up-to-date versions. The software will run on Windows and Linux OS servers in Docker containers or with Kubernetes. The solution records dose data from modalities (CT, RF, CR/DX, NM, MG and hybrids) in an SQL database and plots statistics on common dose metrics or displays raw data (Digital Imaging and Communications in Medicine (DICOM) tags). Data can be filtered manually using regular expressions on DICOM tags and the filter settings can be saved in a library for easy and repetitive access. Automatic e-mail alerts are sent when dose thresholds are exceeded for reference point and peak skin dose. Protocol names can be grouped under standard names to compare patient dose to national or local DRLs or sum up individual patient related effective phantom dose over all modalities.

The enhancements and updates made to OpenREM fulfill the requirements of the authorities and the professional associations in a transparent and safe way. Plugins like the DICOM Viewer and export of raw- or pre-formatted data (for example organ dose calculation or dose survey) enhance the functionality to a level which is typically not needed in a routine clinic.

The updated and enhanced version of OpenREM discussed in this work is a versatile and cost-efficient toolbox for patient dose analysis. The library of preconfigured standard names and analysis offers easy comparison to national DRL while the export to Excel allows further research.

From Manual to Automated: Data Recording, Collection and Analysis

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Patient radiation exposure monitoring includes components, mechanisms and operational processes related to recording, collecting and analysing patient radiation exposure data associated with clinical imaging operation.

Modern digital X ray machines automatically export radiation exposure details in a standard DICOM objects at the end of procedure and record them. These DICOM Dose Structured Reports contain information about all irradiation events from the procedure, including patient demographics, study information, imaging technique, geometry, typical dose metrics, etc. Some imaging. For systems do not output dose information in either DICOM or non-DICOM formats, data recording of exposure information should be performed manually.

Once patient radiation exposure data are recorded, they need to be collected into databases and repositories for systematic analysis.

Depends on the purposes of examining an individual or a population exposure, there are three different levels of exposure data collection from the DICOM objects. At the first level – data set contains minimum information that can be easily derived from records and from values of dose calculated or measures quantities. This level of information is appropriate for resource-limited countries with a prevalence of manual data collection.

At the second level – the collected set of data contain more detailed information. The scope is to allow for optimization of imaging protocols, or to estimate dose metrics specific to an individual patient. The level of accuracy in the calculations depends on the amount of information collected.

Third level, or advanced requirements: the data are used to personalize and optimize the imaging procedures. This includes calculated personalized dosimetric data, such as organ doses, and further details related to the procedure, such as reconstruction and post-processing settings, or relevant image quality metrics.

Despite the availability of automatic patient radiation exposure monitoring systems in the hospitals, data collection for national or international purposes in most cases still relies on manual or semi-manual methods: the patient exposure data are typically inserted into specific templates or Excel files, which are then transmitted to the organization responsible for collection, either electronically or directly with web based collection templates.

The purpose of data analysis can be establishing DRLs and typical values, consistency analysis, protocol optimization, individual patient exposure analysis, tracking patient exposure history, population dose estimation, etc.

Patient exposure data collection and analysis is dependent on the effective use of a procedure classification system. Lack of a good classification framework can lead to inconsistencies in examination and protocol nomenclature, affecting dose data integrity.

Data Quality as Foundation of Effective Exposure Monitoring

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These days, big data are at the origin of exposure monitoring and optimisation. In order to achieve the goal of appropriate doses, it is important to have complete and trustworthy data – as in any data processing exercise. A lot of input data is also needed to allow the next stages in exposure monitoring.

In this presentation we will illustrate the challenges of data collection, the selection of effective dose conversion coefficients, the introduction of other dose and image quality metrics and the quality control of these inputs. This requires a continuous effort, due to sudden connection problems, faulty RDSR and DICOM header tags, but also at updates of imaging devices, new imaging devices, new dose monitoring software releases or new dose data conversion coefficients.

The next stage in effective dose monitoring is then to use the available data, interpret data and results, comply with any dose survey requests, and make the results a foundation for optimisation studies.

Exposure monitoring has then both a more passive observational part and an active one, in which dose optimisation studies are launched that will, in turn, be monitored with the same dose monitoring platform. An example of an observational task is the supervision of the peak skin doses in the interventional rooms. Ad hoc tasks include specific dose and image quality problems or dose requests for specific studies.

In our experience, every application has to include a data quality verification phase first. Big data may require filtering first to avoid biases and make representative, inclusive data.

Quantifying and Managing Imaging Dose in Radiotherapy

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The widespread adoption of image-guided radiotherapy (IGRT), particularly cone-beam CT (CBCT), has improved treatment accuracy but also introduced cumulative imaging dose. As cancer survivorship increases, managing unnecessary radiation exposure and long-term risks is increasingly important for both radiological protection and clinical decision-making.

A primary challenge is the lack of practical tools for imaging dose management in clinical practice. International surveys and ICRP Task Group 116 efforts indicate that most centers rely on vendor-defined protocols with limited optimization and rarely record imaging dose. Multi-institutional dosimetry work has demonstrated the feasibility of standardized CBCT dose measurements in diverse clinical settings and revealed substantial inter-center variability, supporting the development of radiotherapy-specific dose reference levels.

We present a task-based framework for imaging dose optimization in radiotherapy, where imaging parameters are tailored to clinical objectives such as bony alignment, soft tissue imaging, motion management, and adaptive radiotherapy. This approach extends beyond static protocol optimization and applies to complex workflows where imaging is central to treatment guidance, including 4D imaging and online adaptive workflows.

Results from an institutional CBCT optimization program demonstrate that CBCT dose reductions of 50–80% are achievable in standard workflows, with reductions approaching 90% in selected cases, while maintaining clinically acceptable image quality for patient positioning across multiple anatomical sites. 4D-CBCT studies show that lower-dose protocols are feasible for gated lung SBRT, depending on target size and motion.

Beyond protocol optimization, assessing cumulative imaging dose is essential. In a retrospective head and neck cohort (n=43) receiving daily CBCT, imaging contributed measurable dose to organs at risk. While absolute contributions were modest, imaging accounted for up to 15–20% of the available constraint margin in a subset of cases, highlighting its relevance in margin-limited scenarios. These estimates, based on reference organ dose values, emphasize the need for more accurate patient-specific approaches. Future work will use Monte Carlo modeling to refine these estimates and integrate imaging dose into cumulative evaluation.

Together, these results provide a practical pathway for managing imaging dose through

dose quantification, task-based optimization, and clinically driven protocols. Integrating cumulative imaging dose assessment is an important component of treatment evaluation, particularly for highly optimized and adaptive workflows. An important next step is evaluating imaging frequency within this framework, to better balance geometric accuracy, adaptive decision-making, and cumulative imaging dose in modern radiotherapy workflows.

Data for Population Radiation Dose Estimations

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Estimating population radiation dose is essential for informing public health policy, guiding clinical practice, and shaping regulatory frameworks. For medical physicists, radiologists and radiation protection professionals who routinely balance diagnostic benefit against radiation risk—robust, transparent approaches to dose estimation are particularly important. This presentation synthesizes practical experience applying the National Council on Radiation Protection and Measurements (NCRP) reports 160 and 184 to derive population-level dose metrics, highlighting data needs, methodological choices, and implications for clinical and public-health decision making.

NCRP Report 160 (2009) provided an estimation of radiation exposures to US population by aggregating medical, consumer, occupational, and natural sources, with a major emphasis on the rapid rise in diagnostic imaging. NCRP Report 184 (2019) provided estimations of medical radiation exposures of patients in the US providing an opportunity to compare doses after ten years. In both of these reports, there were several recurring challenges and opportunities: (1) heterogeneity and granularity of source data—procedural volumes, modality mix, protocol variations, and patient demographics—directly influence accuracy and interpretability; (2) conversion of technical imaging parameters into organ doses relies on dose coefficients, phantom models, and population-representative anatomical data that must be periodically updated to reflect evolving technology and patient size distributions; (3) aggregation from individual procedures to population doses requires careful consideration of sampling bias, temporal trends, and subpopulation stratification (age, sex, comorbidity); and (4) quantification and communication of uncertainty—including model, measurement, and extrapolation uncertainties—are critical for responsible use of estimates in risk-benefit discussions and policy development. The talk will demonstrate stepwise workflows: assembling and cleaning procedural and dose metric data, selecting appropriate dose conversion methodologies, scaling to population estimates, and performing sensitivity analyses.

The presentation will conclude with considerations for future updates: incorporating dose-tracking registries, improving pediatric and obese-patient models, and fostering multidisciplinary collaborations to ensure that population dose estimates remain relevant and actionable. Such understandings will benefit future population dose estimation studies such as UNSCEAR reports.

Comparison of peak skin dose calculations in Qaelum DOSE to existing manual method for interventional cardiology procedures

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The aim of this project was to quantify the methods used for peak skin dose (PSD) calculations in Qaelum DOSE, with the intention of replacing an existing manual calculation method used for interventional cardiology procedures.

Radiation Science Services at University Hospitals Bristol & Weston NHS Foundation Trust provide support to a tertiary interventional cardiology centre. We estimate PSD for cases where the total air kerma at the interventional reference point exceeds 2.2 Gray. We wanted to utilise the skin dose mapping functionality in Qaelum DOSE to provide skin dose estimates more efficiently than our existing manual method.

PSD was estimated manually using images from PACS and mapping acquisition fields onto the STUK PCXMC phantom. The PSD was then determined by the maximum dose in any overlapped fields. The assumptions used in these manual estimates were compared with those used in Qaelum DOSE. These included back-scatter factors (BSF), dose area product (DAP) calibration, table/mattress attenuation, distance correction factors, field size and overlap, and fluoroscopy contribution. Typical interventional cardiology cases, including bi-plane cases, were selected to compare the calculated PSD from both methods directly.

There were differences in PSD between the two methods. The magnitude of the difference varied between 1 and 45% between cases. The Qaelum DOSE PSDs for bi-plane lab cases were consistently higher, partly due to the inclusion of the patient's arms for lateral beams. We established that there were overall small differences in the BSF, distance correction, table/mattress attenuation and DAP calibration factors. The positioning of acquisition fields on the phantoms was similar for all cases. There was greater uncertainty associated with the position of fluoroscopy fields for the manual method. We determined that a large area of discrepancy arose from decisions on whether adjacent fields overlapped where the distance between these fields was small.

We concluded that PSDs using Qaelum DOSE were comparable with those from our manual method, given the uncertainty around overlap between closely adjacent fields. Understanding the impact of assumptions in Qaelum DOSE has given us the confidence to implement this clinically. We provide advice on likely skin effects and appropriate follow up. We have reviewed the clinical impact of potential changes in PSD estimates on moving from our previous manual method to using Qaelum DOSE.

We gratefully acknowledge the support of the Qaelum team in responding to our questions during this project.

Characterizing global noise level outliers in CT abdomen dose monitoring

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Introduction:

The global noise level (GNL) calculations provided by the dose monitoring system (DMS) of our hospital were used to benchmark CT abdomen protocols. In this work the GNL outliers were investigated and classified to understand the different causes.

Materials and methods:

Abdominal scans of 5 CT scanners were exported from the DMS (DOSE, QAELUM) and filtered for venous phase series, adults and soft reconstruction kernels. The DMS determines GNL by averaging the slice GNL values, adjusted to a 5 mm slice thickness.

First, the soft tissue GNL was compared to the standard deviation (SD) from a 5x5 pixel reference position in the liver (150 series). For a subset the reproducibility was verified in 10 different regions to distinguish between expected variation and unexpected deviations.

Secondly, extreme GNL outliers were studied: 65 series with GNL exceeding 20 HU were randomly selected. The liver SD was calculated, and the scan was labelled in terms of artefacts, patient positioning and others.

Lastly, the data was grouped in cohorts per scanner, protocol, kVp and kernel to investigate cohort outliers. Running average statistics (mean and SD GNL) per cohort was calculated as a function of water equivalent diameter (WED) using 5 cm bins. Scans that deviated by more than two SD from cohort mean were classified as cohort outlier and root cause analysis was performed.

Results:

The Pearson correlation coefficient between GNL and SD was 0.8, and the relative variability of the SD within the liver was 10%.

For 53% of the extreme GNL outliers, the liver SD was normal. The outliers were caused by scan regions extending beyond the abdomen, where soft tissue is lacking for accurate GNL calculations and causing deviations in the average series GNL. Artifacts accounted for most of the remaining 47%.

Cohort outliers comprised 7.6% of the series. Considering the 10% expected variation of SD, 67% would no longer be considered cohort outliers. The average GNL SD of the cohorts was only 1.2 HU, indicating high GNL consistency within cohorts. Outlier causes included inaccurate WED estimation (25%) and artifact presence due to prostheses (20%).

Conclusion:

Extreme outliers frequently result from atypical scanning regions. This could be improved by using the median instead of average when aggregating GNL values. Cohort outliers generally reflected expected scenarios, such as patients with prostheses. This study affirms the reliability of GNL as a metric for quality assurance in CT protocol monitoring via dose monitoring software.

Generalized conversion coefficients for collective dose estimation: a methodological approach for a national data collection system.

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Italian legislation requires transmitting dosimetric data for diagnostic and interventional procedures, aggregated by subcategories, to estimate population exposure. However, translating dose indices into effective dose is hindered by the lack of conversion coefficients representative of the variability within these subcategories. This study, funded by the Ministry of Health, defines a methodology for estimating generalized conversion coefficients DCCs validated on real-world data.

The study involved two phases: a literature review to identify procedure-specific coefficients and the development of a standardized calculation approach where the generalized coefficient is a weighted average of individual procedure DCCs based on frequency and mean dose indicators. To support this analysis, radiation exposure monitoring systems were used to extract exposure parameters and dose indicators, which were then integrated with clinical information from radiological information systems to correctly classify and verify the performed procedures. For projective radiology, Monte Carlo simulations were performed

to evaluate conversion coefficients for several kind of projection radiographies and different beam qualities inside each subcategory and to assess relative macro coefficients.

The methodology was validated using one-year real-world data from six CT systems, three angiographic systems and ten conventional radiology rooms. For CT scans, most subcategories were related to a specific anatomical district and the literature-based factor was found to be suitable regardless of clinical indications. In interventional radiology (embolization procedures), analysis revealed high variability between rooms depending on the anatomical district treated. While customized room-specific weighted coefficients showed discrepancies under 2% compared to individual procedure calculations, using a generic mean district coefficient increased the error margin to -23%/+30% for individual rooms; however, this error decreased to 10% when considering the aggregate dose of all rooms. Monte Carlo simulations for abdominal radiography projections showed coefficients dependent on the beam quality in the range 0.12–0.25 mSv/Gycm^2, consistent within 20% of ICRP recent data.

The proposed weighting formalism allows for consistent collective dose estimation. The use of automated radiation exposure monitoring systems proved essential for the massive collection and classification of data required to refine these coefficients. Ultimately, the uncertainty introduced by subcategory aggregation remains compatible with the objectives of population dose monitoring.

DRL Establishment and Use: Errors and Solutions

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Diagnostic Reference Levels (DRLs) are a fundamental component of radiation protection optimisation in medical imaging, as emphasised by the International Commission on Radiological Protection (ICRP) and required under European Directive 2013/59/Euratom. Beyond their regulatory role, DRLs serve as practical tools to support dose optimisation, while maintaining diagnostic image quality and fostering continuous quality improvement.

Despite their widespread implementation, considerable variability in patient radiation doses persists for identical clinical indications. This variation is frequently not clinically justified, but instead reflects differences in protocol design, equipment configuration, and local optimisation culture. Such inconsistencies point to a gap between the theoretical intent of DRLs and their application in daily practice.

A common conceptual misunderstanding is the treatment of DRLs as dose limits or optimisation targets. In reality, DRLs (typically defined at the 75th percentile of dose distributions) are investigation thresholds. Values below a DRL do not necessarily indicate optimal performance, nor do values above it automatically imply poor practice without clinical context.

Importantly, DRLs are designed for standardised patient groups and defined procedures, not for individual patients. Misapplication at the individual level may lead to unnecessary dose increases or reduced image quality, potentially compromising diagnostic accuracy.

From a methodological standpoint, the robustness of DRLs depends on structured data collection and rigorous analysis. Local DRLs should be based on dose data linked to clearly defined clinical indications, with appropriate patient grouping. Median values should represent typical practice, while DRLs should correspond to third quartile values. However, simplified approaches and inconsistent methodologies are still common, reducing the reliability and comparability of results.

There is also increasing recognition of the limitations of anatomy-based DRLs. A shift toward clinical indication-based DRLs is gaining support, as it better aligns radiation dose with diagnostic purpose, expected image quality, and clinical decision-making. This approach enhances the relevance of optimisation efforts in real-world practice.

At the institutional level, a disconnect often remains between policy and implementation.

Many departments lack local DRLs, structured training, or sufficient involvement of radiologists, radiographers and medical physicists. Although dose management systems offer powerful tools for data analysis, benchmarking, and continuous optimisation, they are not yet fully integrated into routine workflows.

Addressing these challenges requires a coordinated effort: strengthening conceptual understanding, adopting standardised and clinically relevant methodologies, leveraging data-driven systems, and promoting interdisciplinary collaboration.

When properly implemented, DRLs become dynamic instruments for optimisation, ensuring appropriate radiation use while safeguarding diagnostic quality and patient safety.

Data-Driven Optimisation: Integrating Dose and Image Quality

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Modern medical imaging produces increasing data volumes including the actual image data, radiation dose structured reports, image metadata, secondary captures, referrals and diagnostic reports as most common data descriptors. Utilisation of that data comprehensively for optimisation requires automated, objective and quantitative approach with all parts of the imaging process considered from the combined perspective of dose and image quality. Appropriate application of justification is a prerequisite for an effective optimisation. In justification phase, new AI algorithms have been developed to enhance the performance of clinical decision support based on personalised clinical data. Automated protocolling can then take the next step on data-driven process to select an optimal imaging protocol and parameters. When patient enters the imaging room, data-driven algorithms will help to position the patient correctly for the imaging examination and adjust the scan range or exposure area (collimation) to avoid overexposure of individual anatomical areas. Separate algorithms and data-driven models can be used to reconstruct images or enhance the quality of the acquired images. Regarding the title of this talk, the most common interest in optimisation integrating dose and image quality is towards data-driven methods to estimate patient-specific doses and to measure in-vivo clinical image quality. Optimisation principle calls for joint utilisation and analysis of both dose and image quality aspects, noticing that adequate image quality is the absolute requirement for optimisation. Successful optimisation also extends to the quality of diagnostic and clinical tools which are utilising the produced multimodal clinical data. The talk includes several examples of data-driven optimisation methods, also presenting them along the practical medical imaging process.

Using Exposure Monitoring in Cancer Screening

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The European medical exposure directive and other international documents require special attention for population based screening programs that use ionising radiation. The reason for this is that the presumably healthy population is undergoing the examinations. Successful screening requires not only a mortality reduction of the cancer under investigation but also a justification for the use of ionising radiation.

Dose and quality monitoring have been integrated in the QA process of breast cancer screening since the early days, as it was, at least in Europe, even a requirement for the launch of a screening program. Dose monitoring used conversion factors to convert the output of a mammography device for the particular exams into a relevant dose metrics, usually the mean glandular tissue. Several dose conversion methods have been published and there is a broad literature on dose surveys. They were recently accommodated into the AAPM/EFOMP TG 282 breast dose model. Interestingly, the mean glandular doses as observed in population dose surveys can also be predicted – to a large extent – by means of test objects. Recently, exposure settings have been optimized via new filtrations, but did not go down drastically in time. Rather device specific choices and values are seen, each with their image quality level.

Emerging screening methods using ionisation radiation, such as low dose CT for lung cancer screening should follow the same practice: to include QA from the beginning and have also patient doses monitored. The development of tools is on-going. These days, it is aimed for patient specific dose reports, potentially using AI tools. Dose monitoring should be included from day 1, to support the justification of the screening program and establish an appropriate dose communication with the screening participants.

Right Data, Right Care: Managing Radiation Exposure for Pediatric Patients

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Implementing CT technology to meet the needs of the pediatric population requires a dedicated, intentional, multidisciplinary effort. Pediatric imaging requires more than simple dose reduction; it demands deliberate acquisition of the right data to answer the clinical question safely and effectively.

Achieving diagnostically adequate images at the lowest reasonable dose for a specific clinical indication remains both a priority and an ongoing challenge. This presentation will review three key areas relevant to pediatric CT dose optimization.

First, radiation exposure in CT will be briefly reviewed, including common dose metrics such as CTDIvol, DLP, and size-specific dose estimates (SSDE). Development of a radiation dose monitoring and management program will also be discussed, along with the role of pediatric diagnostic reference levels (DRLs) in identifying opportunities for optimization.

Second, opportunities for strategic application of radiation dose will be explored through indication-based imaging. Tailoring protocols to specific pediatric clinical scenarios—such as evaluation of airway foreign bodies—can reduce unnecessary exposure, avoid multiphase imaging, and improve consistency across examinations.

Third, we will discuss our recent clinical experiences implementing new CT technologies and fast scan protocols in pediatric imaging. Reduced acquisition times can minimize motion artifacts, decrease the need for sedation, and support lower-dose imaging while maintaining diagnostic utility.

Throughout the session, the importance of collaboration among radiologists, technologists, and medical physicists will be emphasized, particularly in balancing image quality with radiation safety. Ultimately, the goal is to ensure that every examination delivers the information needed—no more and no less.

Use of Interventional Cardiology datamine for quality improvement

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When considering complex interventional procedures the use of purely a patient Dose Management System [DMS] excludes data that is useful for both analysis and optimisation. At Nottingham University Hospitals [NUH] we have developed a bespoke Cardiology data mine to hold both procedural dose data and clinical data. The clinical data includes all the fields required for our in-house PCI complexity model [that further aligns with data submitted to national Cardiology registries. Furthermore, manual data entry allows the clinicians' personal dosimetry data to be uploaded on a monthly basis.

The DMS employed is OpenREM that allows us to access DICOM RDSRs in real-time. The clinical systems merged are the Philips CVIS (for PCI,s inc structural and ablations) and Clinical Network Systems's PaceNET (for device procedures). The analysis software utilised is R and Python is used for data extraction from clinical systems.

The functionality of the software includes both an annual summary dose survey report and a dashboard for real-time management of both trends and outliers. Patient dose summaries include a by-room and by-Operator analysis across all procedures for KAP, Ka,r and fluoroscopy time. Summary procedure dose data [medians, 95% CI's, distributions] are also collected for comparions with our Local DRLs [this is a UK term that corresponds to the IAEA concept of 'typical dose']. Staff dose summaries include both cumulative annual dose and also their personal doses normalised by KAP workload.

The real-time element of the functionality is delivered via a dashboard that captures the above metrics for any filtered subset of data for a customisable date range. This allows staff to visualise both trends and outliers. The outlier identification is vital real-time to ensure when relevant staff are informed they have a clearer recollection of events.

This presentation will provide an overview of system development and challenges faced along with early experiences from its use within the Cardiology Radiation Management Group that meets monthly to address ongoing and emerging radiation protection issues. Examples of insights gained from the data will be presented.

Cardiology dose comparison for procedures with small sample sizes using precision-weighted pooling

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Purpose

To categorise interventional cardiology dose data into clinical procedure groups and then develop a practical method for comparing radiation dose between cardiology labs that uses data from all clinical procedure groups, including those with small sample sizes, providing robust estimates of inter-lab bias magnitude and uncertainty.

Method

Eighteen month's data were extracted from the cardiology information system including all coded procedure subtypes, vessels involved, number of lesions, number of stents and type of balloon. This was combined with radiation dose data from the dose management system. Discussion was held with the clinical users to identify which factors were expected to contribute to clinically distinct procedure groups. Reference point air kerma and kerma-area product were modelled as log-normal distributions. Data analysis was conducted using Python, with assistance from Claude (Anthropic PBC) for script generation, which was manually validated. For each group with more than 5 examinations a log-bias was calculated from the difference in mean log-dose values between sample and reference labs. Precision-based weights (inverse variance) were applied to combine estimates across all procedure groups, allowing smaller groups to contribute proportionally to the overall bias estimate. The probability density function of the bias factor was estimated to visualise both magnitude and uncertainty of the overall bias between labs.

Results

The method was applied to data from two cardiology labs across 13 procedure groups. The weights applied ranged from 4.2 to 158.3, reflecting substantial variation in group precision. Using only the most common protocol alone (diagnostic left heart catheterisation, no lesions treated) yielded an apparent bias between labs of 20% and 26% comparing

simple means or medians respectively. However, incorporating all 13 sampled protocols reduced this estimate to 4.1%, suggesting the labs were in fact well matched. The probability density function confirmed the bias was relatively small and very likely constrained within the typically accepted ±20% range. Notably, few clinical groups reached the conventional threshold of 20 samples required for standalone comparison.

Conclusions

The precision-weighted bias approach enables meaningful inter-lab dose comparison by pooling information across procedure groups, overcoming sample size limitations inherent in individual protocol analysis. This method provides both a magnitude of bias as well as an estimate of the likely uncertainty and possible real range of the bias based on the volume of data available

Using Exposure Monitoring to Standardize CT Quality Across Diverse Facilities

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The rapid expansion of our hospital system has introduced challenges in maintaining consistency in patient care. Variability in computed tomography (CT) technology, protocols, training and practices across our facilities has contributed to inconsistent image quality and patient exposure. This work describes the development and implementation of a system-wide framework to standardize CT quality using a dose monitoring system to establish system-wide dose reference levels, harmonize scan protocols, and identify improperly performed examinations.

Dose reference levels (DRL) were developed using aggregated local data and aligned with the American College of Radiology (ACR) Dose Index Registry (DIR). Standardized exposure metrics, including volume computed tomography dose index (CTDIvol) and dose-length product (DLP), were used to support consistent performance evaluation across facilities. Training programs were implemented to promote a shared understanding of dose metrics, exposure monitoring workflows, and communication pathways among technologists, radiologists, and medical physicists. Department managers received monthly performance feedback to support accountability and continuous improvement. Implementation was challenged by staffing shortages, leadership transitions, introduction of new technology, and variability in training requirements across sites.

Following implementation, completeness and consistency of exposure data improved across some participating facilities. Variability in reported CTDIvol and DLP for selected high-volume examinations was reduced, enabling more reliable comparison of protocols and identification of outliers for optimization. The standardized approach also supported early detection of improperly performed scans and facilitated targeted education and corrective actions.

An Integrative Approach for Optimizing CT Scan Protocols Regarding Low Contrast Detectability and Radiation Exposure

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To optimize Computed Tomography (CT) scan protocols, a framework including phantoms for dose measurements and image quality assessment, software for low-contrast detectability analysis, and a database for images, scan parameters and low-contrast measures, was developed. This framework is part of a generalizable concept for radiation and image quality optimization, and has been applied successfully to different CT devices in several hospitals.

The phantoms consist of soft-tissue equivalent materials and low-contrast elements with varying diameters and contrasts for the generation of Difference Detail Curves (DDC). The abdominal phantoms have elliptical shapes with varying effective diameters. In addition, a semi-anthropomorphic head phantom including a 3D-printed skull consisting of bone-equivalent material was developed. All phantoms allow the measurement of the dose-length product (DLP) at the central position. The assessment of the low-contrast visibility is based on the evaluation of the visibility contrast objects by a human observer or alternatively, by a Deep–Learning–based model observer. Both options are embedded in an analysis tool, providing a dedicated DICOM viewer and tailored access to a database containing DICOM images, scan parameters, phantom descriptions, low-contrast object masks, and dose measurements. Based on this, a systematic comparison between indicated and measured DLP, low-contrast visibility (DDC) in the phantom, and collected patient DLP using a dose management tool can be performed. The image quality of 11 CT systems and different reconstruction algorithms was compared, enabling the determination of the radiation dose required by each scanner and reconstruction algorithm combination to achieve a predefined image quality.

For head CT protocols, the semi-anthropomorphic head phantom, which incorporates a higher number of built-in structures, demonstrated superior low-contrast detectability

compared to the abdominal phantom. The abdominal phantom showed greater variability, particularly with respect to acquisition and reconstruction parameters. The optimization of abdominal scans resulted in CTDI reduction between 17% and 39%.

The combination of dedicated phantoms and software (analysis tools and database) as integral parts of an optimization workflow provides a straightforward approach for reducing radiation exposure while maintaining diagnostic image quality. Overall, the phantoms enable objective protocol optimization and support visual assessment across multiple reconstruction algorithms and CT systems, making them particularly valuable in the early stages of protocol optimization. Final fine-tuning, however, remains pivotal and relies on visual assessment by medical physicists and radiologists.

Variability of Cone Beam Dose Index in Cone Beam Computed Tomography Protocols: A Multicenter Assessment and National Survey

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Purpose:
Cone beam computed tomography (CBCT) is essential in image-guided radiotherapy, but its repeated use raises concerns about imaging dose. Measuring the Cone Beam Dose Index (CBDI) is fundamental to quantify patient exposure and to identify variability among implemented CBCT protocols. Currently, many CBCT protocols rely on manufacturer-provided default acquisition parameters. This study aims to analyse national variability in CBCT acquisition parameters and to evaluate CBDI associated with clinically implemented adult CBCT protocols, supporting optimisation strategies and the establishment of radiotherapy-specific dose reference levels (DRL_{RT}).

Methods:
A national survey was conducted across Portuguese radiotherapy departments. Participating centers provided adult protocols informations for all CBCT-equipped linear accelerators, including tube voltage (kV), tube current–time product (mAs), and number of projections for head, thorax, and pelvis protocols. The $CBDI_w$ was assessed in 6 gantry-mounted CBCT system and each protocol was measured using a 100 mm pencil ionisation chamber and a Computed Tomography Dose Index (CTDI) phantom. Descriptive statistics, including medians, interquartile ranges, and coefficients of variation, were used to characterise practice variability.

Results:
Twelve departments participated, representing 20 linear accelerators (17 Varian, 3 Elekta) and providing 109 CBCT protocols distributed across pelvis (n=47), head (n=36), and thorax (n=26). Head protocols showed median values of 100 kV, 146 mAs, and 500 projections; thorax protocols used 125 kV, 270 mAs, and 670 projections; pelvis protocols employed 125 kV, 750 mAs, and 670 projections. Substantial heterogeneity was observed in exposure parameters, with coefficients of variation for mAs of 105% (head), 49% (thorax), and 45% (pelvis). Parameter ranges revealed up to 20-fold variation in head mAs (36.6–740) and 17-fold in pelvis mAs (100–1690), while kV settings showed relative consistency (CV<15%). Between-institution analysis demonstrated differences, with institutional median pelvis mAs values ranging from 293 to 1373 mAs (4.7-fold difference). Between 15% and 23% of protocols used mAs values in the highest quartile for their respective anatomical sites, representing potential targets for dose optimization. $CBDI_w$ measurements at 5 institutions (27 protocols) revealed median doses of 2.65 mGy for head (range:0.83–10.35), 4.95 mGy for thorax (range:1.24–17.48), and 18.20 mGy for pelvis (range:5.74–38.04).

Conclusions:

This first national characterisation of CBCT protocols in Portuguese radiotherapy reveals considerable heterogeneity, driven mainly by large variations in mAs and reliance on manufacturer default protocols. The marked inter-institutional differences in CBDI highlight the need for systematic dose audits, protocol optimisation, and the development of national DRL_{RT} to promote harmonised and optimised CBCT imaging practice.

Breaking the Barriers in Dose Tracking of Individual Patients

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The ability to track radiation exposure at the level of individual patients has long been recognized as a goal of radiation exposure monitoring. Despite over a decade of advocacy and the availability of dose management systems, widespread, consistent implementation of patient-level dose tracking remains limited. This gap reflects not a lack of awareness but a complex interplay of technical, clinical, operational, and conceptual barriers.

There is a need to examine the key challenges that continue to hinder effective tracking across healthcare systems. At the technical level, variability in dose metrics (CTDIvol, DLP, SSDE, KAP, administered activity), lack of standardization, and limited interoperability between imaging equipment, dose management systems, and electronic health records impede the creation of longitudinal patient dose histories. In many institutions, data remain fragmented across modalities and vendors, preventing a unified view of cumulative exposure.

Equally important are conceptual barriers. There is persistent ambiguity regarding the role of cumulative dose: whether it should inform clinical decision-making, trigger alerts, or simply serve as a record. Concerns that dose tracking may be misinterpreted as imposing “dose limits” for patients have further slowed adoption. In addition, uncertainties in risk estimation—particularly at the individual level—have led to hesitation in integrating dose data into routine care.

Operational and cultural factors also play a significant role. Competing clinical priorities, lack of clear ownership between departments, and limited engagement of referring physicians contribute to underutilization of available tools. Even where systems exist, their outputs are often not translated into actionable insights.

Practical strategies to overcome these barriers need to be discussed, drawing on global experience and successful implementations. These include harmonization of dose metrics, integration of dose data into clinical workflows, use of automated alerts for outlier detection, and development of user-friendly dashboards that support justification and optimization without introducing unnecessary alarm. The role of international initiatives and collaborations in promoting standardization and adoption will also be discussed.

Ultimately, dose tracking should not be viewed as a regulatory requirement or a constraint, but as an enabling tool, a “clinical compass” to support better decision-making. Moving forward, the focus must shift from simply collecting data to meaningfully using it, ensuring that patient-specific exposure histories contribute to safer, more personalized imaging.

Cumulative Radiation Dose Monitoring and Patient Care: Relevance to the Blind Men and Elephant Parable

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The parable of the blind men and the elephant portrays subjective and limited information and experience taken as absolute truth. This limited, biased, and partial view may result in incomplete or incorrect conclusions rather than the holistic reality and attendant consequences of this reality. Just as there are many ways one might independently interpret the parts to the elephant, there are many more or less independent perspectives on the use and value of cumulative radiation exposure (or dose) monitoring for patient care. These perspectives, however, should be based on recognizing and acknowledging both the clinically salient aspects of cumulative dose as well as what patient care entails. The occurrence of cumulative dose, often classified by effective doses of $\geq$100 mSv, is increasingly reported across a variety of patient populations for purposes of identification of scale and scope, as well as stated and implied implications related to the risk and a call for stewardship. There is little argument against the medical community being responsible for medical radiation exposure monitoring including the challenges which this. These included but are not limited to resources and guidance for efficiently and accurately capturing meaningful data, mindful cultivation of relevant metadata, creation of actionable alerts, and in focusing on perhaps the most emotive aspect of the care of the patient: the clinical relevance (e.g. what populations are affected) and how the paradigm of cumulative radiation is supposed to be part of direct patient care. Provocative questions about the impact on imaging decisions based on past exposure history have taken on particular significance. This will be discussed including how the clinical domain, the understanding of radiation doses and risks from both the patient (and in some settings the parent) as well as the referrer/provider points of view can influence opinions on how, when and why exposure history may (or may not) be of value and what can be action items, especially at the point of care. It is this part of the cumulative dose paradigm, part of the elephant, which can contribute to a more holistic understanding of how the cumulative radiation exposure “animal” can really work for improved health care.

Metrics and Tools to Quantify and Benchmark Recurrent Imaging

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To evaluate the repeated radiation exposure a patient may receive from multiple imaging examinations involving different body regions, modalities, or even different types of radiation, a risk-related metric is needed that allows these various exposures to be combined. The current radiological protection framework provides two such quantities: organ doses and effective dose (ED). Organ doses are more directly associated with individual cancer risk and are therefore commonly used in epidemiological research or when estimating personal risk. In most other contexts, however, ED—despite its recognized limitations and uncertainties—remains the only practical metric that enables exposures from different types of examinations to be summed into a single overall value. Cumulative effective dose (CED) is the total ED resulting from repeated exposures of ionizing radiation of an individual in a set period.

Most published studies describe recurrent imaging by reporting the total number of patients who, over a specified timeframe, reach a particular level of CED – commonly 100 mSv, Calculating the proportion of these patients relative to all individuals who underwent imaging during the same period yields what is referred to in epidemiology as the "prevalence proportion". The incidence proportion—the number of new cases within a specified timeframe—provides a more accurate metric for assessing recurrent imaging than prevalence, which counts both existing and new cases. It has been demonstrated that using prevalence indexes to estimate patients accumulating CED > 100 mSv over several years is methodologically flawed and leads to a significant underestimation of the phenomenon.

The concept of recurrent exposure reference levels (RERLs) has been recently introduced and marks a significant advancement in radiation protection, particularly for patients undergoing multiple imaging examination. While traditional diagnostic reference levels focus on individual examinations, RERLs consider the cumulative radiation dose that patients receive over time. A medical facility can calculate the 3rd quartile of yearly CED for all the patients and compare this value with similar values in other facilities, or with the reference level if established. Unusually high values could result from excessive use of radiation imaging to follow-up of patients with chronic conditions, inadequate justification for imaging procedures, utilisation of suboptimal imaging protocols, and other factors. Investigating the underlying factors and addressing high RERL can contribute to enhanced patient care.

Behind the Images: Unmasking Cumulative Radiation Load

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Recent studies have demonstrated that patients undergoing recurrent medical imaging may receive high cumulative effective doses (CED). The aim of this study was to quantify the highest CEDs from all imaging modalities in patients at our institution over a defined period and to analyse the clinical indications associated with these exposures.

Patients with the highest computed tomography (CT) CEDs in 2023 were identified using a dose management system (DMS). The 50 adult patients with the highest doses were selected for further analysis. For each patient, CEDs from all imaging modalities performed between January 2017 and February 2026 were estimated. Effective doses were calculated using published conversion coefficients for radiography and nuclear medicine procedures, NCIRF software for fluoroscopy, and the DMS for CT examinations.

Patient age at first examination ranged from 19 to 76 years, 40% younger than 50 years. The cohort comprised 60% males and 40% females, and 56% of patients were alive at the time of data collection. The total number of imaging procedures per patient ranged from 7 to 281 (mean 47). CEDs ranged from 100.8 to 996.3 mSv (mean 260.2 mSv). Radiography accounted for up to 82.6% of examinations but contributed only up to 3.4% of total CED. Fluoroscopy comprised up to 27.3% of procedures and up to 50.3% of CED. CT represented 12.8–85.7% of procedures and was the predominant contributor to CED (49.7–99.97%). Nuclear medicine contributed up to 13.3% of examinations and up to 6.7% of CED. Clinical indications included cancer in 24% of patients, trauma in 20%, and other conditions in 56%.

Although many patients had severe or complex conditions, the high CEDs observed, particularly in relatively young individuals, underscore the importance of strengthening justification processes and optimising imaging procedures in patients undergoing recurrent imaging.

Catch Me If You Can: How we can track individual patients

Natalia Saltybaeva, Luzerner Kantonsspital, Switzerland

Tracking patient radiation exposure is an important aspect of modern healthcare, particularly when patients undergo medical procedures involving ionizing radiation. As patients undergo examinations and treatments across multiple institutions, modalities, and geographical locations, maintaining a complete record of their radiation exposure becomes a significant challenge.

This presentation discusses current limitations in tracking patients at the individual level when care is distributed across multiple healthcare providers and data systems. Fragmentation of medical records, limited interoperability between databases, and inconsistent reporting standards often result in incomplete dose histories.

Potential solutions will be discussed, including the development of national or European dose registries and the concept of a patient exposure passport that would allow cumulative exposure data to accompany patients across healthcare systems. Reliable tracking of cumulative exposure can support clinical decision-making and improve patient care, for example by enabling clinicians to tailor imaging strategies or select lower-dose protocols when patients have already undergone multiple or high-dose procedures.

Radiation Exposure Monitoring in Recurrent Imaging: A Single Center Clinical Audit

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Radiation exposure monitoring is most effective when dose-related information is analysed together with the complete imaging history of the patient, including both ionising and non-ionising examinations. Patients undergoing recurrent imaging represent a high-risk group that requires structured exposure tracking, justification review, and clinical audit. Integration of examination frequency, modality selection, and clinical context is essential for optimisation of imaging practice.

To present a multimodality clinical audit of recurrent imaging based on integrated dose-tracking and PACS data, focusing on individual exposure monitoring, justification, and examination frequency in patients undergoing long-term follow-up.

Dose-tracking data from ionizing and non-ionising imaging examinations were combined into a unified Excel-based audit database. All available studies, CT, PET/CT, SPECT/CT, MRI, mammography, and ultrasound, were grouped by study date and study modality.

The audit included long-term followed-up patients between 2016 and 2023. For each patient, the complete imaging history was reconstructed, including all ionising and non-ionising examinations. Imaging frequency and modality distribution were analysed in relation to clinical follow-up. A multidisciplinary audit team (radiologist, radiographer, medical physicist) performed case-based review of justification and image quality using modality-specific subjective criteria.

A total of 23 patients with recurrent imaging were analysed individually. Each patient underwent between 18 and 71 imaging examinations (median: 26). The number of imaging modalities per patient ranged from 3 to 6.

Repeated ionising imaging was the dominant component of follow-up in all patients. CT was the primary modality in the majority of imaging histories, supplemented by PET/CT and SPECT/CT during periods of active disease, staging, or therapy response assessment. MRI and mammography were used for local assessment, while ultrasound was applied for targeted follow-up.

Patient-level analysis demonstrated substantial variability in imaging frequency and modality selection, reflecting differences in disease course and clinical management. In several patients, clusters of repeated CT examinations were observed over short time intervals corresponding to intensive diagnostic or therapeutic phases. In a subset of patients, repeated CT examinations were identified during periods of stable disease or complete response, prompting audit-based discussion on justification and consideration of alternative follow-up strategies using non-ionising modalities.

This single-centre clinical audit demonstrates the importance of patient-based radiation exposure monitoring in recurrent imaging. Individual exposure tracking, combined with justification and image quality assessment, provides a robust framework for optimisation of long-term imaging follow-up. Clinical audit remains an essential tool for improving imaging practice and radiation protection.

Radiation Exposure Monitoring and Early Detection of Deterministic Skin Injury in Paediatric Interventional Cardiology: A Local Workflow Experience

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Background

Radiation-induced skin injuries following fluoroscopically guided interventional procedures (FGI) are well documented in adults but remain extremely rare in the paediatric population. When they occur, they are often under-recognised and under-reported, particularly in countries lacking structured dose registries and systematic exposure monitoring. Early identification of high-risk procedures, appropriate patient information, and structured post-procedural follow-up are essential to prevent progression of deterministic tissue reactions and ensure timely clinical management.

Purpose

To present an institutional clinical workflow model for radiation exposure monitoring in paediatric interventional cardiology based on long-term dose tracking, operator-based dose documentation, and systematic patient follow-up, illustrated by the first documented case of radiation-induced skin injury in a child in Bulgaria.

Methods and Materials

At an interventional cardiology centre in Bulgaria, a dedicated patient dose monitoring system has been implemented for more than 15 years. For every FGI procedure, the interventional cardiologist manually records patient dose indicators immediately after the intervention, including fluoroscopy time, reference air kerma, and dose–area product (DAP). High-dose procedures trigger structured patient information and follow-up instructions.

A multidisciplinary workflow involves interventional cardiologists, a medical physicist, and a radiation therapist consultant when required. Patients exceeding predefined trigger levels are instructed to monitor for early symptoms. In suspected radiation injury, dermatological assessment and coordinated clinical management are initiated.

Results

A 15-year-old female patient (180 cm, 104.0 kg, body surface area 2.23 m^2) underwent transcatheter closure of a persistent ductus arteriosus (PDA) under fluoroscopic guidance. The procedure was technically complex and prolonged, with multiple angiographic attempts required to achieve correct device positioning. The total procedure time was 110 minutes, with 26.5 minutes fluoroscopy time, 4.8 Gy peak skin entrance dose, 5.28 Gy reference air kerma and 795.1 $Gy.cm^2$ total DAP.

Following the established workflow, the patient and family were instructed to monitor for skin reactions. Two weeks later, a well-demarcated erythematous plaque with dry desquamation and focal crusting developed on the posterior right upper arm, consistent with Grade II deterministic injury (NCI). Early dermatological treatment prevented progression.

Conclusion

Although deterministic skin effects are rare in paediatric interventional cardiology, they can occur in prolonged and technically demanding procedures with repeated acquisitions in a limited irradiation field, further amplified by patient body habitus. This case demonstrates the clinical value of long-term exposure monitoring, structured dose documentation, timely patient communication, and multidisciplinary follow-up. Effective data management and exposure tracking contribute to improved patient care and prevention of severe complications.

An investigation of high-dose CT examinations performed on 5 CT systems

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The aim of this study is to survey the frequency and the possible reasons for the appearance of high-dose CT examinations performed on 5 CT systems.

The current study is performed on 5 CT scanners (C1-5). The data is collected from 3 hospitals in Bulgaria for all high-dose CT examinations, which are defined as those with dose-length product (DLP) ≥ 3000 mGy.cm. The data collection period is 1 year (CT1,2,5) and 6 months (CT3,4). The recorded information is: maximum reported volume computed tomography dose index ($CTDI_{vol-max}$), DLP, number of series/phases (NS), body mass index (BMI) (CT1,3,4,5) or effective diameter (D_{eff}) (CT2) of the patients, scan region and possible reasons for the appearance of the high-dose CT examinations.

The frequency of the high-dose CT scans is: CT1: 2.3 %; CT2: 3.3 %; CT3: 3.6 %; CT4: 5.5% and CT 5: 12.6%. The median values for $CTDI_{vol-max}$/DLP±SD, from all high-dose CT examinations, are: CT1: 38.2±44.3mGy/3621.9±1362.8mGy.cm; CT2: 152.0±107.7mGy/3402.0±682.3mGy.cm; CT3: 28.0±22.2mGy/3634.0±1393.1mGy.cm; CT4: 28.0±26.7mGy/3574.5±836.7mGy.cm and CT 5: 30.5±15.5mGy/4282.1±1437.7mGy.cm.

The median values for NS±SD are respectively: CT1: 4.0±1.2; CT2: 3.0±0.9; CT3: 4.0±0.9; CT4: 3.0±0.6 and CT 5: 4.0±0.9, while these values for BMI/D_{eff} ±SD are: CT1: 30.4±6.9kg/m^2; CT2: 35.5±6.9cm; CT3: 32.3±7.9kg/m^2; CT4: 32.1±5.0kg/m^2 and CT5: 30.2±5.3kg/m^2.

The most common scanned region from all CT systems is Abdomen/Pelvis and the most common reason for the appearance of the high-dose CT examinations is the use of multiphase protocols, longer scan ranges and scanning patients with BMI > 30kg/m^2 and D_{eff} > 35cm.

The study revealed that there is unignorable existence of high-dose CT examinations performed on some CT machines that participated despite of the use of advanced CT technology. Scanning obese patients and multiple body regions and applying multiphase protocols appear to be the most contributing factors.

Establishing a Multi Facility Registry: Experience with ACR Dose Index Registry

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Multi-facility dose registries are powerful tools for improving radiation safety, optimizing imaging protocols, and enabling benchmarking across institutions. This presentation shares practical experience establishing and operating a multi-facility registry using the American College of Radiology (ACR) Dose Index Registry (DIR), with lessons directly relevant to medical physicists, radiologists, and radiation protection professionals attending REM2026.

The talk will highlight, stakeholder engagement and governance; technical infrastructure and data flow; site enrollment and credentialing; DICOM Structured Report and Radiation Dose Structured Report (RDSR)/MODALITY configuration; data validation and harmonization; privacy and security considerations; and ongoing quality assurance. Key operational steps included forming a multidisciplinary steering group to set goals and metrics, mapping local scanner tags and protocols to DIR categories, and implementing automated extraction of dose metrics from PACS/RIS and dose monitoring systems.

Real-world challenges and possible solutions will be highlighted: variability in scanner vendor implementations and RDSR completeness required tailored extractor logic and vendor engagement; inconsistent protocol naming and exam coding demands the need for mapping tables and local workflow changes; differences in patient population and practice patterns necessitated stratified benchmarking; and local IT and cybersecurity constraints slowed data transfer until secure VPN and HL7/DICOM routing policies were standardized. Data quality procedures—ranging from automated sanity checks to routine audits and feedback loops with technologists—were essential to maintain reliable comparisons and to identify outlier protocols driving excess dose.

The presentation includes examples of how registry participation drove measurable improvements: identification and harmonization of CT protocols across sites, reduction in repeated scans through workflow changes, and evidence-based protocol updates that lowered dose without compromising diagnostic quality.

Finally, attendees will leave with a practical roadmap, anticipated pitfalls, and strategies to maximize the clinical and safety benefits of multi-facility dose registries.

National E-Health Integration of Imaging Exposure Data

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National scale collection, analysis and reporting of imaging exposure data can be utilised by various clinical facilities in forms of benchmarking, peer comparisons, quality monitoring and continual improvement within radiological optimisation process. For most comprehensive and versatile benefits, exposure data should be integrated into overall digital health infrastructure to be used jointly with other clinical and diagnostic data channels and parameters. This also facilitates the deployment of recent AI models which take various clinical data types as an input to make variety of diagnostic, quantitative and prognostic tasks to improve quality and patient care. Those tasks also include radiation exposure monitoring extending to patient specific models. In Finland, the national Kanta service, specifically within the Imaging Data Repository, utilizes standard-based data structures to manage and store patient radiation dose information nationwide. The Imaging Data Repository includes the DICOM Radiation Dose Structured Report (RDSR), to enable centralized, automated monitoring and optimization of patient radiation exposure across different healthcare organisations. This data is already stored with all other clinical information available by Kanta service. The implementation of integrated exposure data repository supports the long-term goal of the Finnish national health system to enhance the traceability of imaging data and improve patient safety through better tracking of radiation doses. Overseas, the American College of Radiology’s Dose Index Registry (DIR) has been running already for more than a decade to leverage similar benefits for the broader continental level. In Europe, the shared applications of health data will be facilitated by European Health Data Space Regulation (EHDS) which aims to establish a common framework for the use and exchange of electronic health data across the EU. It proceeds with phases to enhance access to and control over personal electronic health data, while also enabling certain data to be reused for public interest, policy support, and scientific research purposes. Additionally, the regulation establishes a harmonised legal and technical framework for electronic health record (EHR) systems, fostering interoperability. The presentation will discuss these aspects and present HUS Data Lake as an example of large organisational solution for integrating digital health data types together for further utilisation.

Radiation Exposure Monitoring and Dose Surveys in a Limited-Resource Setting: The Bulgarian Experience with a Multi-Layer Software Ecosystem

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Introduction

Radiation exposure monitoring is essential tool for optimisation and patient radiation protection in medical imaging. At national level, the establishment and periodic review of diagnostic reference levels (DRLs) require the collection of large volumes of reliable and standardised patient dose and exposure data from multiple institutions and imaging modalities. In limited-resource settings, this process is often constrained by the lack of commercial dose tracking systems, insufficient human resources, heterogeneous information systems, and a strong reliance on manual data entry.

Purpose

This work presents the Bulgarian experience in developing and implementing a multi-layer software ecosystem for radiation exposure monitoring and national dose surveys under limited-resource conditions. The objective is to demonstrate how, modular and vendor-neutral solutions can support dose audits, DRL implementation and optimisation of medical imaging practice.

Methods and Materials

The core of the ecosystem consists of two national web-based platforms developed for patient dose surveys and DRL assessment in diagnostic and interventional radiology, as well as a dedicated platform for mammography dose audits based on mean glandular dose (MGD) calculations.

To overcome the limitations of manual data entry, successive layers of automation were developed. An intermediate Excel VBA-based tool (idRS) was implemented as an early solution, enabling structured data validation and semi-automatic preparation of datasets and online submission. Although this approach is now technologically outdated due to modern browser security restrictions, it played a key role in identifying user needs.

Subsequently, a vendor-neutral DICOM Metadata Extractor, implemented using HTML and JavaScript, was developed to automatically extract patient, exposure and dose-related parameters directly from DICOM headers and export them in structured formats suitable for

further processing. Building on this, browser-based automation was introduced through dedicated Chrome extensions for both the national DRL online system and the MGD platform, enabling automatic form population and data submission from Excel files. The extensions are designed for easy deployment, periodic updates.

Results

The integrated workflow enables an end-to-end data pipeline from DICOM images to national dose databases, significantly reducing manual workload and transcription errors. Practical use demonstrates substantial time savings compared to fully manual procedures, improved consistency of reported data and enhanced feasibility of multi-centre dose surveys across different imaging modalities.

Conclusion

The presented software ecosystem demonstrates that effective radiation exposure monitoring and dose surveys can be implemented in limited-resource settings using modular, and browser-based solutions. By combining centralised web platforms with automated DICOM metadata extraction and browser extensions, the system supports DRL implementation, dose optimisation and continuous improvement of radiation protection.

Radiation Dose Monitoring in Complex Coronary Interventions: Establishment of a National Registry in Bulgaria

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In Bulgaria, a National Interventional Cardiology Registry is currently being established with the purpose of systematically collecting and analyzing data on complex coronary interventions, which are characterized by prolonged fluoroscopy time and increased patient radiation exposure. The registry is designed to collect standardized patient demographic data, including age and sex, as well as optional anthropometric parameters such as height and weight. The registry also collects system-reported dosimetric parameters from the angiographic equipment used during the procedures, including absorbed dose, cumulative air kerma at the interventional reference point (Ka,r), and dose–area product (DAP). These data enable an objective assessment of patient radiation exposure during complex coronary interventions and allow the evaluation of dose variability across different procedures and clinical practices.

The registry provides a structured framework for continuous monitoring of patient radiation exposure and supports optimization of interventional techniques in order to improve radiation safety awareness and maintain high quality of care. The analysis of the registry data will allow comparison of practices between different centers, identification of opportunities for dose optimization, and the establishment of a robust scientific basis for future analyses and research in the field of complex coronary interventions, including the potential development of national diagnostic reference levels.

National Electrophysiology Registries as a Framework for Radiation Dose Monitoring, Optimization, and Establishment of Diagnostic Reference Levels for Electrophysiology Procedures

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Fluoroscopy-guided electrophysiological procedures and cardiac electronic device implantations are complex interventional techniques associated with considerable and highly variable radiation exposure to patients and medical staff. Systematic collection, analysis, and optimization of patient dose data are essential components of radiation protection and quality assurance in interventional cardiology.

The Association of Cardiac pacing and Electrophysiology in Bulgaria maintains two national registries – BG Pace and BG Ephy – covering electrophysiological procedures and fluoroscopy-guided cardiac electronic device implantations. Both registries prospectively collect detailed procedural data, including procedure type, procedural complexity, operator, and clinical center. This structured clinical information provides a basis for radiation dose assessment and benchmarking at a national level.

The BG Ephy registry includes a mandatory requirement for documenting the dose–area product (DAP) for each procedure and has already been used for scientific analysis in electrophysiology. Registry-based dose data from BG Ephy have also been successfully applied for the proposition of national diagnostic reference levels (DRLs), demonstrating the feasibility and clinical value of combining patient radiation exposure with procedural complexity for more meaningful interpretation of dose values in relation to procedural complexity. Building on this experience, we propose extending mandatory radiation dose reporting to the BG Pace registry, including both DAP and cumulative radiation dose. This harmonized approach will improve the completeness and standardization of dosimetric data across fluoroscopy-guided cardiac procedures.

The availability of comprehensive registry-based dose data enables systematic comparison of radiation exposure according to procedural complexity, procedure category, operator experience, and institutional practice. Such analyses facilitate inter-center and inter-operator comparisons and support the establishment and periodic updating of national DRLs for electrophysiological procedures, as recommended by European and international guidelines. Furthermore, registry-driven feedback can assist physicians in optimizing

fluoroscopy use during procedures, thereby reducing unnecessary radiation exposure by detecting suboptimal fluoroscopy practices and guiding targeted optimization strategies.

Integrating dosimetric parameters into national electrophysiology registries represents a practical and scalable approach to continuous radiation dose surveillance. This framework supports compliance with regulatory requirements, promotes optimization in accordance with the ALARA principle, and contributes to reducing radiation-related risks for patients and staff in the interventional medical environment.

Combining dose monitoring data and clinical records to identify systematic issues in interventional radiology and cardiology practices

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Introduction:

Medical physicists use annual quality control tests (QC) to pick up problems with devices. However, the introduction of novel automatic exposure control cannot be fully tested with homogenous, static test objects. To assess safety and quality of a protocol, patient data monitoring is increasingly essential. In interventional radiology/cardiac catheterization (IRCC) the different operators and the variability in procedures, leads to further radiation dose dispersion that complicates the analysis.

In this study, a pipeline is developed that combines IRCC dose monitoring data with clinical indications to allow clinically relevant comparisons in an IRCC suite with 9 systems.

Materials and methods:

Dose monitoring data (DMS) (DOSE, QAELUM) from nine fluoroscopy systems was exported and merged with clinical indications from the radiological information system (RIS.) DMS export fields were standardized across scanners, and free-text clinical indications in the RIS were grouped into ten main categories, such as ablation, pacemaker implantation (PM), TAVI, and PICC; uncategorized indications were excluded.

A Python pipeline then merged the datasets, calculated descriptive statistics, and generated Excel reports, summarizing key metrics like study count, median dose area product (DAP), peak skin outlier count, median pulse width and typical filtration for each indication and system. The report distinguishes study, fluoroscopy study/series, acquisition study/series levels to calculate the metrics.

Results:

Out of 8,110 exported studies, 50% were uniquely matched with one of ten indication categories, resulting in 211,000 series used for the report. For six out of ten categories, over 80% of procedures were conducted on just two of nine systems; for two of these categories, more than 95% were performed on a single system. The difference in median

total DAP between systems exceeded 20% for embolization and PM indications. In embolization cases, this was due to varying numbers of series needed for different systems. System A performed longer fluoroscopy scans (19%) but required fewer fluoroscopy series overall (29%). It also needed fewer acquisitions (30%). For PM procedures, the discrepancy originated mostly from one system delivering a higher dose per frame (25%).

Conclusion:

Combining dose monitoring and RIS data enables the identification of systematic issues and inconsistencies in IRCC, that were not picked up by standard QC. This study proposes a pipeline that can be run on a yearly basis and can serve as starting point for optimisation.

Bridging Occupational and Patient Dose Data in Modern Radiation Monitoring in Interventional Radiology

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Introduction

Interventional radiologists work in high radiation environments and are at risk of exceeding occupational dose limits. Occupational dose monitoring is an essential part of the radiation safety policy, and it is generally performed using passive dosimetry (thermoluminescent or optically stimulated luminescence), which provides reliable monthly readings. Passive official personal dosimeters are quite useful for ensuring that professionals do not exceed regulatory dose limits, but they are not able to provide useful information for the radiation protection optimisation, for example, which procedures contribute the most to the professionals' occupational dose or which procedures requires more attention in the optimisation of the radiological protection.
Electronic personal dosimetry together with patient dose records incorporated in an occupational information system can offer highly useful information for the radiation protection optimisation in interventional practices. In this work we present a prototype for an occupational information system deployed in a university hospital.

Methodology

The prototype is based on the personal use of electronic dosimeters linked wireless with a receiver. This receiver is also in communication with the interventional X-ray unit and is capable of structuring the occupational dose at clinical procedure level. A DICOM listener receives both, the electronic dosimeter structured report and patient dose information (radiation dose structured report) per procedure, and publish it via an HTML service. In this service. In this web service the occupational information is presented in several formats, including cumulative $H_p(10)$ in a period, average, $H_p(10)$ per clinical procedure, or average $H_p(10)$ per unit of kerma area product. Additionally, the % of the $H_p(10)$ and kerma area product can be analysed. A set of alerts can be configured to assist in data interpretation.

Results

The prototype is currently working in 8 interventional rooms recording personal occupational doses from 34 workers since January 2024. A total of 16430 procedures have

been recorded from laboratories dedicated to interventional radiology (1), interventional cardiology (3), electrophysiology (2), neurointerventional (1) and vascular surgery (1) procedures. The information is shared periodically with interventionalists in brief clinical sessions to discuss radiation protection strategies.

Conclusions

This information system provides detailed structured occupational dose data necessary to implement targeted optimisation measures.

Acknowledgements

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Analysis of clinical practice for neuroradiological procedures for exposure optimization

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Neuroradiological procedures are widely used in diagnostic and interventional practice and often involve significant radiation exposure. The aim of this project was to describe the workflow of these procedures and examine the influence of the operator practices in patient exposure.

One year of data from three types of neuroradiological procedures (stroke, aneurysm, cerebral angiography) were collected and analyzed through the hospital's dose management software (DMS: DOSE, Qaelum NV, Belgium). Besides the standard values of interest per procedure, such as the air kerma area product, $P_{K,A}$, fluoroscopy time and air kerma at the reference point, $K_{a,r}$, the software calculates the peak-skin dose (PSD), which was also included in the analysis. Additionally, the X-ray device offers 3d-reconstruction, thus the irradiation mode per procedure (average percentage of contribution of fluoroscopy, stationary acquisition and rotational acquisition for 3d-reconstruction) was also assessed using the DMS. The analysis was performed both across all operators and individually for each operator that performed at least 5 procedures.

For 132 stroke procedures, the median $P_{K,A}$ for all procedures was 989 Gy.cm^2 (with 25th-percentile at 544.14 and 75th-percentile at 1799 Gy.cm^2), the median fluoroscopy time at 28 min (with 25th-percentile at 16 and 75th-percentile at 48 min), the median $K_{a,r}$ was 0.56 Gy (with 25th-percentile at 0.2 and 75th-percentile at 0.86 Gy) and the median PSD was 0.41 Gy (with 25th-percentile at 0.34 and 75th-percentile at 1.19 Gy). The corresponding typical values had been determined in a previous analysis at 1048 Gy.cm^2, 26 min and PSD at 0.4 Gy. The $K_{a,r}$ as provided by the manufacturer was found systematically higher than the PSD. Thus, only the PSD was used for further analysis. The contribution of fluoroscopy was 85.4%, of stationary acquisition 14.3% and of rotational acquisition 0.3%. In general, the clinical practice of all operators was similar. One operator was shown to use more fluoroscopy time (median value of 34 min) and used the acquisition modes more frequently (16.7% for stationary and 0.9% for rotational), which resulted in increased patient radiation exposure (1846 Gy.cm^2 and 0.84 Gy). Aneurysm and cerebral angiography procedures were similarly analyzed.

Even small differences in clinical practice may significantly affect patient radiation exposure. As imaging technology evolves and offers more possibilities, optimization should progress accordingly through regular monitoring of exposure values and systematic evaluation of each practice-related component, including how operators apply and use new technologies, that may contribute to patient exposure.

REM2026

INTERNATIONAL SYMPOSIUM
ON RADIATION EXPOSURE MONITORING IN MEDICAL IMAGING

11-13 June 2026 | Sofia, Bulgaria

ROUND TABLES

We need a working group - recommendation - regulation on quality of patient DICOM dose reporting

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Modern patient dose management relies heavily on Digital Imaging and Communications in Medicine (DICOM) Radiation Dose Structured Report (RDSR) data. The RDSR is generated by the modality. Manufacturers make different choices in their implementation of the DICOM standard, and sometimes make errors. This can prevent data from being imported into patient dose management systems (DMS), and can also affect the usability or validity of the data if it can be imported. Few PACS offer native support for viewing and analyzing the content of DICOM RDSRs. Commercial DMS systems import only data which is compatible with the import rules. A working group of physicists and representatives of the manufacturers should test RDSR implementations and point out necessary improvements to the service and the radiation protection authorities.

A filter was implemented in the import mechanism of an open-source dose management system to find studies which do not have dose information available for ingestion. For those that do, the RDSR files were validated, the tags checked for compliance with the DICOM standard and their content checked for consistency with expected values.

Depending on modality and manufacture the filter finds 10 to 100% invalid or missing dose data files. Some vendors have issued field notices for known incorrect data, some do not utilise available public fields in the DICOM standard and instead put information in private tags or omit them, while others do not comply with their own DICOM conformance statement. In addition, sometimes a clinical or technical workflow issue causes missing data.

While for every medical physicist it is a tedious job to find out if the modality generated RDSR file complies with the dose management system of the hospital, for some it is impossible due to missing software tools or understanding of complicated context. Complaints to the manufacturer can be difficult to raise to the right teams, and it can be difficult to get fixes or improvements onto the development plan. A working group of medical physicists together with manufacturers should test new limitations and list those which are compatible. The known issues should be made transparent and easy accessible for medical physicists and radiation protection experts.

Common data inconsistencies in multi-vendor clinical environments: Lessons learned from real-world dose management

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The evolving landscape of medical imaging technology, including new scanner models, advanced algorithms and the integration of artificial intelligence, has significantly impacted the reporting and collection of data in dose management systems (DMS). Furthermore, clinical workflows, which vary across institutions, often contribute to inconsistencies in data quality and completeness. The purpose of this work is to identify and assess common data inconsistencies which may occur in a DMS, through real-world dose management experience across multi-vendor clinical environments.

A comprehensive review of the common data inconsistencies encountered in dose data collection was performed to identify the impact, root causes, and potential solutions. Impact was evaluated based on its effect on overall data completeness, statistical analyses, regulatory reporting at national and international levels, and calculations such as organ dose and peak skin dose.

Common data inconsistencies were categorized into:

- maintenance-related: including data collection disruptions as a result of software updates and changes in data reporting, primarily affecting data completeness;

- vendor-related: including differences in data collection configuration (e.g., radiation dose structured report generation) and reporting (e.g., variations in reference definitions and image quality (IQ) metrics, among others), impacting DMS calculations;

- workflow-related: associated with combination exams, trauma cases, and technologist practices, affecting quality of statistics and regulatory reporting.

DMS tools offer solutions for these issues, such as flexibility in device identification (e.g., recognition of multiple station and institution name identifiers or forgoing institution name requirements), reporting of disruptions in data collection, and supporting data collection from alternative tags for maintenance-related changes.

Workarounds for vendor-specific data reporting include vendor-tailored algorithms and allowing users (e.g., medical physicists) to adapt DMS data to their needs, e.g., adjusting scan parameters for organ dose calculation and interventional event data for peak skin dose

calculation. Integrations of vendor-neutral IQ metrics such as global noise and noise texture allow noise benchmarking across protocols and device fleets.

Improved monitoring of combination exams can be achieved by offering study- and series-level combination exam mappings to facilitate regulatory reporting, while flexibility in DMS calculations can offer solutions to special cases like monitoring of patient size metrics in trauma scans, to address workflow-related challenges.

In multi-vendor imaging environments, inconsistencies in dose data originating from x-ray systems emphasize the value of flexible and configurable dose management systems designed to handle such variations and ensure reliable dose analysis and reporting. User awareness of common issues is essential for improved error detection.

Implementation of International Safety Standards in the Optimization of Patient Radiation Protection – Based on an IAEA Assessment

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The IAEA Radiation Safety Information Management System (RASIMS) collects and compiles information on regulatory requirements reported by Member States, organized into six thematic safety areas. Thematic Safety Area 3 (TSA 3) addresses radiation protection in medical exposure. Currently, 150 countries maintain national profiles within RASIMS, providing data on existing regulatory frameworks.

Analysis of these data reveals significant gaps in regulatory requirements related to ensuring adequate medical personnel in diagnostic radiology (DR) and interventional radiology (IR), including the availability of qualified medical physicists. Such requirements are fully met in only 3 of 47 countries in Africa, 7 of 38 in Asia and the Pacific, 10 of 33 in Europe, and 10 of 32 in Latin America and the Caribbean.

Similarly, regulatory provisions supporting the optimization of radiation protection in DR and IR remain insufficient. Appropriate requirements are reported in 8 of 47 African countries, 3 of 38 in Asia and the Pacific, 7 of 33 in Europe, and 6 of 32 in Latin America and the Caribbean. In nuclear medicine, requirements for qualified personnel are fully met in 3 of 47 countries in Africa, 5 of 38 in Asia and the Pacific, 7 of 33 in Europe, and 7 of 32 in Latin America and the Caribbean. Regulatory frameworks addressing optimization in nuclear medicine are somewhat stronger but still limited, with compliance reported in 4, 3, 11, and 9 countries, respectively, across the same regions.

Overall, these findings highlight that insufficient regulatory requirements remain a key limiting factor for effective optimization of patient protection.

To further investigate this issue, the IAEA conducted a survey in 2022/2023 on the establishment and use of diagnostic reference levels (DRLs) in Europe and Central Asia. The survey included 26 Member States participating in the IAEA TC Programme in Europe, as well as 34 representatives from relevant professional bodies in medical physics, radiology, nuclear medicine, and radiography.

The results indicate limited awareness of the DRL concept and existing national DRLs among medical imaging professionals, as well as insufficient collaboration between regulatory authorities and professional organizations. Moreover, DRL implementation is not adequately integrated into inspection processes, underscoring the need for strengthened inspection procedures and training of inspectors. Access to clinically qualified medical physicists emerged as a critical factor for the effective establishment and utilization of DRLs.

Support for optimisation of patient protection through the European Union's Strategic Agenda for Medical Ionising Radiation Applications (SAMIRA)

Georgi Simeonov, Team Leader, SAMIRA Action Plan Directorate-General for Energy (DG ENER) European Commission

The SAMIRA action plan is the European Union's first comprehensive plan to support safe, high quality and reliable use of radiological and nuclear technology in healthcare. It defines three priority areas for EU action: (a) securing the supply of medical radioisotopes, (b) improving quality and safety in radiation medicine, and (c) facilitating innovation and development of medical applications. A Steering Group on Quality and Safety (SGQS) composed of national health and radiation protection authorities steers the SAMIRA work on quality and safety. The SGQS supports the development of high-quality evidence, clinical guidelines and practical tools, and coordinates their implementation in clinical practice across Europe. This work is rooted in the "Basic Safety Standards Directive" (Euratom 2013/59/Euratom) and pays particular attention to the interplay with other pieces of EU law in areas such as safety of (radiological) medical devices and (radio-)pharmaceuticals. Optimisation of radiation protection of patients is an integral part of the SAMIRA work on quality and safety. Key studies and projects have been completed, or are undergoing, in areas such as equipment capabilities to record and report patient doses, dosimetry and optimisation in radionuclide therapy, diagnostic reference levels, optimisation of protection in paediatric imaging, etc. In February 2026, the European Commission issued a Recommendation on the establishment, review and use of diagnostic reference levels(Euratom/2026/403). The EU4Health programme provides multi-million direct support to Member States for the implementation of SAMIRA standards and recommendation into the national health systems; the AURORad joint action involves 110 organisations from 29 countries; it will launch by the end of the year for a 5-year duration. The SAMIRA action plan is undergoing review to consolidate the lessons learnt from its implementation and consider them in the next cycle of revision of the Basic Safety Standards Directive.

Training impacts the Effectiveness of Radiation Protection communication beyond healthcare professionals

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Background: Radiation protection is not static. As science advances and technologies progresses, the principles, standards, and best practices for protecting people must also develop. The definition of radiation protection keeps changing and professionals must stay informed to ensure safety and compliance not only for them but also for their patients. A recent systematic review synthesized the importance of training to improve not only on behaviors but also communication skills beyond healthcare professionals related to ionizing radiation exposure.

Purpose: This presentation aims to draw attention to the importance of training as part of a Radiation Safety Culture, we should achieve, in this specific subject, to guarantee effective communication beyond healthcare professionals.

Methods: The systematic review employed a structured search strategy across PubMed, Scopus, and the Cochrane Library to identify relevant articles published between 2017 and 2024. Studies were screened independently by two reviewers using predefined eligibility criteria and another third reviewer to analyze any disagreements, and methodological quality was assessed using standardized risk-of-bias tools. The present abstract reports exclusively on the findings related to the importance of training to reinforce communication beyond healthcare literacy concerning radiation protection.

Results: The search identified 566 potentially relevant references, which, after applying inclusion/exclusion criteria, resulted in 12 scientific articles. The studies found that the overall knowledge of these healthcare workers was unsatisfactory, and there was a lack of knowledge in radiation protection. Training is essential and must emphasize how radiation exposure can be minimized, safeguarding health professionals' trust and sense of security. Training strategies focused on basic radiological risks and radiation safety must be improved. The attitude and behavior towards ionizing radiation are limited and less accurate in professionals with fewer years of experience, referring to a lack of training towards radiation protection.

Conclusion: The focused analysis indicates that training is important not only for behaviors but also to improve communication effectiveness.

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JUBILEE SESSION

30 Years International Projects in Medical Physics Education - The Pioneering of e-Learning in the Profession: A Mosaic of Ideas and Activities

Slavik Tabakov, 1IOMP Past President, 2Formerly MSc Director King's College London, UK, 3 Chair Editorial Board of Encyclopaedia of Medical Physics

2025 and 2026 celebrate 30 years of the beginning of a sequence of innovative international projects focussed on medical physics education. The results of these projects spread globally and were fundamental for the growth of medical physics in many countries, especially Low and Middle Income (LMI) countries. The sequence of projects were supported by various European programmes and attracted nearly 500 specialists from 51 countries.

The first large project ERM was the development of an MSc programme on medical physics in Bulgaria. The results from the project were used for the formation of new MSc programmes, initially in Bulgaria and the Baltic states, and after this in 15 other countries. These programmes continue to produce annually hundreds of young medical physicists. This experience was used in the IAEA TCS 56 "Postgraduate Medical Physics Academic Programmes".

In parallel with the above projects was developed the project EMERALD, which was the first e-learning project in the profession. The project developed electronic materials to support medical physics training: 5 Taskbooks, 5 Image databases and 2 Guides. This project developed one of the first in the world e-books. The project spread all over the world and laid the foundation of medical physics training in many countries. On its base in 1999 was developed (through project EMERALD II) the first educational web site in medical physics (www.emerald2.eu), which continues to serve the profession with over 2000 users per month. These projects were made before the words "e-book" and e-learning" existed.

The next project EMIT continued further the training materials and developed the first Scientific Dictionary of Medical Physics terms, which currently cross-translates in 32 languages. The projects were awarded the inaugural EU prize for vocational education – The Leonardo da Vinci Award. This played an additional role for the later recognition of our profession through the International Labour Organisation.

The following project EMITEL used the Thesaurus of the Scientific Dictionary to develop the first e-Encyclopaedia of the profession. This was the largest project in medical physics. In it volunteered around 400 specialists. Its result www.emitel2.eu was launched in 2010 and since has at least 50,000 searches per month. In 2024 the second update of the e-

Encyclopaedia was completed– now with 3900 terms, supported by 1300 images, diagrams and tables.

Apart from me as developer and Coordinator of these projects, other Bulgarian specialists took prominent role in these – e.g. the Encyclopaedia website was developed by Prof. M. Stoeva and Ing. A. Cvetkov; Prof. J.Vassileva coordinated the Bulgarian part of the Dictionary, etc. Alongside these projects were organised other activities – e.g. the First International Conference in Medical Physics Education; the First International Conference in Medical Physics Training; the First International Conference in Medical Physics e-learning and the IOMP Journal "Medical Physics International" to support educational activities. This mosaic of 7 innovative projects contributed significantly to the international growth of medical physics. The project are described in detail in the free e-book "The Pioneering of e-Learning in Medical Physics" (www.emerald2.eu/mep_index.html). I would like to specially thank all colleagues who took part in these fundamental projects of the profession.

Advancing Radiation Protection in Medicine Through International Collaboration: Bulgaria’s Experience

Jenia Vassileva, National Center of Radiobiology and Radiation Protection and Roentgen Foundation

Radiation protection of patients and medical staff has been an essential component of the medical use of ionizing radiation in Bulgaria since the establishment of radiological practice. Research and professional activities in this field began in the 1950s and evolved in parallel with international scientific and technological developments. At the First Congress of Bulgarian Radiologists in 1961, key principles for patient radiation protection were outlined, alongside early studies on patient dosimetry and quality control. Since the 1960s, the National Center of Radiobiology and Radiation Protection (NCRRP) has regularly assessed the contribution of medical exposure to population dose. Important national milestones included the first radiation protection regulation for medical use of X-rays issued in 1958, the establishment of a postgraduate specialisation in medical radiological physics in 1982, and the First National Conference on Patient Protection in Medicine in 1983.

Progress slowed during the final decades of the 20th century due to economic and political challenges, but significant advances resumed in the early 2000s during Bulgaria’s preparation for accession to the European Union. Between 2002 and 2003, the NCRRP implemented a PHARE Twinning Project with German partners entitled *Radiation Protection and Safety at Medical Use of Ionising Radiation*. The project supported harmonisation of Bulgarian legislation with Euratom Directive 97/43 and strengthened the institutional framework for implementation. Key outcomes included the adoption of a new Ordinance on Radiation Protection of Individuals undergoing Medical Exposure, introduction of quality assurance and patient dosimetry requirements, and the first national surveys of patient doses in diagnostic radiology and administered activities in nuclear medicine, leading to the establishment of first national diagnostic reference levels (DRLs).

To coordinate these activities, the NCRRP established the Laboratory for Radiation Protection at Medical Exposure in 2002. International collaboration further expanded through participation in European and IAEA projects. A major milestone was the 2008–2009 PHARE Twinning Project with STUK, Finland, focused on strengthening administrative structures for radiation protection in diagnostics and therapy. Participation in the European research project “Safety and Efficacy for New Techniques and Imaging using New Equipment (SENTINEL)” and the EU project “Study on European Population Doses From Medical Exposure”, Dose Datamed 2 (DDM2) further enhanced national expertise and research capacity in medical physics and patient dosimetry.

Since 2003, the NCRRP has also actively participated in IAEA regional and national

technical cooperation projects on radiation protection in medicine, supporting capacity building, professional training, and implementation of international standards. Continuous international collaboration has played a key role in the modernization of radiation protection practices in Bulgaria and remains essential for future development in the field.

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WORKSHOPS

Fetal Dose Assessment in X-Ray Imaging

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The use of X-ray-based imaging procedures is integral to modern clinical practice, enabling accurate diagnosis and effective patient management. In certain clinical scenarios, however, diagnostic imaging is required during pregnancy, necessitating careful consideration of potential radiation exposure to the embryo or fetus. Appropriate assessment and management of fetal radiation dose therefore remain essential component of radiation protection in clinical care.

This presentation will review the principles of fetal dose assessment in clinical practice, with particular emphasis on the biological effects of ionizing radiation. Deterministic and stochastic radiation effects will be discussed in relation to absorbed dose and gestational age, highlighting the varying radiosensitivity of the embryo and fetus throughout the stages of development.

Typical fetal dose levels associated with a range of X-ray-based imaging procedures and modalities will be presented. In addition, methods for fetal dose assessment applicable in clinical routine will be outlined, including analytical, computational, and dosimetric approaches, as well as the use of dedicated calculation tools and software.

Particular emphasis will be placed on the practical aspects of fetal dose estimation. The presentation will include illustrative examples of fetal dose calculations performed in clinical routine, aimed at supporting informed clinical decision-making and effective radiation protection for pregnant patients.

IFMBE WORKSHOP

Ratko Magjarevic, IFMBE, Croatia
Magdalena Stoeva, Medical University of Plovdiv, Bulgaria

The International Federation of Medical and Biological Engineering (IFMBE) established in 1959 as a federation of national and transnational organizations which represent national interests in medical and biological engineering. The Federation now has an estimated 120,000 members in 84 affiliated organizations (as of 2025).

Medical and Biological Engineering integrates physical, mathematical and life sciences with engineering principles for the study of biology, medicine and health systems and for the application of technology to improving health and quality of life. It creates knowledge from the molecular to organ systems levels, develops materials, devices, systems, information approaches, technology management, and methods for assessment and evaluation of technology, for the prevention, diagnosis, and treatment of disease, for health care delivery and for patient care and rehabilitation.

The mission of the IFMBE is to encourage, support, represent and unify the world-wide Medical and Biological Engineering community in order to promote health and quality of life through advancement of research, development, application and management of technology.

The objectives of the IFMBE are scientific, technological, literary, and educational. Within the field of medical, biological and clinical engineering IFMBE's aims are to encourage research and the application of knowledge, and to disseminate information and promote collaboration.

The IFMBE joins the International Organization for Medical Physicists (IOMP) in a Union called the International Union for Physical and Engineering Sciences in Medicine (IUPESM). These organizations coordinate the World Congress on Medical Physics and Biomedical Engineering every three years.

www.ifmbe.org

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COMPANY PRESENTATIONS

COMPANY PRESENTATION: From Dose Data to Clinical Insight: Supporting Optimization in Medical Imaging

Niki Fitousi, Qaelum NV, Leuven, Belgium
Janne Vignero, UZ Leuven, Belgium

This presentation will introduce Qaelum and its medical imaging software suite, centered on its flagship radiation dose management system designed to monitor patient exposure across medical imaging exams. While fully addressing regulatory requirements for dose tracking and reporting, the solution goes further by enabling deeper analysis of clinical and operational data. In particular, it supports the identification of outliers, assessment of protocol and equipment performance, and benchmarking across devices, helping departments move from compliance-driven monitoring to proactive performance management.

The software will be also presented from a user perspective, demonstrating how advanced tools, such as automated image quality assessment, are integrated into daily practice. Through concrete examples, we will show how users leverage these capabilities to gain a more comprehensive understanding of their imaging workflows and equipment behavior, balance dose and image quality, benchmark performance across systems or sites, and support continuous optimization.

Finally, the presentation will outline a forward-looking vision of an interconnected ecosystem of software solutions, each addressing specific needs while collectively contributing to radiation exposure monitoring and broader quality management in medical imaging.

COMPANY PRESENTATION: What 35 Million Studies Has Taught Us About Standards

Kaye Bonython, PACSHealth Limited (UK)

Medical imaging has revolutionized modern healthcare, but the increasing dependence on ionizing radiation raises concerns about patient safety, especially regarding radiation exposure.

This abstract highlights key insights from analyzing millions of studies on radiation dose and exposure using DICOM (Digital Imaging and Communications in Medicine) data, imaging protocols, and the ongoing lack of industry-wide standardization. DICOM serves as a vital framework for storing and transmitting imaging information, including radiation dose metrics such as Dose Length Product (DLP) and Computed Tomography Dose Index (CTDI). While these data points offer valuable opportunities for dose monitoring and optimization, their practical application is often hampered by inconsistent implementation, incomplete metadata, and variations in how dose information is recorded.

A major challenge identified is the wide variation in data collected across different devices, software levels, and even clinical protocols. Differences in scanner technology, technician training, and institutional preferences lead to inconsistent radiation doses delivered to patients.

Without standardized protocols, patients could receive doses that are unnecessarily high or low, increasing risks without improving diagnostic accuracy. This highlights the importance of harmonizing DICOM standards among vendors.

The lack of standardization encompasses inconsistencies in DICOM data formatting and dose reporting. Not all imaging systems fill dose-related fields uniformly, with some relying on proprietary tags or omitting key information altogether. This fragmentation makes large-scale data analysis, benchmarking, and automated dose-tracking systems difficult. Consequently, healthcare providers face obstacles in accurately tracking patient exposure over time or comparing performance across different institutions.

Addressing these issues involves creating dose registries, standardizing reporting templates, assessing whether IHE (Integrating the Healthcare Enterprise) is the solution, and enhancing regulatory oversight. However, adoption remains inconsistent. Improving interoperability, ensuring data completeness, and promoting standardized imaging protocols are crucial steps to enhance patient safety. Ultimately, maximizing the potential of DICOM data requires not only technological advances but also coordinated efforts among

clinicians, technologists, vendors, and policymakers to establish consistent practices and accountability in radiation dose management.

We analyzed more than 35 million studies across over 1000 facilities, 400 device models, and 25 manufacturers. The Global Dose Registry and DoseMonitor are registered trademarks of PACSHealth, LLC. Presenter Steve Massey, Vice President of Product Development at PACSHealth, has over 30 years of experience in radiology imaging and actively participates in AAPM and DICOM committees.

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POSTERS

Quality Assurance Framework for Deep Learning Models in Radiation Dose Prediction

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Objective: This study presents a comprehensive, standardized quality assurance framework for validating deep learning models in radiation dose prediction applications. Unlike existing studies that focus on individual quality control aspects, this work addresses the critical need for unified evaluation methodologies and systematic uncertainty quantification in medical physics.

Methods: A multi-dimensional quality control framework was developed incorporating statistical accuracy assessment, clinical relevance evaluation, and computational efficiency metrics. The framework implements traditional error measures (MSE, MAE, RMSE) alongside clinically relevant gamma index analysis with varying acceptance criteria (3%/3mm, 2%/2mm, 1%/1mm). Uncertainty quantification techniques were integrated using Monte Carlo Dropout and ensemble methods to assess model reliability. A weighted composite scoring system normalizes individual metrics according to clinical relevance: $S = \Sigma(w_i \cdot M_i)$, enabling customizable prioritization of performance aspects. The gamma index methodology incorporates both dose difference and distance-to-agreement criteria: $\gamma(r) = \min[\sqrt{((\delta r/\Delta dM)^2 + (\delta D/\Delta DM)^2)}]$, optimized through machine learning-enhanced neighborhood search algorithms. Model optimization was investigated across different training dataset sizes using ResNet-3D, Transformer, and enhanced CNN architectures.

Results: The quality assurance framework successfully identified optimal model configurations and performance trade-offs. ResNet-3D architecture demonstrated performance with gamma index pass rates of 95.6% (3%/3mm) and 89.4% (2%/2mm). Optimal performance was achieved with 150-250 training samples, demonstrating non-linear relationships between dataset size and model accuracy. Monte Carlo Dropout uncertainty analysis revealed systematic patterns with highest prediction variability in dose gradient regions ($\sigma=2.1\pm0.5$ cGy) and heterogeneous material interfaces. However, all tested architectures exhibited performance degradation in high-gradient zones, indicating systematic limitations requiring specialized attention. Resource constraints significantly affected larger models, with training beyond 250 samples showing diminishing returns due to computational limitations.

Conclusions: The developed QA framework provides the standardized methodology for deep learning model validation in radiation dose prediction, while identifying key limitations in current approaches. Primary innovations include: (1) unified evaluation system combining multiple assessment dimensions previously studied separately, (2) systematic optimization

analysis revealing optimal training dataset sizes (150-250 samples) and computational constraints, (3) comparative uncertainty quantification framework demonstrating Monte Carlo Dropout advantages with associated computational trade-offs, and (4) weighted composite scoring system enabling customizable clinical prioritization. Despite demonstrating significant improvements, the framework revealed persistent challenges in dose gradient regions and heterogeneous materials that require future algorithmic developments. This work establishes new benchmarks for AI model validation in medical physics, providing foundation for regulatory guidelines while highlighting areas needing continued research to achieve full clinical reliability.

Keywords: quality assurance, model validation, uncertainty quantification, radiation dosimetry, artificial intelligence

Enhancing diagnostic accuracy in digital mammography using an integrated deep learning framework

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Accurate interpretation of digital mammography is essential for effective breast cancer screening, yet it remains challenging due to complex breast tissue composition, overlapping anatomical structures, and variability in image acquisition quality. These factors contribute to diagnostic uncertainty, increased false-positive and false-negative findings, unnecessary recalls, and repeat imaging examinations, which may cumulatively increase patient radiation exposure. This study presents an integrated deep learning framework designed to enhance diagnostic accuracy, improve robustness in lesion recognition, and support optimisation within mammography screening workflows.

The proposed system incorporates advanced image preprocessing, including wavelet-based denoising, local contrast normalisation, and histogram scaling, to enhance lesion visibility. A multi-scale convolutional feature extractor based on a modified ResNet–Inception architecture is employed to capture both fine-grained textures and global structural patterns. Features from multiple network depths are fused and refined using principal component analysis, followed by an attention mechanism that prioritises diagnostically relevant features. In parallel, a lightweight U-Net segmentation branch provides spatial localisation of suspicious regions, which is used as soft guidance to improve classification robustness. The network is initialised using ImageNet-pretrained weights and fine-tuned on a dataset of 2800 labelled digital mammograms, with data augmentation applied to enhance generalisation. Class imbalance is addressed using focal loss.

The proposed framework achieved an accuracy of 94.93%, precision of 93.66%, recall of 89.21%, and an F1-score of 98.86%, outperforming several established deep learning approaches reported in the literature. The results indicate a marked reduction in both false-positive and false-negative classifications, contributing to more consistent and reliable diagnostic outcomes.

By improving diagnostic confidence and reducing unnecessary follow-up imaging, the proposed approach has the potential to support radiation exposure optimisation in mammography screening programmes. Its scalable, workflow-oriented design facilitates integration into clinical environments as an artificial intelligence–assisted decision support tool.

Artificial intelligence in medical exposures in Greece - users' perception, awareness, competence

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Purpose: A pilot survey is in progress in Greece aiming to explore the perception, awareness and competence of the artificial intelligence (AI) users in medical applications of ionizing radiation (IR).
Method: An electronic questionnaire was developed and disseminated to a selected sample of approximately 70 medical facilities that, may have incorporated AI systems in radiotherapy (RT) and in diagnostic radiology with recently installed or upgraded existing devices (PET/CTs, CTs, SPECT/CTs and SPECTs). Medical physics experts (MPE) were mainly addressed in this pilot phase.
Results: Initial results indicate that 40% of the medical facilities that responded use AI systems. They are mainly used in RT for contouring and segmentation of targets and organs at risk and in diagnosis (PET/CT and CT) for image reconstruction and quality improvement. A considerable percentage of responders are neither aware of, nor familiar with the specific utilization of AI systems. Nevertheless, almost 40% of the responders believe that AI systems were properly trained when released, note that the supplier/vendor and the MPEs conduct the commissioning and acceptance tests and confirm the AI systems' training by the vendor with independent QC dataset. Relevant proof or certification appears available to less than 10% of the responders. Half of the responders are concerned or not aware of the AI system validation and appropriateness for the medical facility's patient population. Almost 70% of the responders confirm the staff training by the AI systems supplier/vendor. The main concerns for AI systems use seem to be algorithms trustworthiness, lack of transparency, explainability, interpretability and legal responsibility in case of errors. In general, the responders do not appear familiar with the European Union (EU) AI Act or the national AI Law.
Conclusions: AI systems are already used in ionizing radiation medical applications in the country, mainly in RT. Human oversight, risk assessment, and rigorous testing will be long term areas for enhancing capacity and awareness. Comments collected underline the fact that discussions for the use of AI systems in more medical facilities are currently in progress; thus, the findings of this study will be of added value to the users.

“Bringing Monte Carlo to the Clinic: AI-Driven Real-Time Radiation Dosimetry in Medical Imaging”

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This work presents a novel idea for real-time, patient-specific radiation dose monitoring in medical imaging by integrating artificial intelligence with high-fidelity Monte Carlo simulation. While Monte Carlo methods are widely regarded as the gold standard for accurate Radiation dosimetry, their extensive computational cost limits their applicability in time-sensitive clinical environments.

We propose a hybrid methodology in which large-scale Monte Carlo simulations are used offline to generate high-resolution dose distributions across diverse anatomical models and imaging parameters. These datasets are subsequently used to train deep learning architectures capable of approximating radiation transport and energy deposition with near Monte Carlo accuracy.

The trained model enables real-time inference of patient-specific dose distributions during imaging procedures such as computed tomography and interventional radiology. This approach allows dynamic optimization of imaging parameters, reducing unnecessary radiation exposure while maintaining diagnostic image quality.

Preliminary validation demonstrates that the proposed AI-driven framework achieves a substantial reduction in computation time, from hours to millisecond while preserving clinically acceptable accuracy. The integration of this system into imaging workflows has the potential to transform radiation exposure monitoring from a retrospective estimation process into a proactive, adaptive, and personalized tool.

This work bridges the gap between computational accuracy and clinical feasibility, paving the way for next-generation intelligent imaging systems and enhanced patient safety. AI enabling the transition toward intelligent, self-optimizing imaging systems.

Iterative and Deep Learning reconstruction-based imaging dose reduction in Lung sparse-view computed tomography

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Low-dose computed tomography (CT) imaging can be achieved by reducing the number of X-ray projections around the patient. However, this approach significantly reduces image quality and diagnostic fidelity. We implemented an iterative reconstruction algorithm using a deep learning model to improve image quality while reducing patient dose. A total of 10,000 lung CT images were collected and split into input and target datasets, each containing 5,000 images. The input dataset consists of sparse-view images, while the target dataset comprises routine full-projection CT images. The sparse-view CT images were generated using only 16, 32, 64, 128, and 256 projections, instead of the standard full-projection acquisition. A Generative Adversarial Network (GAN) was developed to translate input images into outputs that closely resemble the ground-truth routine CT images. Sparse-view sinograms were extracted, and the corresponding images were reconstructed using the Simultaneous Iterative Reconstruction Technique (SIRT). The generated higher-quality images were compared with the original full-projection images using the Root Mean Squared Error (RMSE), Peak Signal-to-Noise Ratio (PSNR), and Structural Similarity Index (SSIM). The results showed a continuous improvement in model performance as the number of projections increased from 16 to 256. For 16 projections, the RMSE, PSNR, and SSIM were 4.342, 33.561, and 96.407%, respectively. These values improved significantly to 2.379, 38.721, and 98.882% for 64 projections, indicating higher image quality. At 256 projections, the reconstruction accuracy further improved, achieving RMSE, PSNR, and SSIM values of 1.822, 40.881, and 99.277%, respectively. At 256 projections, a dissimilarity of 0.723% was observed between the reconstructed and original images. The mean Hounsfield Unit (HU) differences were limited to 8 HU for 16 projections and 1.5 HU for 256 projections. Iterative reconstruction in sparse-view CT is capable of reducing the imaging dose by decreasing the number of projections and X-ray exposures. However, higher diagnostic fidelity can be maintained using the developed GAN model.

Determination of size-specific dose estimates in PET/CT: A deep learning approach for anatomical classification and dosimetry

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Hybrid imaging modalities like Positron Emission Tomography/Computed Tomography (PET/CT) contribute significantly to the cumulative radiation of oncological patients through both internal radiopharmaceutical exposure and external X-ray irradiation. While acknowledging this dual contribution, this work specifically targets the accurate quantification of the CT component, addressing the limitations of standard metrics. Currently, the Computed Tomography Dose Index (CTDIvol) displayed on consoles does not account for individual anatomical variations.

To solve this, we present an AI-driven solution for calculating Size-Specific Dose Estimates (SSDE) by training a neural network to automate the segmentation and anatomical classification in patients undergoing knee-to-head PET/CT scans. The methodology focused on training a Convolutional Neural Network (U-Net architecture) to process DICOM datasets from 47 record files. This deep learning model was trained to perform two simultaneous tasks: segmentation of the body contour to calculate the Water Equivalent Diameter (Dw), and classification of anatomical zones (head vs. body). This classification step is crucial for the automatic selection and application of the appropriate conversion factors defined in AAPM Reports 220 (for body) and 293 (for head), ensuring the dosimetric model adapts dynamically to the scanned region.

Bland-Altman analysis confirmed high accuracy with a marginal mean bias of 0.105 cm, indicating a slight but systematic tendency of the neural network to overestimate the diameter by approximately 1 mm. The SSDE in body were of 23.92 ± 1.95 mGy and 42.45 ± 3.4 mGy in head.

In conclusion, implementing a Deep Learning-based workflow provides an automated tool for tracking individual exposures. By integrating AAPM 220 and 293 standards through intelligent anatomical recognition, this solution facilitates precise exposure monitoring and supports the optimization of hybrid imaging protocols.

Monte Carlo–based clinical systems for CT organ dosimetry: a comparative study

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Accurate estimation of organ absorbed doses in computed tomography (CT) is essential for radiation protection, protocol optimization and risk assessment. Monte Carlo (MC)–based dosimetry tools are widely regarded as reference methods for organ dose estimation; however, different MC dosimetry systems rely on distinct computational phantoms, scanner models, and implementation assumptions, which may lead to systematic differences in reported organ doses.

This study aims to compare organ absorbed dose estimates obtained using two independent Monte Carlo–based dosimetry systems for CT. A retrospective study was performed on a cohort of adult patients who underwent CT examinations which specifications were acquired in routine clinical practice, using common clinical protocols and scanners from different manufacturers. Patient modeling was performed using the information available in routine clinical datasets, following harmonized assumptions across both platforms.

For each examination, equivalent scan parameters and acquisition ranges were implemented in both dosimetry systems. Organ absorbed doses were estimated for a predefined set of organs and compared using relative differences in organ dose estimates. The analysis explored potential dependencies on patient size, scanner characteristics, and organ position relative to the scan range.

This work proposes a structured framework for cross-platform comparison of Monte Carlo–based CT organ dosimetry using routine clinical CT data. The results provide insight into the robustness and consistency of organ dose estimates derived from different simulation tools, supporting their appropriate use in clinical audits, research applications, and dose optimization initiatives.

Validation of a Dose Management System for PET/CT and SPECT/CT examinations in Nuclear Medicine

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Dose management systems (DMS) are essential for patient radiation protection in imaging departments. While several commercial and open-source solutions are available, many require substantial financial resources or provide limited support for nuclear medicine applications. The aim of this study is to present the validation methodology and functional performance of a newly developed DMS for nuclear medicine examinations.

The BULDOSE DMS, developed within a national IAEA project BUL9026, was evaluated. A total of 105 PET/CT and 50 SPECT/CT examinations from two nuclear medicine departments were retrospectively uploaded from PACS into the system for validation. Patients were selected according to protocol type to ensure the inclusion of different exposure scenarios. PET/CT and SPECT/ examinations were analysed separately. Validation was performed across the following categories: patient and dose data acquisition; statistical and analytical capabilities; system customisation, including alerts, master protocols, diagnostic reference level (DRL) libraries and user access rights and data export functionalities, including reporting and anonymization.

Patient identifiers, examination details and dosimetric parameters were correctly stored and displayed. All examination series were available within the DMS. Only series associated with physical radiation exposure were included in detailed dose reports. No data duplication or inconsistencies in dose units were observed. For hybrid imaging, data from both the CT and nuclear medicine components were successfully extracted, including CT exposure parameters, radiopharmaceutical type, administered activity and patient dose indices. DRL compliance assessment was available for both nuclear medicine and CT components of PET/CT and SPECT/CT examinations. Variability in protocol naming across systems was addressed through the implementation of “general protocol names,” enabling grouping of examinations with similar clinical intent and facilitating comparative analysis. Usage patterns and potential protocol deviations could be efficiently assessed using the graphical data visualisation tools integrated into the system.

The validation results demonstrate that the BULDOSE DMS reliably captures, processes and

analyses dosimetric data for nuclear medicine hybrid imaging. The system is technically ready for clinical implementation and supports patient dose monitoring and optimisation in PET/CT and SPECT/CT practice.

Comparison of the practice at two Nuclear medicine departments with and without dose collection software

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The type and number of nuclear medicine procedures has increased in recent years, due to the introduction of newer radiopharmaceuticals. This increases the need of patient exposure monitoring and optimization. The aim of this study is to present the challenges for medical physicists during both patient automatic and manual collecting, monitoring and analysis of patient doses.

Two depatrments (Department 1 and Department2) are included in this study, equipped with PET-CT and SPECT-CT. In Department 1 radiation dose management system (RDMS) is available and data for a ten years of period are collected and stored for administered activity, CT exposure . In Department 2 RDMS is not available and the only way to make an assessment of the typical doses or any related to work analysis was manual data collection from PACS and internal journals.

RDMS users have the opportunity to use the integrated analysis tools and to extract data for all type of examinations into excel spreadsheet, where further analysis can be performed. The extracted data includes the basic scan parameters, but also many additional parameters like effective diameter, size specific dose estimate (SSDE), iterative reconstruction level, noise index etc. Information can be extracted for several minutes, but the extracted data requires verification before performing statistical analysis. The RDMS provides option for graphical presentation and dose alerts, as well. A relative disadvantage of the system is that data for nuclear medicine and CT part of the examination are extracted in separate files, which complicates radiation exposure monitoring of the individual patient. Manual data collection trough PACS and internal journals proves information for protocol type, patient administered activity and dose indexes of the CT part of examination. All other information, related to the examination parameters must to be collected thought investigation. This approach is very time consuming, supplemented with a risk of errors during data transfer, which can affect the analysis of the results.

RDMSs present advantages when comparing with manual data collection. Careful verification of the data is necessary, but nevertheless, they allow a quick and reliable assessment of patient exposure and the possibility of assessing the need for optimization. Manual data collection is very time consuming and provides only basic data for the analysis of the practice. The analysis is highly dependent on the experience of the person responsible for data collection and the number and selection of patients in the sample.

Monitoring patient radiation exposure in emergency department radiography: a large-scale analysis of dose indicators and reference levels

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Emergency Departments (EDs) perform a high volume of conventional radiographic examinations, often under urgent conditions and frequently involving multiple projections per patient visit. This practice may contribute to increased cumulative radiation exposure, highlighting the importance of monitoring dose indicators as a basis for dose optimization. This study aimed to evaluate patient radiation exposure for common X-ray procedures in a high-volume ED by quantifying key dose indicators, assessing compliance with diagnostic reference levels (DRLs), and establishing local benchmarks to support radiation protection.

A retrospective analysis was conducted at Vilnius University Hospital Santaros Klinikos, including 46,712 X-ray examinations performed in 18,548 patients over a one-year period from December 2024 to December 2025. Radiation exposure indicators, including dose–area product (DAP) and reference point air kerma (Ka,r), were extracted from a digital radiography system (Siemens Ysio Max) and analyzed using statistical software. The frequency of examination types, number of images per procedure, and median dose values were evaluated and compared with national DRLs and published international data.

Chest radiography was the most frequently performed examination (35.1%), followed by lower extremity (29.3%) and upper extremity (17.2%) imaging. Median DAP and Ka,r values for all common procedures, including chest, head, spine, pelvis, and hip radiography, remained below established Lithuanian DRLs. The median number of images per examination ranged from 2 to 6, with lower values observed for chest and extremities, and the highest recorded for long-bone studies. Although extremity procedures are associated with low individual doses, their high frequency contributes substantially to overall radiation burden in the ED setting, underlining the importance of including such procedures in local dose assessments.

The results demonstrate that routine monitoring of radiation exposure indicators provides valuable insight into imaging practice in high-throughput ED environments. The establishment of local DRLs for frequently performed procedures lacking national

benchmarks provides an important tool for quality assurance and continuous optimization. This study highlights the critical role of local dose audits in identifying optimization opportunities and ensuring adherence to radiation safety principles in emergency radiography.

CBCT Dose Monitoring in Radiotherapy: Pediatric–Adult Comparison and National Pediatric Survey Results

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Purpose: Cone-beam computed tomography (CBCT) is widely used in radiotherapy for pre-treatment positioning. In pediatric radiotherapy, increased radiosensitivity and longer life expectancy require low-dose imaging protocols. National data on pediatric CBCT practices are scarce, particularly regarding acquisition parameters. This study compares pediatric and adult CBCT doses in a single institution and, through a national survey, identifies pediatric CBCT protocols used across Portuguese institutions, highlighting variability and opportunities for harmonization and optimization.

Methods:A national survey was conducted in Portugal to collect pediatric CBCT acquisition parameters (kV, mAs, and number of projections). In parallel, an institutional quantitative dose assessment was performed using the weighted Cone Beam Dose Index ($CBDI_w$). Four CBCT protocols (Head, Thorax, Pelvis, and Image Gently) were evaluated with 15 acquisitions per protocol (150 measurements) using a TrueBeam CBCT system, a 100 mm pencil ionization chamber, and Computed Tomography Dose Index (CTDI) phantoms. A 10 cm CTDI phantom was used for pediatric head and Image Gently protocols, while 16 cm and 32 cm CTDI phantoms were used for pediatric body and adult head and adult body configurations, respectively.

Results:CBDIw values were determined for all protocols and grouped by phantom type, enabling direct comparison between pediatric and adult anatomical representations. For pediatric phantoms, CBDIw values were 5.198 mGy (Head), 12.366 mGy (Thorax), 44.370 mGy (Pelvis), 1.65 mGy (Image Gently – Head), and 1.23 mGy (Image Gently – Body), while

adult phantom values were 3.822 mGy, 5.558 mGy, 20.796 mGy, 1.230 mGy, and 0.501 mGy, respectively. Significant differences were observed between pediatric and adult phantoms, highlighting the influence of phantom diameter on CBDIw.
The national survey included three institutions and showed mean pediatric CBCT parameters of 90 kV (±10), 124 mAs (±30,37), and 467.5 projections (±65) for head protocols; 110 kV (±21,21), 203 mAs (±92.93), and 742.5 projections (±194.66) for thorax; and 113.75 kV (±22.5), 674 mAs (±488.34), and 742.5 projections (±194.66) for pelvis protocols.

Conclusion: Measured $CBDI_w$ values were consistent with those reported in the literature and by manufacturers. On average, the doses measured in the pediatric phantom were 103% of those measured in the adult phantom. Image Gently protocols demonstrated substantially reduced dose levels and represent a valuable reference for pediatric and adult imaging. The observed variability in pediatric CBCT acquisition parameters across Portuguese institutions highlights the need for harmonization and optimization of pediatric CBCT protocols to improve radiation exposure monitoring and dose reduction in radiotherapy.

Dosimetry, radiation exposure metrics and quality assurance of the Gamma Knife stereotactic CBCT – first Bulgarian experience

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The Gamma Knife (GK) is the first ever stereotactic radiosurgery (SRS) device, developed specifically for intracranial applications and widely accepted "gold standard" in cranial SRS. Up to its 5th generation it was used only with minimally-invasive stereotactic frame, defining the stereotactic space, with no on-board imaging. Stereotactic space was defined on CT/MRI by imaging the patient with the frame and appropriate fiducial box. The latest 6th generation, from ICON (2015) on, was built on the solid 5th generation foundation – same radiation unit and positioning system (better than 0.10 mm precision), adding a combination of frameless immobilization with individually moulded cushions and thermoplastic masks, motion management (0.10 mm precision) for real-time tracking/gating and X-ray cone-beam computed tomography (CBCT) with a better than 0.15 mm volumetric accuracy for stereotactic space definition. Aside from non-invasiveness, this allows for fractionated/split treatments, adaptive re-irradiation and plan verification adaptation.
Due to the specific geometrical limitations and considerations of the GK, the CBCT uses a fixed angle (not full) arc of 197.4 degrees (30s, 332 projections). The detector (CsI/TFT(amorphousSi), 780x720 pixels, 0.368 mm pixel resolution) is strikingly close to the head (adapter, frame), leading to more scatter on it from the object. The X-ray tube, 0.6 mm spot size, operates at 90 kVp in “half-beam” geometry for maximum field of view in caudal direction. Source-to-axis distance is 790 mm, source-to-detector – 1000 mm, cone beam angle – 15^0, fan angle – 16^0. A modified FKP + Parker weighting algorithm is utilized for a reconstructed volume 224x224x224 mm3, 0.5 mm3 voxel size. Clinically available are two pre-defined presets named as their expected CTDIw: “2.5mGy”, “6.3mGy”.
We studied the technical specifics and performed CBCT dosimetry, including patient exposure metrics, and baseline quality control (QC) measurements on the first and only GK in Bulgaria (6th generation, ICON), installed at the Heart and Brain Center of Clinical Excellence, Pleven (end of 2019), following international practices and our national legislation. We measured half-value-layer (7.3 mmAl), total filtration (16 mmAl), radiation

output (+constancy), kV (+constancy), spatial resolution, linearity, contrast-to-noise (CNR), field size, volumetric accuracy and some other parameters. CTDIw, CTDIfree,air were within 4% of the vendor stated values.

These results are of use not only in our periodic QC, but also in the context of establishing national guidelines and regulations on CBCT use in radiotherapy and internationally, with not so many publications on the topic and some measurements performed for first time.

Evaluation of Dose Index and Image Quality in Cone-Beam Computed Tomography

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One of the main goals in today‘s radiotherapy is to increase precision in order to accurately target the tumor while sparing healthy tissue. An important step towards achieving this goal is accurate patient positioning before treatment, which is verified using cone-beam computed tomography (CBCT). Image quality is essential for correct positioning; therefore, an appropriate scanning protocol must be selected to obtain optimal image quality.

In the development of an improved CBCT protocol for the cranial area, the dose index for protocols with different characteristics had to be measured. Due to the lack of specialized equipment, an alternative method was applied. This method uses widely available equipment and takes into account the cone geometry of the beam. Using a Farmer ionizing chamber and an RW3 slab phantom, the cone-beam dose index (CBDI) was measured for a new CBCT protocol operating at 125 kV.

To evaluate image quality, two modules of the Catphan 604 phantom were used – the module for Hounsfield units (HU) verification and the high contrast resolution module. The Catphan was scanned using protocols with 100 kV and 125 kV at different exposure levels.

The high contrast resolution was rated at 0,125 cm for the 100 kV protocol and 0,083 cm for 125 kV protocol. Higher homogeneity was observed with increasing exposure.

Analysing the HU verification module showed improved visualization of certain inserts when using the CBCT protocol at 125kV. These inserts had HU values in the range of 92:137 HU and 211:263 HU, which are close to the HU values of soft tissue.

The comparison between CBCT protocols using 100 and 125 kV with similar image quality demonstrated lower patient dose, higher high-contrast resolution, and better soft tissue visualization when using the 125 kV protocol.

In conclusion, a new CBCT protocol using 125 kV is proposed, providing improved soft tissue visualisation and higher high-contrast image resolution.

Optimization for Fractionated Gamma Knife Radiosurgery (F-GKRS) planning treatment based on integrated stereotactic Cone Beam Computed Tomography (CBCT)

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The Leksell Gamma Knife performs highly accurate stereotactic radiosurgery for brain tumors. Gamma Knife treatments have traditionally been performed in single sessions, but for treating larger targets, a fractionation approach could be useful, due to the better cell repair capacity between fractions in healthy tissue and tumors. Treatment plan optimization using Cone Beam Computed Tomography (CBCT) in Gamma Knife Radiosurgery (GKRS) improves precision by enabling accurate, image-guided verification of patient positioning and target location. CBCT allows in-room pre-treatment imaging, reducing uncertainties in stereotactic space and enhancing the accuracy of dose delivery compared to fiducial methods alone, crucial for high-gradient SRS treatment plans. The integration of CBCT-driven imaging supports fast, accurate treatment planning, reducing the time required to evaluate patient setup. This work aims to investigate non-uniform fractionation of Gamma Knife treatments, with focus on the mathematical optimization of the treatment planning for patients. By combining CBCT-based image guidance with automated, inverse treatment planning, Gamma Knife procedures achieve higher quality dose distributions while ensuring optimal patient safety and accurate treatment delivery.

Diagnostic Reference Levels from Sub-Saharan Africa

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Background: Diagnostic Reference Levels (DRLs) are an optimization tool for medical imaging procedures using ionizing radiation. DRLs indicate whether the dose to the patient in a specified imaging procedure is unusually high or low for that procedure. DRLs can be established either locally, nationally, or regionally, usually on the basis of surveys of median or third quartile doses representing standard practice for a particular procedure. DRLs have been proven to be an effective dose optimization tool and can be used as a regulatory benchmark.

Method: An extensive and country-specific literature search was done to collate DRL data from sub-Saharan Africa in order to establish what work has already been done, what countries have attempted to set national DRLs (NDRLs), and what efforts are underway to set regional DRLs (RDRLs). The search was conducted in English, and only full-length manuscripts were included.

Results: 132 full-length manuscripts were found from 18 of the 46 sub-Saharan countries included in the search. The earliest publication was from 2001. Nigeria had the most publications (31), followed by South Africa (20), Ghana (12) and Kenya, Côte d'Ivoire, and Ethiopia (9 each). 68 manuscripts were on DRLs for computed tomography, 26 on fluoroscopically guided procedures, 30 on general X-ray rooms, and six on DRLs for mammography. Two publications were also found on DRLs in nuclear medicine. Five countries proposed NDRLs. Three studies included data from multiple countries; however, only one of these studies proposed RDRLs.

Discussion and Conclusion: One of the roles of an imaging medical physicist is the optimization of dose that a patient receives during an imaging procedure. There is a very large variability in the published DRL data from Africa. Some imaging centers have made clear progress in their dose optimization efforts, while in some countries doses for the same procedure can differ by an order of magnitude, indicating a clear need for harmonization of imaging protocols. Regional efforts, particularly under the umbrella of the International Atomic Energy Agency, have helped to establish networks that can be leveraged to improve and expand on both NDRLs and RDRLs.

Establishment of National Diagnostic Reference Levels (DRLs) for Cardiovascular Interventional Procedures in Korea: A Multicenter Study

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Purpose
Cardiovascular interventional procedures play a vital role in the diagnosis and treatment of cardiovascular diseases. However, these procedures are associated with high radiation exposure and extended fluoroscopy time. To improve patient safety and promote dose optimization, ICRP recommends that each country establish Diagnostic Reference Levels(DRLs). In 2024, we conducted a nationwide survey to develop the first national DRLs for cardiovascular interventional procedures in Korea.
To establish national DRLs for seven common cardiovascular interventional procedures in Korea, based on real-world clinical data collected from multiple hospitals.

Methods
This multicenter study collected radiation exposure data from 1,980 patients who underwent cardiovascular interventional procedures at 20 hospitals across Korea during the third quarter of 2024. The seven most frequently performed procedures were included: Coronary Angiography(CAG), CAG with Percutaneous Coronary Intervention(PCI), CAG with Percutaneous Transluminal Coronary Angioplasty(PTCA), CAG with Spasm Provocation Test, Acute Myocardial Infarction(AMI) intervention, Chronic Total Occlusion(CTO) intervention, and PCI alone. Dose-area product(DAP) and fluoroscopy time were automatically extracted from angiographic systems using DICOM Radiation Dose Structured Reports(RDSRs) via the national dose registry system. The 75th percentile values were proposed as the national DRLs.

Results
The 75th percentile DAP values ranged from 18.68 Gy·cm² (CAG) to 106.83 Gy·cm² (CTO), and fluoroscopy times ranged from 341.26 seconds (CAG + Spasm) to 2819.00 seconds (CTO). These values were established as the proposed national DRLs. Detailed statistics are available in supplementary tables.

Conclusion
This study provides the first national DRLs for cardiovascular interventional procedures in Korea. These values can serve as benchmarks for radiation dose optimization and patient safety enhancement. Further efforts are needed to develop real-time monitoring and national benchmarking systems.

Preliminary Assessment of Local Diagnostic Reference Levels for Routine Chest X-ray Examinations in Kazakhstan

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Chest X-ray imaging is one of the most frequently performed diagnostic procedures worldwide and remains a cornerstone of clinical practice in Kazakhstan. Despite its undeniable clinical value, chest radiography involves exposure to ionizing radiation, making dose optimization a critical aspect of patient radiation protection. At present, diagnostic reference levels (DRLs) have not been established at the national level in the Republic of Kazakhstan. As a result, there is no standardized framework for systematic comparison and optimization of patient radiation doses in routine diagnostic radiology. This study represents the first step toward the installing of DRLs in Kazakhstan, initiating their establishment at the local level based on real clinical dose measurements from routine chest X-ray examinations.

The aim of this study was to establish local diagnostic reference levels (LDRLs) for posteroanterior (PA) chest X-ray examinations in adult patients based on real clinical data from selected medical centers in Astana, Kazakhstan. An additional objective was to assess the dosimetric performance and routine use of different digital radiography systems in clinical practice.

The study was conducted in three diagnostic centers using digital radiography systems of different generations: Siemens Opti 150/30/50HC-100 (installed in 2007), Siemens Axiom Aristos MX (2009), and Floor-mounted DR Series Angell Technology DFM818 (2024). Data were collected from 60 adult patients (≥18 years, body weight 70 ± 20 kg), with 20 examinations performed on each system using standard PA chest protocols. Entrance Surface Air Kerma (ESAK) and incident air kerma were measured using calibrated RTI X-ray multimeters.

The results demonstrated statistically significant differences in ESAK values among the three radiographic systems ($p < 0.05$). Higher patient doses were observed in older systems, reflecting differences in equipment performance and exposure parameter

selection. The third quartile (75th percentile) of the ESAK distribution was used to propose a local DRL for PA chest radiography, which was determined to be 1.31 mGy.

This study represents the first attempt to establish local diagnostic reference levels for conventional radiography in Kazakhstan. The proposed LDRL exceeds typical DRL values reported in European countries and the United States, indicating a need for optimization of radiographic protocols, particularly through appropriate selection of tube voltage and exposure parameters. The findings highlight the importance of systematic dose monitoring, staff training, and modernization of radiographic equipment. This pilot study provides a foundation for the development of regional and national DRLs in Kazakhstan in accordance with international radiation protection standards.

DETERMİNATİON OF TYPİCAL DOSE LEVELS İN MAMMOGRAPHY EXAMİNATİONS USİNG DİFFERENT METHODS AND COMPARİSON OF THESE METHODS

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Breast cancer is one of the most frequently diagnosed cancers among women in developed countries, and mammography remains the primary imaging modality for its detection and diagnosis. Since mammographic examinations involve the use of X-rays, assessment of the radiation dose delivered to breast tissue is of considerable importance.

In this study, data obtained from 2,568 patients examined using an IMS Giotto tomosynthesis-equipped mammography system were analyzed. The study population consisted of 1,083 patients aged 40–49 years and 1,485 patients aged 50–64 years. Average Glandular Dose (AGD) values were calculated for 10,280 images acquired from all projections using the Dance, Boone, and 2ABD methods. Dosimetric data were collected through the hospital's PACS system. The study aimed to determine typical dose levels, compare them with national and international diagnostic reference levels (DRLs), and evaluate optimization strategies to minimize radiation-induced cancer risk. In addition, AGD values obtained from the three calculation methods were compared.

For the 40–49 age group, AGD values for the craniocaudal (CC) projection were calculated as 1.900 mGy using the Dance method, 1.352 mGy using the Boone method, and 1.587 mGy using the 2ABD method. For the mediolateral oblique (MLO) projection, AGD values were 1.600 mGy, 1.916 mGy, and 2.139 mGy, respectively. In the 50–64 age group, CC projection AGD values were determined as 2.900 mGy (Dance), 1.139 mGy (Boone), and 1.338 mGy (2ABD), while MLO projection values were 2.600 mGy, 1.757 mGy, and 1.952 mGy, respectively.

After identifying that some projections exceeded national DRLs, optimization studies were conducted involving 678 patients and 2,712 projections. Following optimization, AGD values for the 40–49 age group in the CC projection were reduced to 1.600 mGy (Dance), 1.652 mGy (Boone), and 1.452 mGy (2ABD), whereas MLO projection values were 2.300 mGy, 1.450 mGy, and 1.793 mGy, respectively. For the 50–64 age group, post-optimization CC projection values were 1.400 mGy (Dance), 1.401 mGy (Boone), and 1.255 mGy (2ABD), while MLO values were recorded as 2.200 mGy, 1.412 mGy, and 1.697 mGy, respectively.

Final analyses demonstrated that the optimization process successfully reduced typical dose levels below national reference limits, resulting in an overall reduction of approximately 20% in AGD values. Furthermore, the Dance method consistently produced higher AGD

estimates compared with the Boone and 2ABD methods, and the differences between calculation methods became more pronounced with increasing breast compression thickness.

Initial assessment of mean glandular dose (MGD) from a newly installed mammography unit

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The purpose of this study was to evaluate mean glandular dose (MGD) in 2D and 3D mammography and to assess compliance of 2D mammography with the established diagnostic reference levels (DRLs) in Bulgaria.

Radiation dose data were retrospectively collected from a newly installed 2D full-field digital mammography (FFDM) unit (Senographe Pristina, GE Healthcare) equipped with 3D digital breast tomosynthesis (DBT). The data set was extracted from the hospital SC PACS and included MGD, compressed breast thickness (CBT), patient age, entrance surface air kerma (ESAK), tube potential (kV), and tube current-time product (mAs). The data were classified by imaging technique (2D or 3D) and projection view (craniocaudal, CC, or mediolateral oblique, MLO). A total of 50 2D mammography examinations and 51 3D mammography examinations were analyzed, where a standard mammographic examination of each breast includes CC and MLO projections. The analysis confirmed that the data set accurately reflects routine mammography practice in Bulgaria. Relationships between MGD and CBT, kVp, mAs, and ESAK were also assessed.

The results show that the median MGD for 3D mammography were very similar. The median MGD was 1.15 mGy (IQR: 1.04 – 1.32 mGy) for 2D CC views and 1.19 mGy (IQR: 1.07 – 1.48 mGy) for 2D MLO views. For 3D CC views the median MGD was 0.99 mGy (IQR: 0.99 – 1.17 mGy) and 1.08 mGy (IQR: 0.99 – 1.26 mGy) for 3D MLO views.

Based on these results, it can be concluded that the median MGD for 2D mammography is within the established DRLs in Bulgaria. In addition, our results for 2D and 3D are comparable to the DRLs of several European countries.

Unit-aware dose benchmarks and technique targets for pediatric AP portable chest and abdomen radiography

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Portable pediatric radiography is challenging because patient condition, positioning limits, variable source-to-image distance (SID), and bedside workflow require manual technique selection. We quantified baseline exposure, created unit-aware diagnostic reference level (DRL)–style dose benchmarks, and derived weight-binned technique targets for pediatric anteroposterior (AP) portable chest and abdomen radiography across 15 Carestream mobile X-ray units.

Dose monitoring exports (DoseTrack) were analyzed for patients <14 years and 0–80 kg and grouped into weight bins (kg): <5, 5–<15, 15–<30, 30–<50, and 50–<80. Exposure metrics were dose–area product (DAP) and entrance skin dose (ESD), with ESD recorded as reported by the monitoring system. To avoid over-weighting high-volume units, a unit-aware DRL method was applied: for each unit (identified by Application Entity Title, AET) and weight bin, the median DAP and median ESD were calculated; the benchmark for each weight bin was defined as the 75th percentile of the distribution of AET medians across eligible units, excluding AET-by-bin groups with fewer than 20 examinations. Data integrity quality control included validation of AET-to-device mapping, removal of duplicate exports, and screening for implausible dose outliers. Technique targets were derived from observed manual technique distributions within each weight bin: the median kilovoltage peak (kVp) and milliampere-seconds (mAs) were set as default targets, and the 75th percentile mAs served as a step-up option for difficult bedside conditions.

Portable pediatric chest included 7,714 examinations and portable pediatric abdomen included 1,467 examinations. For chest, benchmark DAP ranged 0.053–0.213 Gy·cm² and benchmark ESD ranged 0.148–0.228 mGy across eligible bins. For abdomen, benchmark DAP ranged 0.082–0.934 Gy·cm² and benchmark ESD ranged 0.225–0.801 mGy. Technique benchmarking from AET medians showed abdomen kVp clustered around 70 kVp while mAs increased stepwise with weight (median 3.6 to 18.5 mAs), whereas chest kVp increased with weight (median 77 to 100 kVp) with a narrow mAs band (about 1.2–1.6 mAs). Inter-unit variability in dose was substantial: AET-median DAP varied by about 1.6–4.8× within most abdomen weight bins (up to about 30× in <5 kg) and by about 1.8–3.7× for chest.

Corrective actions included targeted staff training on technique optimization and exposure feedback using deviation index (DI) where available, with structured bedside shadowing by medical physicists. Monthly dose monitoring with feedback was scheduled to track adherence, identify outliers, and support continuous optimization.

Assessment of the Impact of Adult Computed Tomography head Protocols on Radiation Exposure in Paediatric Patients

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Computed tomography (CT) is an essential imaging modality in pediatric emergency and diagnostic settings due to its speed and high diagnostic accuracy. Despite its clinical value, children are more sensitive to ionizing radiation than adults because of their developing tissues and longer life expectancy, increasing the potential for radiation-related risks. The inappropriate use of head CT protocols in pediatric patients remains a concern and may lead to unnecessary radiation exposure. This study aimed to evaluate the use of head CT protocols in pediatric imaging and to assess their impact on radiation dose on head by age groups.

A retrospective observational study was conducted across six institutions, including 312 consecutive head CT examinations performed in patients aged 0–17 years. The mean age was 7.6 5.0 (*MSD*). Data were retrospectively collected from the radiology information systems and picture archiving and communication systems and included patient age, acquisition parameters, dosimetric indicators such as computed tomography dose index volume (CTDIvol) and dose–length product (DLP), and protocol type. Examinations were stratified by age group and dosimetric values were compared with European Diagnostic Reference Levels. Descriptive and comparative statistical analyses were performed to evaluate differences between protocol types and institutions.

The key findings revealed that DLP on CT Equipment 2 and 6 were significantly different from all others showing lower doses of DLP, but had no significant difference between them. The CTDIvol on CT Equipment 2, 6 and 3 were significantly different from the rest of the group and also demonstrated significant differences when compared to each other.

The results of the comparison between clinical local doses and European DRL by age group demonstrated a DLP Overexposure across all age groups. The local DLP values significantly exceeded the European DRLs ($p < .001$). This suggests that the total scan length or the number of series may be higher than the European average.

The CTD remains compliant with European Standards for children under 6 years old, but

revealed to be significantly lower for children of the oldest cohort.

These findings demonstrate that adult CT protocols are still commonly applied in pediatric imaging, contributing to avoidable radiation exposure. The findings highlight the need for improved standardization, continuous auditing of CT practices, and increased awareness among radiology professionals. Optimization of pediatric CT protocols through a multidisciplinary approach is essential to ensure radiation dose reduction while maintaining diagnostic image quality.

Analysis of Computed Tomography Imaging procedures of the paediatric population in a non-paediatric hospital

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The aim of this study was to investigate the most common indications and typical dose values of the paediatric patients during computed tomography (CT) procedures of the head.

A total of 448 CT scans from 394 patients who underwent cranial CT examination within two years at the University Hospital Centre Osijek, Croatia, were retrospectively analysed. The Volume Computed Tomography Dose Index (CTDIvol) from three CT devices namely Siemens X.cite, Siemens Definition AS and Philips Ingenuity were compared to European Diagnostic Reference Levels (EDRLs) published by European Commission in Radiation Protection N185 (RP N185).

The patients were divided into two groups, 1-6 years and above 6 years with an average age of 11 years. Most patients underwent a single scan; 22 patients had two scans while one patient received five scans. The most common indications were trauma (33.1 %) and acute intracranial events (35.4 %). The median CTDIvol for Siemens X.cite and Definition As were 38.10 and 26.26 mGy respectively for patients between 1-6 years, while the median CTDIvol of the Siemens X.cite, Siemens Definition As and Philips Ingenuity were 65.50, 64.77 and 51.70 mGy respectively for patients above 6 years.

The published EDRLs for head CT scans for paediatric patients between 1 -6 years and above six years are 40 and 50 mGy respectively. The median CTDIvol for patients between 1-6 years is lower than the recommended value while the median CTDIvol above 6 years of all three devices are higher than the recommended value.

The patients' cohort above 6 years were like adolescence, thus the use of adult protocols which results to higher CTDIvol. Although there is an increased trend of using CT scans in the paediatric population, establishing typical values can be a challenge in hospital which

are non-paediatric hospitals due to the insufficient number of patients in each category, especially in thorax and abdomen. Therefore, it is suggested to use Diagnostic Reference Level (DRL) curves for optimization and need to multi-center studies to derive national DRLs for paediatric patients that are typical to Croatia.

Optimisation of Chest X-ray protocols for adolescent patients

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A paediatric dose audit calculating Diagnostic Reference Levels (DRLs) found radiography x-ray systems are defaulting to the adult protocol for patients aged above 10 years leaving radiographers uncertain what settings to use for adolescent patients. The purpose of this project was to optimise the x-ray chest posteroanterior (PA) protocol settings for adolescent patients.

Chest PA x-ray images were acquired under automatic exposure control with a Kyoto full body phantom in two BMI configurations to simulate patients aged 10-14 and 14-18 years. The following settings were manipulated: 70-110 kVp, 0.1/0.2mm copper filtration (Cu), grid in/out, under Automatic Exposure Control (AEC). Clinical image quality was reviewed by a team of four paediatric radiologists and graded from 1-5 (1=undiagnostic, 3=average, 5=excellent) looking at the following anatomical areas: mediastinum, lung apices, mid zone, bases, spine and ribs.

For age 10-14 years the optimal protocol settings were 70kVp with 0.1mm Cu filter which is the same as the Child protocol on the system. For age 14-18 years the optimal protocol settings were 90kVp with 0.2mm Cu filter and AEC which is significantly lower than the adult protocol at 125kVp. Highest image quality scores were found in both age categories with the grid in situ; however, the related patient dose increased by over 100% and any improvement was specifically in the spine/ribs therefore this is not justifiable for chest imaging.

It was recommended that the system should default to the child protocol up to age 14 years. The small adult protocol will be altered to 90kV/0.2mmCu/grid out/AEC and used for patients aged 14-18 years. Once these changes have been implemented patient images will be acquired and scored by the same radiologists to assess the clinical image quality.

Survey of the patient exposure and clinical practice during interventional embolization procedures

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Interventional procedures are considered minimally invasive and provide good therapeutic efficacy. However, during these procedures, the patient and medical team receive high radiation exposure, which highlights the importance of optimizing the radiation protection. For example, during embolization procedures (minimally invasive procedures that block specific blood vessels), some patients may receive doses that exceed the threshold for tissue reactions.

The aim of the current study is to survey the patient exposure and clinical practice during interventional embolization procedures, as well as to prove whether an optimization of the radiation protection is possible.

The investigation is performed in Military Medical Academy, Sofia on one angiography X-ray system. For each procedure and every patient, the following data are collected: age and sex of the patients, kerma - area product (P_{ka}), fluoroscopy time (FT), cumulative dose (CD), number of series acquired (NS) as well as other parameters: tube voltage (U) and tube current (I).

The current procedures are divided into embolizations performed in the thoracic region (TH-embolizations) and those performed in the abdominal and/or pelvis region (ABD-embolizations) of the patient. The P_{ka} values for the TH-embolizations vary between 8603 µGy.m^2 and 84013 µGy.m^2 and for ABD-embolizations - between 8089 µGy.m^2 and 113322 µGy.m^2. The FT values for the TH-embolizations vary between 5 min and 33 min, and for ABD-embolizations between 4 min and 39 min. The analysis show that the median values for P_{ka}, CD, NS, FT, U and I are respectively:

- **TH-embolizations:** 18528 µGy.m^2, 742 mGy, 19, 14 min, 86 kV and 371 mA;
- **ABD-embolizations:** 55710 µGy.m^2, 1441 mGy, 14, 10 min, 88 kV and 317 mA;

Results of the current survey show that the patient exposure during ABD-embolizations is three times higher than the patient exposure during TH-embolizations. On the other hand, a large variation in patient doses is observed for both procedures, so that must be investigated in addition. In order to improve the patient exposure and image quality is recommended to use optimized U/I settings and appropriate FT and NS. Despite the higher patient exposure, ABD-embolizations provide an excellent therapeutic effect, which make it suitable to use in some particular case.

Cardiology run-level analysis for optimisation

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Purpose

To use run-level data from cardiology procedures for dose audit and optimisation, with a particular objective of allowing comparison at different patient sizes.

Method

Individual radiation event data was extracted from radiation dose structured reports (RDSRs) for 2975 procedures carried out in the cardiology labs at the Royal Free Hospital over a one-year period. Cardiology procedures typically use defined views in generally similar angulations with slight variations due to patient anatomy. Data were clustered using a k-means algorithm to group similar views together by angulation. The first high-dose acquisition run (as opposed to screening for positioning) from each different angulation was then extracted, representing a similar diagnostic purpose regardless of the overall purpose or complexity of the procedure. A reference air kerma rate was then calculated using the run length and compared across views, equipment and patient weights.

Results

Ten clusters were used to classify views. Clusters were found to have a standard deviation of both primary and secondary angle of less than 10 degrees, with most clusters below 5 degrees standard deviation. Summary statistics (mean and standard deviation) were generated for each cluster and lab for comparison as well as in separate patient weight categories. Scatter plots were generated of reference air kerma rate against patient weight for each cluster. The analysis produced between 170 and 1194 data points per cluster per lab.

Similar equipment was found to produce similar distributions within a cluster. Different clusters were found to have different air kerma rates by up to a factor of approximately five, both from the summary statistics and from the scatter plots. Clusters representing steeper angles, particular large left-right angles combined with large cranial-caudal angles were found to generally have higher air kerma rates than shallower angles, as might be expected from a system operating under automatic exposure control.

Conclusions

The use of the first acquisition run from each new view is a novel approach to analysing cardiology dose data. This approach side-steps the common difficulties caused by high procedure variation by allowing data to be collated across procedures with different complexities. The larger sample size per cluster compared to grouping by clinical procedure details allows more robust comparisons between equipment, particularly with patient size. This becomes increasingly important with modern systems that allow behaviour for large and small patients to deviate substantially from more typically sized patients.

Continuous Computed Tomography Urography Protocol Optimisation: An Eight-Year Journey

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Introduction: Computed Tomography Urography (CTU) is associated with a high radiation dose due to multiple scan series, which produce a mean effective dose of more than 70% compared to conventional excretory urography. This led to Radiographers studying changes in radiation dose and image quality to achieve a dose-efficient CTU protocol.

Methods: The study was conducted on CTU patients grouped into A, B, and C. Group A patients were scanned with a baseline CTU protocol. Groups B and C patients were scanned with the optimised protocols, which were first tested on a Quality Assurance (QA) phantom before being applied to patients. The image quality was assessed using quantitative and qualitative methods.

Results: Group A had 56 CTU patients with a mean dose of 9.5 mGy and 2273 mGy*cm in volume computed tomography (CTDIvol) and dose length product (DLP), respectively. Group B had 16 CTU patients with a mean radiation dose of 6.98 mGy and 952 mGy*cm, providing a 35% and 59% reduction in CTDIvol and DLP, respectively. Group C also had 16 patients with a mean dose of 5.16 mGy and 686 mGy*cm, providing further dose reductions of 26% and 28% in CTDIvol and DLP, respectively. Clinical images in Groups B and C were noted as diagnostic.

Conclusion: The findings have revealed that continuous dose monitoring and optimisation in the CTU protocol provide the needed dose reduction while maintaining image quality in line with the ALARA principle, which should be encouraged in medical imaging departments.

Implication for practice: The study demonstrated the impact of dose optimisation in the CTU protocol, which should be encouraged and sustained among Radiographers.

Keywords: CT Urography, Radiation Dose, CTDvol, DLP, Image Quality, Image Optimisation

Optimisation of interventional radiology and cardiology procedures following the publication of new national diagnostic reference levels

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In 2025, new UK National Diagnostic Reference Levels (NDRLs) were introduced. During the update of local Diagnostic Reference Levels (DRLs) for six interventional radiology (IR) and five cardiology systems, it was observed that the typical patient doses for several procedures (based on median values) exceeded the new NDRLs. This study aimed to optimise IR and cardiology protocols for those procedures where typical doses were above the NDRLs.

Dose-area product (DAP) and pulse rate data were collected for sets of 20 average-sized patients per procedure and per system, using the Radimetrics radiation exposure monitoring system. Significant variation in fluoroscopy pulse rate settings was observed across different systems for the same IR procedures, particularly in the abdominal region. In many cases, pulse rates (15 pulses per second (pps)) exceeded the optimal values for the corresponding procedures. A collaborative meeting between medical physicists, application specialists and clinicians resulted in the association of three distinct pulse rate settings (3.125/3.75, 6.25/7.5, and 12.5/15 pps, depending on the system model) with different dose rate configurations. Additionally, the dose per pulse was reduced by 33% to 50% across systems.

For pacemaker implantation procedures in cardiology rooms, the pulse rate for the 3.75 protocol was reduced from 7.5 pps to 3.75 pps for the low dose rate setting, with a further 36% reduction in dose per pulse.

Following the implementation of these optimised protocols, patient skin air kerma rates were measured using a standard PMMA phantom. Air kerma rates at the image receptor input and phantom image quality were also assessed using the Leeds TO10 (low contrast) and Huttner test object (high contrast). Although some deviations from the planned settings

were noted during the measurements, application specialists promptly corrected them. The dose reduction achieved with the new protocols ranged from 30% to 70%, depending on the dose and pulse rate settings. Phantom image quality assessments showed no significant deterioration.

Typical patient doses will be reassessed and feedback from clinicians will be reviewed. Further data will be presented once sufficient data has been collected.

Patient centering assessment and its impact on global noise level: effects on CT image quality and dose efficiency

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Background:
Accurate patient positioning at the CT scanner isocenter is essential for the CT image quality and dose efficiency. Off-centering affects the performance of the automatic exposure control and bowtie filter, leading to increased image noise and suboptimal dose utilization. Global noise level (GNL) is a fully automated metric that enables objective assessment of image noise across the entire scanned volume of the patient.
Purpose:
To evaluate the relationship between patient centering and GNL in clinical CT abdomen examinations.
Materials and Methods:
The study included in total 120 patients who were referred to CT abdomen examinations. The CT abdomen examinations included one non-contrast and two contrast-enhanced phases. All examinations were performed on CT systems from a single vendor, using different scanner models.
Patient centering was quantified using automated body contour-based analysis to estimate vertical offset from the scanner isocenter. The analysis was performed with a custom developed Python script.
Image noise was assessed using GNL, calculated with another specially dedicated software (IQ-GNL Pro) on a per-slice basis. Only slices with more than 30% soft tissue (0–170 HU) were included in order to ensure anatomically relevant measurements.
The following CT dose indexes (CTDIvol and DLP) and some exposure parameters were extracted from DICOM metadata. The relationship between centering deviation and GNL was assessed using correlation analysis and subgroup comparison.
Results:
Patient off-centering was observed in almost all CT examinations, with a vertical offsets around and in some cases even more than 20 mm. Increasing off-centering was followed by an increase in GNL values, indicating higher image noise. A correlation was observed between centering offset and GNL. Despite comparable CTDIvol values across examinations, off-centered patients showed consistently higher GNL, suggesting reduced dose efficiency. Variability between institutions indicated differences in patient positioning.
Conclusion:
Patient centering has a significant impact on CT image noise. The results of the current survey highlight the importance of accurate patient positioning and support the use of automated tools for both centering assessment and global image quality evaluation in clinical practice.

Advantages and Disadvantages of Pre-Planned Computed Tomography Angulation in Angiographic Procedures

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Accurate selection of angiographic projection angles is essential to reduce radiation exposure and contrast medium use during endovascular procedures. This study evaluated the advantages and limitations of using pre-planned optimal angulation derived from pre-procedural computed tomography (CT) to guide angiographic image acquisition, with particular emphasis on the number of digital subtraction angiography (DSA) acquisitions, radiation dose, and contrast volume.

A retrospective observational analysis was performed including angiographic procedures with available pre-procedural CT imaging for planning. Optimal working angles were determined from CT datasets prior to the intervention and applied during angiography. Procedural parameters were collected, including number of DSA acquisitions, fluoroscopy time, radiation dose indicators, and contrast medium volume. Outcomes were compared with procedures in which angulation was selected intra-procedurally without prior CT-based planning.

Use of CT-based pre-planned angulation demonstrated several advantages. A reduction in the number of DSA acquisitions was observed, as appropriate working angles were identified in advance, limiting the need for repeated projections. Improved vessel visualisation, with reduced overlap and foreshortening, contributed to more efficient procedures. This strategy was associated with lower radiation dose indicators, reduced contrast medium consumption, and shorter procedure times, supporting radiation protection principles for both patients and staff.

However, several limitations were identified. The requirement for pre-procedural CT introduces additional radiation exposure that must be clinically justified. Differences in patient positioning and anatomical variation between CT acquisition and the angiographic procedure occasionally reduced the accuracy of pre-planned angles. The method also requires additional planning time and depends on image quality and operator experience, limiting its applicability in emergency settings.

Pre-planned CT-based angulation offers measurable benefits in reducing DSA acquisitions, radiation exposure, and contrast use, but presents workflow and applicability constraints. Careful patient selection is required to balance benefits and limitations in clinical angiographic practice.

Enhancing Pediatric Patient Safety: Reducing Radiation Dose During CT Examinations Using a TQM-Based PDCA Framework at Al Jalila Children's Hospital

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Background: Pediatric patients are particularly vulnerable to ionizing radiation due to increased tissue radiosensitivity and longer life expectancy. Monthly CT dose Key Performance Indicator (KPI) monitoring at Al Jalila Children's Hospital identified that approximately 10% of pediatric CT examinations exceeded the Diagnostic Reference Levels (DRLs) established by Dubai Health during the last six months of 2024 . This highlighted the need for systematic quality improvement intervention.

Objective: To optimize pediatric CT imaging practices and reduce the percentage of examinations exceeding DRLs from 10% to 5% within six months while maintaining diagnostic image quality.

Methods: A Total Quality Management (TQM) approach using the FOCUS–PDCA quality improvement methodology was implemented. Baseline KPI data were analyzed by protocol type, patient demographics, and scan indications. Root cause analysis identified outdated pediatric protocols and variability in staff training as major contributors. Interventions included updating age- and size-specific CT protocols, structured staff education on pediatric dose optimization, technologist competency assessments, daily dose monitoring with case review, and regular multidisciplinary protocol review meetings .

Results: Implementation of targeted protocol optimization and enhanced dose governance improved compliance with pediatric DRLs and strengthened real-time dose oversight. Continuous monitoring enabled rapid identification and correction of dose outliers, supporting sustained improvement in pediatric radiation safety performance.

Conclusion: Application of a structured PDCA-based TQM framework significantly enhanced pediatric CT dose management and safety culture at a tertiary pediatric center. This approach demonstrates a scalable model for sustainable radiation dose optimization and KPI-driven quality improvement in pediatric imaging.

A National Paediatric Interventional Cardiology Registry with Integrated Radiation Exposure Monitoring

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Introduction

Fluoroscopically guided interventional cardiology (FGIC) procedures in children are associated with relatively higher radiation exposure compared to most diagnostic imaging examinations and higher radiation risk. Effective radiation protection requires structured exposure monitoring, long-term individual dose tracking, and integration of dosimetric data into dedicated clinical registries. Paediatric interventional registries provide opportunity to combine procedural, clinical, and radiation exposure information within a unified digital workflow.

Purpose

To present the Bulgarian paediatric interventional cardiology registry RIKI-BG as a digital platform integrating procedural documentation with patient radiation exposure monitoring, and to demonstrate its role in individual dose tracking, quality assurance, and optimisation.

Methods and Materials

RIKI-BG is a web-based registry designed for structured documentation of paediatric FGIC procedures. The platform supports data entry, editing, and searching of catheterisation procedures (diagnostic, transcatheter closure, valve procedures, angioplasty, electrophysiology, etc) and patient anthropometric parameters, haemodynamics, procedural characteristics, complications, and clinical outcomes. In addition to clinical and procedural information, the registry contains records for dose-related information. Each procedure is stored as an individual digital record, enabling tracking of repeated interventions and cumulative exposure.

A home-developed web-based script (HTML/JavaScript) was implemented for automated extraction of structured clinical and dosimetric parameters from PDF reports, with direct

export to Excel spreadsheet format. The algorithm applies rule-based text parsing and numerical processing locally within the user's web browser, without reliance on external software or server-side processing. To ensure compliance with personal data protection and cybersecurity requirements, all processing is performed exclusively on the user's local computer, and no patient-identifiable information is transmitted, uploaded, or stored outside the user's personal device.

Results

RIKI-BG provides a unified digital workflow for documentation and radiation exposure monitoring. The platform supports retrospective analysis of exposure trends across procedure types and patient subgroups. The integration of clinical, procedural, and dosimetric data within a single paediatric registry allows identification of high-dose procedures, tracking of children undergoing repeated interventions, and assessment of practice variability. The registry also facilitates quality assurance and audit activities, supporting optimisation of interventional techniques and radiation protection strategies.

Conclusion

The RIKI-BG registry represents a digital solution for paediatric interventional cardiology documentation with integrated radiation exposure monitoring. By combining procedural with dose data, automated data extraction from imaging reports, and patient tracking, the platform demonstrates how dedicated paediatric clinical registries can serve as effective IT solutions for radiation exposure monitoring and contribute to enhanced patient care through structured and secure data management.

Advancing Radiation Exposure Monitoring through Education for Global Capacity Building

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Advancing educational practices in medical physics and related disciplines through the introduction of timely and technologically viable concepts for education and training is essential for strengthening the profession and sustaining high-quality radiation exposure monitoring standards worldwide. The development and dissemination of practically oriented teaching materials remain challenging due to organisational, logistical, and financial constraints. Among the most influential resources supporting global education in diagnostic radiology (DR) physics is the IAEA Diagnostic Radiology Physics Handbook for Teachers and Students. First published in 2014, the handbook is now undergoing a comprehensive update through a collaborative initiative involving the IAEA, IOMP, EFOMP, AFOMP, AAPM, and ICTP, reflecting more than a decade of technological advancement and evolving clinical practice.

In addition to updated coverage of DR physics and modality implementation, the revised handbook expands into key areas not previously addressed in detail, with radiation exposure monitoring taking an important part thus outlining its central role in contemporary diagnostic radiology practice - a key component related to patient safety, optimisisation of imaging protocols, and support of evidence-based regulation. As imaging technologies evolve and utilisation increases worldwide, standartising approaches to measuring, analysing, and interpreting radiation dose becomes critical for the area. Effective monitoring enables healthcare institutions to identify trends in exposure, benchmark performance against reference levels, and implement targeted optimisation strategies that reduce unnecessary dose while maintaining diagnostic image quality.

This book resource plays a decisive role in strengthening global capacity for radiation exposure monitoring. It integrates contemporary concepts such as automated dose-tracking systems, dose-management software, and structured reporting of modality-specific dose metrics. The handbook also emphasises the importance of understanding dose measurement techniques that are indispensable for medical physicists tasked with establishing diagnostic reference levels, conducting audits, and advising clinical teams.

This educational resource aims to provide the international DR community with an up-to-date, freely accessible resource describing the physics and clinical implementation of modern imaging modalities. Approximately eighty authors from 6 continents have

contributed to the early draft of the second edition.

The updated handbook, comprising sixteen chapters, is expected to reach full draft form by mid-2026. Once released, the electronic version will be freely available through the IAEA website. By modernising one of the field’s flagman educational resources, this initiative strengthens global capacity building in radiation exposure monitoring, enhances consistency in DR physics education, and supports the professional development of medical physicists and related disciplines worldwide.

Communication as the Third Pillar of Radiation Protection Culture: Integrating "Emotional Dose" into Clinical Practice and Public Outreach

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Abstract:

Radiation protection (RP) has traditionally converged upon two fundamental pillars: technological optimization and regulatory frameworks. This work proposes that strategic communication constitutes a vital, yet overlooked, **Third Pillar of RP culture.** It operationalizes a dual-scalar intervention model to manage the **"Emotional Dose" (ED)**—defined as the patient's aggregate of anticipatory anxiety, sensory stress, and misinformation, grounded in Slovic's risk perception frameworks.

The methodology distinguishes between two specific domains of action:

1. **The Social Shield (@interRadiologia):** A digital health literacy initiative with over 19,000 followers. It acts as a pre-dosimetric educational shield, neutralizing the "Digital Infodemic" and lowering baseline community radiophobia.

2. **The Clinical Intervention (TEAyudo):** A microsystem focused on specialized "Social Stories" for patients with Autism Spectrum Disorder (ASD). These protocols utilize standardized visual supports from the ARASAAC Collaborative Network to deconstruct the radiological act (MRI, Mammography, Ultrasound) by anticipating sensory triggers.

The analysis suggests that managing the ED through sensory predictability acts as a direct, non-ionizing intervention. It increases **somatic stability**, mitigating the primary trigger for non-justified dose increases: involuntary patient movement and the subsequent need for repeat examinations. This work concludes that the radiographer's role as a "Scientific Translator" is an essential clinical safety competency. By regulating the Emotional Dose, we optimize physical dose and ensure strict adherence to the **ALARA principle**, fostering a modern, human-centered RP culture.

Medical Radiation Exposure of the Population in Bulgaria: A 16-Year Review of Diagnostic Practice and Dose Trends

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Introduction

Medical exposure is the dominant source of artificial ionizing radiation to the population. Over the last two decades, Bulgaria has experienced substantial changes in diagnostic imaging practice, including rapid growth of computed tomography (CT), interventional procedures, and hybrid imaging. Periodic national assessments provide a unique opportunity to evaluate long-term trends in population exposure and the effectiveness of radiation protection measures.

Purpose

To present a comprehensive overview of medical radiation exposure of the Bulgarian population over a 16-year period (2008–2024), focusing on trends in examination frequency, modality distribution, and population dose, and to identify the main drivers influencing dose evolution.

Methods and Materials

The analysis integrates data from national surveys conducted by the National Centre of Radiobiology and Radiation Protection (NCRRP) covering diagnostic radiology and nuclear medicine, combined with national healthcare statistics. Population exposure indicators, including collective effective dose and average annual effective dose per capita, were evaluated using internationally accepted methodologies consistent with UNSCEAR recommendations.

Results

Between 2008 and 2024, the overall frequency of diagnostic examinations increased markedly, with CT examinations showing the most pronounced growth. While CT constituted a relatively small fraction of total procedures in the earlier period, it consistently contributed a disproportionally high share of the collective dose. The average annual

effective dose to the population increased substantially over time, reflecting both technological expansion and changing clinical practice patterns. Nuclear medicine examinations, although less frequent, demonstrated a notable relative increase in per-capita dose contribution in the later years.

Conclusion

The long-term increase in population dose is primarily associated with expanded access to high-dose imaging modalities, increased oncological imaging, and growth in interventional procedures. Contributing systematic factors include uneven implementation of diagnostic reference levels, limited availability of dose-tracking systems, and a persistent shortage of medical physicists in diagnostic imaging.

This 16-year review demonstrates a clear shift in the structure and magnitude of medical radiation exposure of the Bulgarian population. The findings highlight the need for sustained optimization of imaging protocols, strengthened justification practices, enhanced dose monitoring infrastructures, and reinforcement of the role of medical physicists to ensure effective population dose management under evolving healthcare conditions.

Evaluation of population exposure and DRLs and calculation of patient's doses using e-health system data in Lithuania

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Radiation Protection Centre is regulatory body with one of the functions to supervise radiation protection in medicine and estimate population doses from medical exposures. There is established e-health system (ESPBI) in Lithuania that connects all Lithuania hospitals (this is mandatory requirement). There is all information about patient ‘s „path“ in any hospital of Lithuania including any procedure performed for patient. Any diagnostic radiology procedure performed has special Radiology Image Description form with patient’s data, description of the procedure results, patient’s exposure information, used equipment and etc.. Radiation Protection Center gains appropriate data from e-health system and can estimate population exposure from medical exposure taking into account patient’s age and gender as well as tracking the patient doses including cases then many procedures were performed for the same patient. The sufficient amount of data also allow to evaluate how is kept DRLs as well as use these data for DRLs review.

But there are challenges due to different databases, that are used by medical facilities. Some hospitals have equipment that cannot be connected to databases. At this moment data about exposures are submitted to ESPBI from 70 % medical facilities that perform diagnostic radiology procedures. There were information about more then 1,3 mln. procedures in 2024. Each year data amount increase.

Also there were noticed that there are mistakes in data entry process, because now Radiology Image Description form is filled manually. Therefore, not all gained data are proper for analysis at the moment. Inappropriate data are eliminated before analysis. But ESPBI is under further development now with purpose to save diagnostic images (DICOM files) in ESPBI. That would ensure possibility to see any diagnostic radiology image performed in any medical facility in Lithuania at any time. Therefore and Radiology Image Description form is under development also with plans to ensure that data in Radiology Image Description are collected automatically from DICOM files. Also, there will be expanded collected data range.

Characterisation of Ionising Radiation Exposure in Medical Procedures During 2025

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The increasing use of medical imaging and interventional procedures involving ionising radiation highlights the need for continuous monitoring and optimisation of patient radiation exposure. This study aimed to characterise patient exposure to ionising radiation in clinical practice during 2025.

A retrospective observational study with descriptive and analytical components was conducted using a non-random convenience sample. All patients who underwent diagnostic or therapeutic procedures involving ionising radiation during the study period were included. Data were retrospectively collected from institutional information systems and a dose monitoring platform (DoseWatch), including patient age and sex, type of examination or procedure, technical exposure parameters, recorded effective dose, and referring clinical service. Descriptive statistics were used to summarise demographic and procedural characteristics and radiation dose distributions. Analytical methods were applied to explore associations between radiation dose and patient- and procedure-related factors.

The analysis demonstrated substantial variability in radiation exposure across different examination types and clinical services. Higher radiation doses were associated with specific procedure categories and patient groups, allowing the identification of procedures with increased dose burden and populations potentially at greater risk.

This study provides a comprehensive overview of ionising radiation use in clinical practice during 2025 and highlights variability in patient radiation exposure. The findings support the evaluation of current practices and reinforce the importance of radiation dose optimisation strategies. These data contribute to quality assurance initiatives and support radiation protection measures aimed at improving patient safety while maintaining diagnostic effectiveness.

Selection and Development of a Representative Computed Tomography Database to Identify Common Diagnostic Procedures in Georgia

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Modern radiological diagnostics, particularly computed tomography (CT), play a crucial role in early disease detection but involve patient exposure to ionizing radiation. Because the principle of dose limitation/normalization does not apply in medical radiation procedures of patient, which may limit the diagnostic information or make it incomplete, justification and optimization principles of safety must be used. For more effective use of optimization of protection in the country, accurate information of distribution of patient doses from most common diagnostic radiology procedures in Georgia is needed. This study focuses on selecting and developing a representative CT database to analyze typical dose distributions for frequently performed diagnostic procedures. The database will support optimization of patient protection in line with ICRP and IAEA recommendations and form the foundation for future national DRLs.

In order to determine the national DRLs and, for this purpose, to identify the most common diagnostic procedures in Georgia, data was provided by the national regulator, based on which we created a database of all computed tomography scanners (except SPECT/CT, PET/CT and Angio-CT) in the country - a total of 181 scanners as of October 1, 2025.

To obtain a representative group of scanners in the country, according to the recommendations of ICRP and IAEA, 20-25% of the CT scanners available in the country should be included. Accordingly, it became necessary to select 35-45 units of computed tomography (CT) scanners of all generations, different manufacturers, operating in different regions and clinics.

The CT data collection forms kindly provided by the IAEA, which already identify the most

common procedures, are the basis for Georgian professionals to confirm, clarify, or amend the list of CT scanners.

The results obtained allow us to proceed to the stage of data collection to identify typical doses for each procedure.

Selection and Development of a Representative Angiography Devices Database to Identify Common Diagnostic Procedures in Georgia

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Modern medical imaging, particularly angiography and interventional radiological procedures, plays a vital role in the diagnosis and management of cardiovascular and other complex diseases. Despite their significant clinical benefits, these procedures are associated with relatively high patient radiation doses, making optimization of radiation protection essential. In Georgia, systematic information on patient dose distribution from commonly performed angiographic procedures is limited. This study aims to select and develop a representative database of angiography devices and related diagnostic practices to identify common procedures and typical patient dose levels. The resulting database will support evidence-based optimization, contribute to the establishment of national Diagnostic Reference Levels, and enhance patient radiation safety in accordance with ICRP and IAEA recommendations.

In order to determine the national DRLs and, for this purpose, to identify the most common diagnostic procedures in Georgia, data was provided by the national regulator, based on which we created a database of all angiography devices in the country – a total of 94 devices as of October 1, 2025.

To obtain a representative group of devices in the country, according to the recommendations of ICRP and IAEA, 30-40% of the devices available in the country should be included. Accordingly, it became necessary to select 28-37 units of angiography devices of all generations, different manufacturers, operating in different regions and clinics.

The fluoroscopy data collection forms kindly provided by the IAEA, which already identify the most common procedures, are the basis for Georgian professionals to confirm, clarify, or amend the list of angiography devices.

The results obtained allow us to proceed to the stage of data collection to identify typical doses for each procedure.

Geographical Distribution and Technical Data Analysis of CT Scanners and Angiography Devices in Georgia

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The number and types of radiological procedures are increasing worldwide. Along with significant benefits, these procedures are also associated with certain negative impacts. Proper management of the patient's radiation exposure is essential to mitigate and prevent adverse effects. CT scanners and angiography devices contribute significantly to the patient's radiation dose load. Since dose limitation principles do not apply in medical imaging as they do in other fields, safety relies on the principles of justification and optimization. Accurate data on patient dose distribution in Georgia are essential for improving radiation protection strategies nationwide.

The aim of this study is to assess the geographical distribution and technical characteristics of computed tomography (CT) scanners and angiography devices across Georgia and develop database.

Based on the database of the Nuclear and Radiation Safety Agency, geographical distribution of medical facilities in whole country were done. A database is developed for the selected research equipment, incorporating information on their respective organizations.

The Obtained database will make a significant contribution to the future establishment of Diagnostic Reference Levels (DRLs) and will help reduce the radiation dose load on the population.

Expansion of IAEA’s Remote and Automated Quality Control for Radiography and Mammography: The MEFOMP Initiative

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Introduction:

Consistent image quality in radiography and mammography is vital for accurate diagnosis and patient safety. Traditional quality control (QC) practices, however, are often hampered by logistical challenges and high costs, resulting in infrequent assessments and increased risk of undetected imaging issues. In response, the International Atomic Energy Agency (IAEA) launched the Coordinated Research Project (E24025, 2021–2025), introducing a pioneering remote and automated QC methodology. This approach leverages affordable phantoms and automated analysis software, enabling frequent, standardized assessments, particularly benefiting resource-constrained settings.

Aims:

This project aimed to implement and evaluate a remote, automated QC system for general radiography and mammography across Middle East Federation for Organizations of Medical Physics (MEFOMP) member states. The system was designed to support routine quality assurance, facilitate early detection of imaging performance issues, and uphold high diagnostic standards. An interactive dashboard was developed to compare detector performance across hospitals and countries, fostering regional cooperation and benchmarking.

Materials and Methods:

Dedicated radiography and mammography phantoms, produced locally in Qatar, were distributed to participating MEFOMP countries. The automated PyATIA software was employed to analyze key image quality metrics—including detectability index (d'), SNR, SDNR, MTF, EXI, air kerma, KAP, and AGD for mammography—from single phantom exposures. Training sessions equipped medical physicists with the skills needed for system operation and remote data analysis. Data were collected from 12 countries, anonymized, and visualized on an interactive dashboard hosted by Hamad Medical Corporation, Qatar.

The dashboard allowed users to filter results by country, hospital, manufacturer, model, and detector type, with automated exclusion of outlier values to ensure data robustness.

Results:

Implementation of the IAEA methodology led to significant improvements in the frequency and standardization of QC procedures. The automated system enabled timely detection of image quality deviations and contributed to enhanced radiation safety. Positive outcomes encouraged MEFOMP's expansion of the initiative to additional countries, promoting broader adoption and capacity building throughout the region. Local phantom production further reduced costs and supported long-term sustainability.

Conclusion:

The IAEA's coordinated project, in partnership with MEFOMP, presents a scalable and effective solution for radiography and mammography QC. By integrating remote monitoring, automated analysis, and cost-efficient phantoms, the initiative has improved the accessibility, efficiency, and reliability of QC processes. Ongoing efforts will focus on expanding training, integrating advanced digital tools, and fostering cross-border collaboration, ultimately advancing imaging quality and patient safety across the Middle East.

Analysis of compliance of quality control parameters of radiological equipment: mammography units in the south-western region of Bulgaria

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Introduction

Mammography is a key radiological imaging modality for the early detection of breast cancer, where achieving an optimal balance between image quality and radiation dose to the patient is essential. The quality control (QC) of radiological equipment, particularly mammography units, plays a crucial role in ensuring diagnostic reliability and compliance with radiation protection principles in both screening and diagnostic practice.

Purpose

The aim of this study is to analyse the compliance of quality control parameters of mammography units, in the south-western region of Bulgaria with national regulatory requirements and applicable international quality assurance guidelines.

Methods and Materials

Data from periodic quality control tests of mammography units in the south-western region of Bulgaria were analysed. Both analogue and digital mammography systems were included. The evaluated QC parameters comprised accuracy and reproducibility of tube voltage, performance of the automatic exposure control (AEC), tube output, image uniformity, spatial resolution, presence of artefacts, and mean glandular dose, assessed using standard mammography phantoms. Parameters obtained from protocols following specialised inspections were analysed for compliance with the requirements of Ordinance No. 2 of the Ministry of Health. The results were additionally compared with relevant European guidelines for quality control of radiological equipment in mammography.

Results

The majority of the analysed mammography units demonstrated compliance with the regulatory requirements for image quality and dosimetric QC parameters. Isolated non-compliances were identified, which may affect both image quality and patient radiation dose. The assessed mean glandular dose values remained within the recommended diagnostic reference levels.

Conclusion

Regular and systematic quality control of radiological equipment, specifically mammography units, is essential to ensure compliance with regulatory requirements, maintain high diagnostic image quality, and provide optimal radiation protection for patients. The findings highlight the importance of specialised inspections and continuous monitoring to identify and correct deviations in a timely manner, particularly at the regional level.

Funding

The present study was carried out through funding from the Ministry of Education and Science, and the National Science Fund under contract No КП-06-М78/2.

Comparative Evaluation of Radiation Attenuation by Tungsten and Lead Syringe Shields in Nuclear Medicine Practice

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Purpose

This study aimed to quantitatively assess and compare the radiation exposure rate reduction achieved by tungsten and lead shielding of different thicknesses, and to determine how the presence of a lead carrier influences shielding effectiveness and measurement variability.

Materials and Methods

A prospective audit was conducted at a Sultan Qaboos comprehensive cancer care and research center in Oman, evaluating two syringe shield materials, tungsten and lead, with varying thicknesses (tungsten: 6 mm and 14 mm; lead: 8 mm). Dose-rate measurements were obtained for syringes containing identical activities and fitted with the respective shields. Using a calibrated radiation survey meter positioned at a fixed distance under standardized geometry, 29 measurements were recorded for each shielding configuration. Mean percentage dose-rate reductions and standard deviations were calculated relative to an unshielded syringe.

To assess the effect of additional shielding, each syringe type was subsequently placed within a lead shield carrier and measurements were repeated under identical conditions. For this setup, 25 dose-rate measurements were acquired per shield, and percentage dose-rate reductions were calculated and compared across shield materials and thicknesses.

Results

Dose rate attenuation varied according to shielding material and thickness. The highest mean reduction was observed with the 14-mm tungsten syringe shield (**94.63% ± 1.01**), followed by the 8-mm lead (**85.03% ± 1.73**) and 6-mm tungsten (**66.88% ± 4.59**) shields. The incorporation of a lead shield carrier resulted in similar attenuation across all configurations, with mean reductions of **88.56% ± 0.86** for 6-mm tungsten, **84.62% ± 0.87** for 8-mm lead, and **80.95% ± 1.32** for 14-mm tungsten.

Conclusion

The 14-mm tungsten syringe shield provided the greatest reduction in radiation exposure, supporting its potential benefit for occupational dose minimization during radiopharmaceutical handling. However, when a lead shield carrier was employed, dose rate reductions became comparable across all shielding configurations, suggesting that the use of a carrier may mitigate differences between shield materials and thicknesses, with important implications for practical radiation safety optimization in clinical settings.

X-Ray Output Characteristics of an Angiography System Under Clinical Conditions

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Angiographic X-ray systems are widely used in interventional radiology procedures and contribute significantly to patient and occupational radiation exposure. Recent observations at Hospital Sungai Buloh indicated an increase in interventional procedures exceeding the deterministic dose monitoring level of 5 Gy, despite the angiography system having passed routine quality control (QC) testing. This study aimed to evaluate the X-ray output characteristics of the angiography unit under clinical operating parameters and to assess its compliance with radiation protection requirements.

Output measurements were performed using a calibrated RaySafe dosimetry system with a 10 cm PMMA phantom. Entrance Skin Dose (ESD) was measured and analysed as a function of field size, fluoroscopy mode, frame rate, and pulse rate. Linearity and repeatability of the system were assessed, and results were compared qualitatively with established QC standards.

The results demonstrated a strong linear relationship between ESD and both field size and fluoroscopy mode ($R^2 = 0.962$), with ESD increasing as field size decreased and fluoroscopy mode intensity increased. ESD also increased with frame rate and pulse rate, showing an exponential trend ($R^2 = 0.798$). Fluoroscopy modes Medium and Normal produced comparable ESD values due to identical pulse rate settings (10 pulses/s). Repeatability testing yielded a coefficient of variation of 0.27%, well below the 10% threshold specified by national QC guidelines.

In conclusion, the angiography system exhibited acceptable output consistency and repeatability, with ESD values strongly dependent on selected exposure parameters. Optimization of fluoroscopy modes and frame rate settings is recommended to further enhance dose management and support the principle of keeping radiation exposure as low as reasonably achievable (ALARA).

Occupational radiation exposure in medical imaging: linking individual dose tracking with immunological biomarkers

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Background:

Occupational exposure to ionizing radiation remains an important occupational health issue for medical personnel involved in diagnostic imaging and interventional procedures. Although individual dosimetry monitoring is mandatory and dose limits are generally respected, dose values may not fully reflect the biological impact of long-term occupational exposure to low doses of ionizing radiation. In this context, integrating individual exposure data with medical records and selected biological parameters may contribute to a more comprehensive assessment of occupational risk.

The aim of the study was to investigate the relationship between occupational exposure to ionizing radiation and biological response by correlating individual dose monitoring with selected immunological parameters.

The main objective was to evaluate the associations between individual occupational exposure data and immunological biomarkers obtained from occupational health surveillance and specific laboratory investigations in medical imaging staff.

Materials and methods:

A cross-sectional observational study is being conducted among healthcare workers occupationally exposed to ionizing radiation in public healthcare institutions, compared with a control group of healthcare workers not exposed to ionizing radiation. Data are collected retrospectively from personal medical records, including demographic characteristics, occupational history, duration of exposure, and results of mandatory periodic medical examinations. A subsample of participants undergoes additional immunological investigations, including lymphocyte immunophenotyping and assessment of serum immunoglobulin G (IgG). Comparative statistical analyses are performed between the exposed group and the control group, along with exploratory analyses of associations between exposure parameters and biological markers.

Results:

The exposed group includes healthcare workers with varying durations of occupational

exposure, the majority of whom had effective annual doses below internationally recommended limits (less than 1 µSv). Compared to the control group, measurable differences were identified in the immunological parameters analyzed. Changes in T-lymphocyte subpopulations and killer cells, as well as variations in serum IgG levels, suggest the existence of subtle immunological responses associated with chronic occupational exposure, even at low doses. Significant interindividual variability was also observed, which cannot be explained solely by dosimetric data.

Conclusions:

Linking individual dose monitoring with immunological biomarkers represents a valuable, data-driven approach with significant potential for assessing occupational risk from ionizing radiation. This strategy can improve occupational health surveillance, facilitate more effective risk communication, and support the development of more personalized radiation protection measures for medical staff in the field of medical imaging.

Energy Response Characterization of a PIN diode Semiconductor-based Detector for Operational Personal Dosimetry in Medical Radiation Fields

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Background and aims
Personal dosimetry based on thermoluminescent detectors (TLD) provides reliable estimates of accumulated dose but does not allow reconstruction of the temporal distribution of exposure during the monitoring period. To address this limitation, a hybrid personal dosimetry system combining Harshaw TLD-100 cards from Thermo Fisher Scientific with a PIN diode detector has been developed as a low-cost operational dosimetry solution. This work evaluates the energy response of the semiconductor-based detector and its suitability for operational radiation protection in medical environments.

Methods and materials
A prototype hybrid system developed by Aplicaciones Tecnológicas S.A. in collaboration with our radiation protection unit was evaluated. Sixteen semiconductor detectors were irradiated under reference photon beam qualities defined in ISO 4037, spanning the N40–N250 range. Irradiations were performed in a secondary standards dosimetry laboratory. Detector response was analysed in terms of air kerma for the different radiation qualities to assess its energy dependence.

Results
The detector response showed a near-linear behaviour across the evaluated qualities (N40-N250), indicating a weak dependence on photon energy within this range. This behaviour suggests that the detector can provide consistent dose estimates under varying radiation qualities typically encountered in medical environments.

Conclusions

The semiconductor-based detector exhibits a promising energy response for operational personal dosimetry. Although preliminary results indicate near-linear behaviour in low-dose-rate conditions, ongoing measurements are expected to further refine and accurately define the energy response curve, particularly at lower photon energies.

Keywords
Personal dosimetry; PIN diode detector; hybrid dosimeter.

Operational Challenges in Pediatric CT Dose Monitoring Using a TQM-Based Monthly KPI Framework: Experience from Al Jalila Children's Hospital

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Background: Pediatric computed tomography (CT) requires continuous radiation dose optimization due to increased radiosensitivity and cumulative lifetime cancer risk. Total Quality Management (TQM) frameworks supported by monthly Key Performance Indicator (KPI) monitoring are increasingly adopted to improve radiation dose governance. However, real-world operational and financial workflow constraints may compromise dose attribution accuracy.

Objective: To evaluate practical challenges affecting pediatric CT dose monitoring accuracy within a TQM-based KPI system at Al Jalila Children's Hospital.

Methods: A continuous monthly pediatric CT dose audit program was implemented at Al Jalila Children's Hospital, a tertiary pediatric referral center, using a TQM-based quality improvement approach. Dose indicators (CTDIvol and DLP) were extracted from the dose monitoring platform and analyzed according to anatomical region, protocol category, and patient age group. KPI outliers were reviewed through multidisciplinary case discussions involving radiologists, anesthesiology, and medical physics teams.

Results: Two major challenges were identified. First, combined sedated examinations (such as abdomen–pelvis) are often acquired as a single continuous scan to minimize anesthesia duration. Automated dose monitoring systems frequently assign the total dose to a single anatomical category, leading to apparent dose exceedance when benchmarked against single-region Diagnostic Reference Levels (DRLs). Second, insurance authorization limitations and self-pay cost constraints sometimes result in only one examination order being entered into the radiology information system. During scanning, additional anatomical regions may be included to avoid repeat sedation and reduce patient financial burden. Consequently, cumulative dose from multiple anatomical regions is recorded under a single protocol category, compromising KPI benchmarking accuracy and dose accountability.

Conclusion: While TQM-based monthly KPI monitoring improves pediatric CT dose oversight at a tertiary pediatric center, sedation workflow and financial-driven protocol consolidation introduce significant limitations in automated dose classification. Improved order–protocol integration, standardized combined-examination labeling, and customized KPI thresholds are necessary to ensure accurate dose reporting and sustainable pediatric dose optimization.

INFORMATION FOR AUTHORS

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COMPARATIVE ASSESSMENT OF AVERAGE GLANDULAR DOSE IN DIGITAL BREAST TOMOSYNTHESIS AND FULL-FIELD DIGITAL MAMMOGRAPHY IN OMAN

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ABSTRACT

Background: With the integration of Digital Breast Tomosynthesis (DBT) into breast imaging, there has been a significant advancement in the capabilities of Full-Field Digital Mammography (FFDM) for early breast cancer detection. However, the increased use of DBT raises concerns regarding radiation exposure levels.

Objective: This study seeks to determine diagnostic reference levels (DRLs) at the Sultan Qaboos Comprehensive Cancer Care and Research Centre (SQCCCRC) for both FFDM and DBT across different compressed breast thicknesses (CBT), contributing to enhanced understanding of radiation dosimetry in breast cancer diagnosis.

Methodology: Data including average glandular dose (AGD), kVp, mAs, entrance surface dose (ESD) and CBT were retrospectively collected on FFDM and DBT exams. For seven CBT groups ranges from 20 mm to 89 mm, the mean, median, range and 75th percentile of AGD values were determined for craniocaudal (CC) and mediolateral oblique (MLO) views. The differences in AGD values between FFDM and DBT were analyzed, and correlations among AGD and CBT, kVp, mAs and ESD were investigated.

Results: Across all CBT ranges, AGD values for DBT were (1.3±0.10) higher than those for FFDM. The DRLs at SQCCCRC range from 0.70 mGy to 2.55 mGy for FFDM and 0.94 mGy to 3.67 mGy for DBT, Fig. 1. The AGD highly showed correlation with kVp, mAs, ESD and CBT. A significant difference in the AGD value was noticed between FFDM and DBT acquisition in both CC and MLO projections ($p < 0.005$).

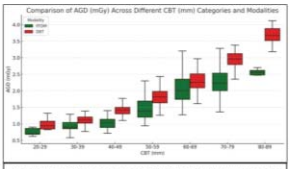

Fig.1: The AGD per woman for full-field digital mammography (FFDM) and digital breast tomosynthesis (DBT) at seven breast thickness groups

Conclusion: The study confirms that DBT generally results in higher AGD levels than FFDM across various CBT ranges, aligning with those established internationally. This research highlights the need for balancing radiation exposure with diagnostic accuracy in clinical decision-making, reinforcing DRLs as a benchmark for radiation safety in breast cancer screening practices.

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