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P01

Radiation Dose Reduction in CT Simulation for Radiotherapy Treatment Planning

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Computed Tomography (CT) simulation is a critical component of radiotherapy treatment planning, providing essential anatomical and electron density information required for accurate target delineation, organ-at-risk definition, and dose calculation. While CT simulation is indispensable for modern radiotherapy workflows, standard protocols are often adopted from diagnostic imaging settings and may result in excessive radiation exposure due to high tube current (mAs), unnecessarily long scan lengths, and uniform acquisition parameters that do not account for site-specific imaging requirements. This can be particularly relevant in patients who require multiple simulation scans throughout their treatment course or for adaptive radiotherapy planning. In this work, we propose a systematic, task-oriented approach to optimize CT simulation protocols with the aim of reducing radiation dose while strictly preserving image quality and dosimetric accuracy. A phantom-based study will be performed using a radiotherapy CT simulator, where standard clinical protocols will be compared with optimized protocols involving controlled adjustments of acquisition parameters such as tube current, pitch, and scan length tailored to the anatomical site being treated. Radiation dose metrics, including CTDIvol and Dose-LSength Product (DLP), will be measured and analyzed to quantify the potential reduction in patient exposure. Image quality will be rigorously evaluated by assessing noise levels, Hounsfield Unit (HU) stability, and spatial resolution to ensure that electron density mapping for treatment planning remains reliable. The potential impact on radiotherapy treatment planning will also be assessed by examining the suitability of optimized scans for accurate contouring, target volume definition, and dose calculation within a treatment planning system. The proposed methodology is expected to demonstrate that site-specific, QA-guided optimization of CT simulation protocols can achieve substantial reductions in patient radiation dose without compromising the quality or accuracy of radiotherapy planning. This approach emphasizes a "fit-for-purpose" imaging philosophy, translating principles commonly used in radiotherapy planning into practical and reproducible strategies for routine clinical implementation, thereby supporting safer imaging practices, improved workflow efficiency, and enhanced quality assurance in CT simulation

References

1-Sodickson, A., Strategies for Reducing Radiation Exposure From Multidetector Computed Tomography in the Acute Care Setting. *Canadian Association of Radiologists Journal*, 64, 119–129, 2013. http://dx.doi.org/10.1016/j.carj.2013.01.002

2- Kalender WA. Dose in x-ray computed tomography. Phys Med Biol. 2014 Feb 7;59(3):R129-50. doi: 10.1088/0031-9155/59/3/R129. Epub 2014 Jan 17. PMID: 24434792.

3- IAEA. Optimization of the Radiological Protection of Patients Undergoing Radiography, Fluoroscopy and Computed Tomography. Human Health series.

P02

ASSESSMENT OF EXTERNAL RADIATION DOSE RATES FROM PATIENTS UNDERGOING ^{18}F-FDG PET/CT: IMPLICATIONS FOR POST-INJECTION SAFETY RECOMMENDATIONS

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Abstract:

Patients injected with ^{18}F-FDG for PET/CT imaging emit external radiation for several hours following radiotracer administration. Quantifying the magnitude and temporal decline of these dose rates is essential for developing evidence-based radiation safety recommendations for the public, particularly for vulnerable groups such as children and pregnant individuals [1].

This prospective study included 54 patients (45 adults and 9 pediatric patients). The mean administered activity was 227 MBq for adults and 224 MBq for pediatric patients. External dose-rate measurements were performed using a calibrated survey meter at two distances, 1 m and 2 cm from the patient's body. Measurements were recorded immediately after FDG injection and again after completion of PET/CT imaging, approximately 60 minutes post-injection. Body mass index (BMI) was documented for all patients (mean BMI: adults 25.16, pediatric patients 24.22).

At a distance of 1 m, the dose rate decreased from 20 µSv/h immediately post-injection to 15 µSv/h after imaging, corresponding to a 25% reduction. At 2 cm, the dose rate decreased from 400 µSv/h to 150 µSv/h, representing a 62.5% reduction. The effective half-life of external radiation was estimated to be approximately 144 minutes at 1 m and 42 minutes at 2 cm. Both adult and pediatric patients demonstrated similar dose-rate decline patterns.

These findings indicate that external radiation levels at 1 m are low at all measured time points and do not require public distancing. However, close contact within 1 m, particularly with infants, children, and pregnant individuals, should be minimized during the first 2–3 hours post-injection until radiation levels decrease sufficiently. This study supports practical, evidence-based post-PET/CT safety guidance and reinforces the overall safety of FDG-based imaging for the public in accordance with international recommendations [1,2].

References:

[1] International Atomic Energy Agency, *Radiation Protection in Nuclear Medicine*, Safety Reports Series No. 68, Vienna (2013).

[2] Barrington S.F., et al., *Eur. J. Nucl. Med. Mol. Imaging* 42, 328–354 (2015).

P03

ESTABLISHMENT OF LOCAL DIAGNOSTIC REFERENCE LEVELS FOR ADULT CT EXAMINATIONS

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1. PURPOSE

Computed tomography (CT) is a major contributor to patient radiation exposure in diagnostic imaging [1, 2]. Optimization in radiation protection requires that patient doses be kept as low as reasonably achievable while preserving diagnostic image quality [1, 2]. Diagnostic Reference Levels (DRLs) are internationally recommended investigation levels to identify unusually high radiation doses and guide protocol optimization [1, 2]. Libya currently lacks established DRLs. This study aims to establish preliminary local DRLs for adult CT Brain, Chest, and Abdomen examinations in Tripoli as a foundation for a national dose management framework [1, 2].

2. METHODS

A retrospective audit is conducted for adult patients undergoing routine CT Brain, Chest, and Abdomen examinations in Tripoli. $CTDI_{vol}$ (mGy) and Dose-Length Product DLP (mGy·cm) were extracted from scanner-generated dose reports. Dose indices are calculated according to IEC standards embedded in the CT system [3,4,5].

Internal validation was performed by verifying the mathematical relationship DLP = $CTDI_{vol}$ × scan length to ensure consistency of recorded dose metrics [5,6]. Exposure parameters (kVp, mAs) and scan length were documented. Descriptive statistics were computed for each protocol, and the 75th percentile of dose distribution was proposed as the local DRL, following international methodology [1, 2].

3. CONCLUSION

Establishing local DRLs for CT Brain, Chest, and Abdomen examinations provides the first structured baseline for patient dose assessment in Tripoli. Data collection is ongoing. This work supports systematic optimization practices, strengthens radiation protection infrastructure, and contributes to developing a national DRL framework aligned with international standards [1, 2].

4. REFERENCES

[1] International Commission on Radiological Protection, Diagnostic Reference Levels in Medical Imaging, ICRP Publication 135, 2017.
[2] International Atomic Energy Agency, Radiation Protection and Safety in Medical Uses of Ionizing Radiation, GSR Part 3, 2014.
[3] International Electrotechnical Commission, CT Dose Measurements: CTDI100 and Weighted CTDI Definitions, IEC 60601-2-44.
[4] International Electrotechnical Commission, Medical Electrical Equipment – Part 2-44: Particular Requirements for the Safety of CT Equipment, IEC 60601-2-44, 2009 + AMD 1 2012.
[5] NEMA, XR-25 Computed Tomography Dose Check Standard, 2011.
[6] IEC / DICOM, CTDIvol and DLP Reporting Guidelines, 2020.

P04

Impact of Gender and BMI on PET SUV Overestimation: A Liver and Blood Pool Analysis

Aims

This study investigates the impact of gender and body mass index (BMI) on the overestimation of Standardized Uptake Values (SUVs) compared to lean body mass-adjusted SUVs (SULs) in liver and blood pool PET/CT scans, aiming to identify quantification biases and their implications for clinical interpretation.

Materials & Methods

A retrospective analysis was conducted on 182 adult patients (93 females, 89 males) who underwent F-18 FDG PET/CT imaging. Patients were stratified into BMI categories: normal weight (18.5–24.9), overweight (25–29.9), and obese (≥30). SUVmax and SUVmean for the liver and blood pool were compared with SUL values, calculated using the formula:

SUL=SUV X Lean Body Mass (LBM)/Total Body Weight

Percentage differences between SUV and SUL were analyzed across gender and BMI groups. Statistical significance was assessed using a two-sample t-test.

Results

SUV overestimation increased significantly with BMI ($p<0.0001$) in both genders. Females exhibited greater discrepancies, with liver SUVmax exceeding SUL by 28.1% in normal-weight individuals and 43.4% in obese individuals, compared to 22.4% and 37.4% in males, respectively. Blood pool SUV-SUL differences followed a similar trend, with overweight and obese females showing the highest discrepancies.

Conclusion

Females, particularly those with higher BMI, demonstrate greater SUV overestimation compared to males. These findings emphasize the importance of incorporating body composition adjustments, such as lean body mass, for accurate PET quantification. Standard SUV measurements may lead to misinterpretations of metabolic activity, especially in overweight and obese individuals, underscoring the need for refined approaches in PET image analysis.

Keywords: PET/CT, SUV, SUL, Lean Body Mass, BMI, Gender Differences, Quantification Bias, Obesity

P05

A Medical Physics–Driven Framework for Multimodal AI in Breast Imaging

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Abstract

Breast cancer imaging increasingly relies on complementary modalities, including mammography, digital breast tomosynthesis (DBT), ultrasound (US), magnetic resonance imaging (MRI), and positron emission tomography (PET). Each modality provides distinct anatomical, structural, functional, or metabolic information, but also presents modality-specific limitations related to image quality, spatial resolution, artifacts, acquisition protocols, and, for ionizing modalities, radiation exposure. Artificial intelligence (AI), particularly deep learning, has demonstrated substantial potential for breast lesion detection, segmentation, classification, and treatment-response prediction; however, many existing approaches focus on individual modalities and may not fully exploit complementary information across imaging sources.

This work proposes a medical physics–driven framework for multimodal AI in breast imaging, integrating image-quality assessment, radiation-dose considerations, multimodal data harmonization, deep representation learning, fusion strategies, explainable AI (XAI), and clinical decision support. The proposed workflow incorporates modality-specific preprocessing followed by feature extraction using convolutional neural networks, vision transformers, Swin Transformers, or U-Net-based architectures. Multimodal information is subsequently integrated through data-level, feature-level, decision-level, or hybrid fusion strategies. XAI approaches, including Grad-CAM and feature-attribution methods, are incorporated to improve the interpretability of AI predictions.

The current work focuses on framework development, literature-based taxonomy, and computational implementation; quantitative experimental validation is ongoing. Future studies will evaluate the framework using breast imaging datasets for lesion detection, segmentation, classification, molecular characterization, and treatment-response prediction. By explicitly integrating medical physics principles with multimodal AI, the proposed framework aims to support the development of robust, interpretable, reproducible, and clinically relevant AI-assisted breast imaging systems.

[1] Litjens G, Kooi T, Bejnordi BE, et al. MIA. 60–88(2017).

[2] Ronneberger O, Fischer P, Brox T. 234–241, (2015).

[3] Liu Z, Lin Y, Cao Y, et al. *ICCV*.,10012–10022(2021).

P06

OPTIMIZATION AND ASSESSMENT OF PATIENT RADIATION DOSE IN DIGITAL BREAST TOMOSYNTHESIS: ANALYSIS OF INFLUENCING FACTORS AND DOSE OPTIMIZATION STRATEGIES

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Abstract:

Digital Breast Tomosynthesis (DBT), implemented on full-field digital mammography (FFDM) systems, has improved breast cancer detection through enhanced lesion conspicuity and reduced tissue overlap. However, the acquisition of multiple low-dose projections raises concerns regarding cumulative radiation exposure, particularly in screening programs. In Morocco, limited published data are available on patient dose levels in DBT, highlighting the need for local dose assessment and optimization.

This study aims to evaluate patient radiation dose during DBT examinations performed on a FUJIFILM full-field digital mammography system and to identify the main factors influencing dose variability. A retrospective analysis was conducted on 100 patients who underwent DBT examinations. Dose-related parameters, including Average Glandular Dose (AGD), tube voltage (kVp), tube current–time product (mAs), compressed breast thickness, and target/filter combinations, were extracted from DICOM headers via the PACS system.

Statistical analysis was performed to assess the correlation between AGD and technical as well as anatomical parameters. Breast thickness and exposure settings were identified as primary determinants of dose variation. Based on these findings, optimization strategies were proposed, focusing on protocol standardization, appropriate use of automatic exposure control (AEC), and reinforcement of quality assurance practices to ensure adherence to the ALARA principle without compromising diagnostic image quality.

The outcomes of this study provide baseline data for establishing local Diagnostic Reference Levels (DRLs) for DBT in Morocco and contribute to strengthening radiation protection practices in breast imaging. This work aligns with IAEA safety standards and supports the development of medical physics expertise in dose optimization and quality assurance in emerging imaging technologies.

[1] I. Sechopoulos, Med Physics, **40**, 014301 (2013).

[2] D. R. Dance, K. C.Young, R. E. van Engen, **144**, 58 (2011).

[3] International Atomic Energy Agency, Radiation Protection and Safety in Medical Uses of Ionizing Radiation. IAEA Safety Standards Series No. GSR Part 3 (IAEA, Vienna, 2018).

[4] European Commission, European Guidelines for Quality Assurance in Breast Cancer Screening and Diagnosis (European Commission Brussels 2017).

P07

QA verification of CBCT and kV/MV imaging performance for image-guided radiotherapy

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Abstract

Accurate onboard imaging is essential for precise patient positioning and safe treatment delivery in image-guided radiotherapy (IGRT). Quality assurance (QA) programs ensure that cone-beam CT (CBCT) and planar kV/MV imaging systems maintain stable image quality, geometric fidelity, and reliable registration accuracy. This work reports quantitative verification results from imaging QA measurements performed in a clinical radiotherapy department.

QA tests were carried out following international recommendations using CATPHAN 503 for CBCT evaluation, TOR 18FG for planar image quality, a Ball-Bearing phantom for geometric verification at gantry angles, and a Penta-Guide phantom for CBCT isocenter alignment and repositioning. Evaluated parameters included 3D image uniformity, low-contrast visibility, spatial resolution, geometric scaling, kV/MV registration accuracy, planar geometric precision, low-contrast detectability, spatial resolution, and CBCT isocenter reproducibility.

Measured CBCT uniformity variation was 0.36% (tolerance ≤1.5%), low-contrast visibility was 1.9% (≤3.0%), and spatial resolution reached 11 lp/cm (≥10 lp/cm). Geometric scaling measurements were 117.1 mm in both transverse directions (117 ±1 mm) and 110 mm sagittal (110 ±1 mm). Registration accuracy showed kV deviations of −0.7, 0.2, and −0.7 mm and MV deviations of −0.59, 0.32, and −0.81 mm along X, Y, and Z axes respectively, with kV–MV differences within ±0.12 mm. Planar geometric accuracy showed a maximum Ball-Bearing centre deviation of 1 mm across gantry angles. Low-contrast detectability reached 13 visible disks (≥12), and spatial resolution demonstrated visibility up to the 14th frequency group (≥10th group). CBCT isocenter repositioning deviations were 0.3, 0.5, and 0.4 mm in X, Y, and Z respectively (≤1 mm).

These quantitative results confirm stable imaging performance, sub-millimetric geometric accuracy, and reliable registration consistency, providing strong assurance for reproducible patient positioning and minimized geometric uncertainty in precision IGRT delivery.

Keywords: Cone-Beam CT (CBCT); Image-Guided Radiotherapy (IGRT); Quality Assurance (QA); Registration Accuracy; Geometric Accuracy.

References

[1] E. E. Klein et al., “Task Group 142 Report: Quality assurance of medical accelerators,” Med. Phys. 36(9), 4197–4212 (2009).
[2] Elekta, XVI R5.0 Customer Acceptance Tests (2015).

P08 **Performance Evaluation of Various Radio Diagnostic Equipments in Clinical Practices**

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The fundamental goal of diagnostic radiology is to provide the best possible image with minimum radiation dose to the patient. The present study is aimed to assure the quality of various radio diagnostic equipments such as screen film radiography, mobile radiography, computed radiography, digital radiography, computed tomography, cone beam computed tomography, simulator, dental radiography, lithotripsy, C-arm and mammography in order to reduce the dose to the patient, occupational and public. [1] The focus has been in the hospitals around our region (southern parts of India) to examine whether the units have been kept to the quality recommended by the Atomic Energy Regulatory Board (AERB), Mumbai, India. In the present work 230 equipment from 151 institutions that include equipments from 7 multiple speciality hospitals, 39 National Accreditation Board for Hospitals and Healthcare Providers (NABH) accredited hospitals, 63 Indian Medical Association (IMA) registered hospitals and 42 radio diagnostic centres were tested. Out of these, 78% of the equipments were found to be passed all the tests recommended by the AERB and the remaining 22% of the equipments with malfunction were identified and rectified. Most of the equipments that needed critical analysis were from radio diagnostic centres. By this way, the present research work supported enormously to reduce unnecessary exposure to approximately 175 patients who have been undergone radio diagnostic procedure in carious centres every day. It is also noted that the medical care for women and pediatrics has been compromised and should be addressed. Recently, the AERB has also implemented rigorous monitoring guidelines through e-Licensing of Radiation Application (e-LORA) to assure radiation safety. [2]

References:

1. IAEA Human Health Series No. 47, Handbook of Basic Quality Control Tests for Diagnostic Radiology (2023)
2. https://elora.aerb.gov.in/ELORA/populateLoginAction.htm

P09

PATIENT DOSIMETRY IN SELECTED HOSPITALS AND INVESTIGATION OF A LOW-COST PHANTOM SUITABLE FOR QUALITY ASSURANCE MEASUREMENTS IN COMPUTED TOMOGRAPHY IN NIGERIA.

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The use of ionizing radiation is one of the established medical procedures globally of which Computed Tomography (CT) contributes about 34% of the collective dose. It is therefore important to establish a functional Quality Assurance (QA) procedure in CT with relevant phantom facilities in order to reduce cancer risk to patients. This study was designed to develop a low-cost CT phantom for QA measurements and develop a regression model based of patient BMI for pre-scan protocol optimization. Data were collected on 545 patients in purposively selected seven hospitals in North-central, South-west and South-south Nigeria comprising information on 295 (54.1%) males and 250 (45.9%) females that underwent common CT examinations. These included: Head (314), Chest (86), Abdomen (145). Volume Computed Tomography Dose Index ($CTDI_{vol}$), Dose Length Product (DLP), organ and effective doses were calculated using standard methods. A linear correlation between Height (H), Weight (W) and Effective Dose (E) was estimated and used to obtain a linear regression model. This model was used to establish patient-specific protocol for optimisation. The physical density and Hounsfield Unit (HU) number of Carboxymethylcellulose (CMC), texapon and glycerol were measured to determine their suitability as CT phantoms. The regression model was of the form $E = 18.45 + 0.102H - 0.089W$. Physical density and HU numbers determined from materials tested for tissue-equivalence showed average density and HU of 1.60 g/cm^3, 1.04 g/cm^3, 1.20 g/cm^3 and -483, 119, 133 for CMC, texapon and glycerol, respectively. These values are similar to HU of human tissues which makes them suitable for low-cost phantom development. The carboxymethylcellulose, texapon and glycerol materials are suitable to develop low-cost tissue-equivalent phantoms for quality assurance measurements in computed tomography.

[1] Radiological Protection in Paediatric Diagnostic and Interventional Radiology. International Commission on Radiological Protection, ICRP Publication 102. Ann ICRP 42(2) ICRP (2013).
[2] Dousi, M., Fatsi, A., Sotirakou, K., Gkatzia, N., Patelarou, M., Theodosiou, A. Helical vs Conventional CT in Routine Head Imaging: A comparison of Dose and Image quality using VGC Analysis. Journal of Radiology and Clinical Imaging 4: 036-049 (2021).

P10

Abstract template for College on Medical Physics 2026 | (smr 4232)

Optimization of Radiological Protocol Parameters and Reduction of Absorbed Dose in Pediatric CT scans by Radiology Technologists in Selected African Countries (Cameroon, Benin, and Senegal).

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Short title: Optimization of radiological protocol parameters in selected African countries

Abstract

Objective: In this study, we assess how radiology technologists contribute to optimizing radiological protocol parameters and reducing absorbed doses in several African countries. This investigation aims to facilitate the harmonization of CT (Computed Tomography) examination practices in Cameroon, Senegal, and Benin.

Materials and Methods : Radiology parameters, experimental protocols, and dosimetry estimates for all cases in the selected countries were retrospectively analyzed. Data were collected from 286 randomly selected pediatric patients under 18 years of age who underwent head CT procedures. Six CT scanner models were used: three Siemens units, two Hitachi units, and one Neusoft/Neuviz ACE SP. The mean values of the dose parameters, DLP and CTDIvol, were calculated using the Analysis ToolPak in Excel.

Results : For each age group (≤1, 1–5, 5–10, and 10–15 years), the established local CTDIvol values (in mGy) were 24.7, 38.1, 38.8, and 53.9 for Cameroon ; 28.6, 29, 31.7, and 39.2 for Senegal ; and 14.4, 15.2, 18.2, and 22.8 for Benin, respectively. The corresponding DLP values (in mGy·cm) were 375, 735, 930, and 1164 for Cameroon; 512.4, 560.1, 646, and 822 for Senegal; and 625.6, 429.5, 521.8, and 630.1for Benin. The image quality obtained from the data collected in the selected countries were clinically satisfactory. Dosimetry indices were not standardized in the selected countries.

Conclusion : In developing countries, where dosimetry equipment and quality control tools are limited or non-existent, monitoring of radiation doses, ongoing training in new protocol-optimization techniques, and academic collaboration with medical physicists will enable radiology technologists to strengthen radiation protection and optimize the doses received by patients.

Keywords: Radiology technologists; Radiological protocol parameters; Developing country; Optimization of doses; Radioprotection.

Key points

- Mastering the impact of radiological parameters on patient dose is the first step toward reducing absorbed radiation by radiology professionals.

- Optimization of radiological protocol parameters are currently insufficient or inconsistently applied.

- Develop strategies to improve the involvement of radiology technologists in optimizing protocol parameters and lowering absorbed doses.

P11

ASSESSMENT OF AVERAGE GLANDULAR DOSE AND DETERMINATION OF A LOCAL DIAGNOSTIC REFERENCE LEVEL IN THE UNIVERSITY HOSPITAL

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Breast tissue is highly sensitive to ionising radiation, and the average glandular dose (AGD) is the principal dosimetric quantity for patient risk assessment and optimisation in mammography. According to ICRP Publication 135, diagnostic reference levels (DRLs) are established using the third quartile (75th percentile) of dose distributions and serve as optimisation tools rather than dose limits [1]. The IAEA Basic Safety Standards emphasise the role of DRLs in patient dose optimisation [2].

A retrospective analysis was conducted on 59 patients (37–75 years) examined in 2025 using a Hologic Selenia Dimensions system. AGD and compressed breast thickness (CBT) values were obtained from DICOM metadata. AGD evaluation was performed using established glandular dose conversion models [3]. Patient-based mean AGD values were calculated, and descriptive statistics (mean ± SD, median, and 75th percentile) were determined. The 75th percentile was considered the local DRL candidate.

Mean AGD values were 1.45 mGy (RCC), 1.56 mGy (LCC), 1.95 mGy (RMLO), and 1.99 mGy (LMLO). Combined CC and MLO means were 1.59 mGy and 1.92 mGy, respectively. The overall mean AGD was 1.74 ± 0.62 mGy (median: 1.66 mGy), and the 75th percentile was 2.08 mGy. Higher AGD values were observed in MLO projections compared with CC, consistent with national DRL findings in Türkiye [4]. The dose distribution falls within commonly reported screening ranges [5].

The determination of local DRL (2.08 mGy) is consistent with international optimisation principles and supports institutional dose monitoring for continuous quality improvement.

REFERENCES

[1] ICRP. Diagnostic Reference Levels in Medical Imaging. ICRP Publication 135. Ann. ICRP 46(1), 2017.

[2] International Atomic Energy Agency (IAEA). Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (GSR Part 3). Vienna, 2014.

[3] Okunade A.A. Evaluation of average glandular dose in mammography. Med. Phys. 33(4), 1153–1164 (2006).

[4] Parmaksız A., Ataç G.K., Bulur E., et al. Average glandular doses and national diagnostic reference levels in mammography examinations in Turkey. Radiat. Prot. Dosim. 190(1), 100–107 (2020).

[5] Maimani A., Kinsara A.A., AlTaayeb B., Molla N.I. Assessment of Breast Doses in Mammography Screening. Bangladesh J. Nucl. Med. 18(2), 2015.

P12

Multi-Institutional CT Radiomics for Stroke Patient Stratification and Clinical Characterization

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Introduction:
Radiomics enables the extraction of quantitative features from medical imaging, providing insights into lesion shape, intensity, and texture beyond conventional interpretation. While deep learning requires large datasets, radiomics can be applied effectively with smaller cohorts. This study aimed to investigate whether radiomic features from CT scans can distinguish between hemorrhagic and infarct strokes.

Table 1: Patient demographic information

	Institute 1		Institute 2	
Characteristics	Hemorrhage	Infract	Hemorrhage	Infract
Number of patients	46 (57%)	35 (43%)	24 (48%)	26 (52%)
Sex (P=0.312)				
Male	27 (59%)	25 (71%)	12 (50%)	14 (54%)
Female	19 (41%)	10 (29%)	12 (50%)	12 (46%)
Age (P= 0.345)				
Ranges	13-88	22-82	13-87	12-85
Mean	56.33	58.55	56.20	58.20
Median	60.50	60.36	58.40	58.20

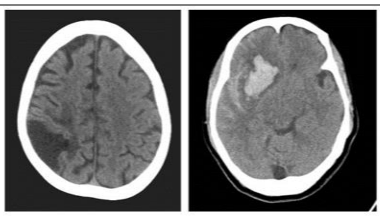

Figure 1. (a) Infract for a stroke patient in axial in the CT image; (b) hemorrhagic for a stroke patient in axial CT image

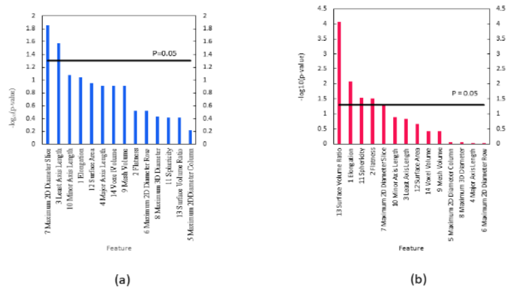

Figure 2. Bar graph of negative logarithm with base 10 of p-values ($-\log_{10}$ p value) for shape features, where the horizontal line (p=0.05) indicates the threshold for statistical difference, (a) for institute 1, (b) for institute 2.

Methods:
A total of 131 stroke patients from two institutions were included. DICOM CT scans were acquired using a Siemens 128-slice multidetector scanner at Institute 1 and a Siemens True64 CT scanner at Institute 2. Preprocessing included voxel resampling, skull stripping, and intensity normalization. Radiomic features covering shape, first-order statistics, and texture properties were extracted using 3D Slicer. Significant features were identified using Student's t-test ($p < 0.05$), and their discriminative power was evaluated with the Area Under the Receiver Operating Characteristic Curve (AUC).

Results:
Radiomic features demonstrated significant differences between hemorrhagic and infarct strokes. At Institute 1, mean AUCs were 0.9453 for hemorrhage and 0.9203 for infarct, while at Institute 2, the corresponding AUCs were 0.9696 and 0.9623, indicating excellent diagnostic accuracy. Shape and texture features were particularly effective in differentiating stroke types.

Conclusion:
CT-based radiomic analysis shows strong potential for distinguishing between hemorrhagic and infarct strokes, supporting its use as a non-invasive diagnostic tool for stroke stratification. Despite promising results, larger datasets, standardized imaging protocols, and external validation are required to confirm clinical applicability and facilitate integration into routine practice.

Acknowledgement: We are acknowledged for providing CT data of stroke patients from Popular Clinic Ltd, Rajshahi (Institute 1) and Gazi Medical Hospital, Khulna, Bangladesh (Institute 2). Alamgir Hossain would like to acknowledge support from the ICTP through the Associates Program (2024-2029).

P13

Institutional dose reference levels for common interventional cardiology procedures: a preliminary study

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Objectives: To investigate patient radiation doses during two commonly performed interventional cardiology (IC) procedures: coronary angiography (CA) and percutaneous transluminal coronary angioplasty (PTCA) in a dedicated cardiac catheterization laboratory, and to establish institutional dose reference levels (DRLs).

Materials and Methods: The study was performed in 'normal' fluoroscopy mode with a digital image acquisition rate of 15 frames/second for CA and PTCA procedures. The values of dose-area product (DAP) were recorded for 808 CA and 854 PTCA procedures performed in the catheterization laboratory. The institutional DRLs for these procedures were estimated as the third quartile of the distribution of recorded DAP values for each procedure type. Also, the recorded DAP values were used to calculate the average effective dose (E_{av}) by using an appropriate conversion factor.

Results & Discussion: The recorded DAP values ranged from 0.79 to 82.49 Gy-cm^2 for CA and from 4.37 to 345.44 Gy-cm^2 for PTCA procedures. The estimated values of DRLs and E_{av} were 15 and 74 Gy-cm^2, and 2.34 and 10.90 mSv for CA and PTCA procedures, respectively. DRL values were in agreement with the corresponding DRLs reported in the literature.

Conclusion: The large variation in doses for both types of procedures indicates an opportunity to reduce patient exposure. The proposed DRLs may help optimize patient doses during IC procedures at the institutional level by employing appropriate dose-saving techniques in routine clinical settings.

P14

Estimation of Radiation Exposure Based on Size-Specific Dose Estimates (SSDE) in Adult Chest and Abdomen CT Examinations on a 64-Slice MDCT System

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Abstract:

Introduction: Computed tomography (CT) accounts for 60–70% of the total medical radiation dose worldwide despite comprising only 20–25% of diagnostic imaging procedures. Conventional dose descriptors—CTDIvol and DLP—do not account for patient size and therefore do not represent true patient-absorbed dose. Size-Specific Dose Estimate (SSDE), based on AAPM Report 204, provides a more accurate dose metric by incorporating patient body dimensions. To determine SSDE for adult NCCT chest and abdomen scans using four measurement methods (AP, LAT, AP+LAT, and effective diameter). To assess correlation of SSDE with CTDIvol, DLP, patient age, and body size.

Materials and Methods: A cross-sectional analytical study was conducted on a 64-slice Siemens Somatom Definition AS CT system. Data of 130 adults (65 chest and 65 abdomen NCCT scans) were retrospectively evaluated. AP and LAT measurements were taken from axial images using digital calipers. SSDE was computed using AAPM Report 204 conversion factors. Correlations were assessed using Friedman and Wilcoxon tests.

Results: Mean CTDIvol and SSDE for chest scans were 5.83 ± 1.37 mGy and 9.15 ± 1.92 mGy, respectively. For abdomen, values were 8.59 ± 2.13 mGy and 13.53 ± 3.03 mGy. SSDE values significantly differed across the four measurement methods ($p < 0.01$). SSDE demonstrated a stronger correlation with patient size than CTDIvol in both chest ($r^2 = 0.23$) and abdomen ($r^2 = 0.26$). Dose levels were 36–55% lower than ACR DRLs.

Conclusion: SSDE provides a more reliable estimation of patient dose compared to CTDIvol. The lower SSDE values observed highlight appropriate protocol optimization at our centre. Routine SSDE reporting should be incorporated into CT practice in India, and national DRLs should be established.

References:

[1] IAEA. Radiation Protection in Diagnostic and Interventional Radiology. International Atomic Energy Agency; (2018).

[2] AAPM Report No. 220. Use of Water-Equivalent Diameter for Patient Size and SSDE Calculation. AAPM; (2014).

P15

Diagnostic Reference Levels Based on Clinical Indications for Adult CT: A Study in a Brazilian Academic Centre

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The growing adoption of CT images in the diagnostic chain and the strong correlation between image quality and radiation dose associated to these studies reinforce the need for implementing regular optimization of clinical protocols [1]. The establishment of diagnostic reference levels (DRLs) has become one of the most effective tools for this purpose. Defined by the International Commission on Radiological Protection (ICRP) in its publication 135 [2], DRLs represent an effective approach to allow the implementation of optimization strategies in diagnostic and interventional procedures. Despite this progress, there remains a need for DRL studies that incorporate clinical indications (CIs) [3], an approach recommended in international guidelines but still underrepresented in the literature.

This study addresses these gaps by implementing a CI-based methodology to determine Typical Values (TVs) for the most frequent adult CT examinations performed in the largest public academic hospital in Brazil [4]. By comparing dose metrics across four scanners from different manufacturers and benchmarking them against published DRLs, the proposed approach enables the identification of clinically relevant dose outliers even in the absence of comparable national data.

Radiation dose metrics and demographic information were analysed from 1382 CT studies performed between July 2022 and July 2023 across four scanners from different manufacturers. Examinations were categorized into three CIs: urolithiasis, abnormal chest findings, and headache, based on the 10th Revision of the International Classification of Diseases. These exams were stratified by patient's Body Mass Index (BMI) to determine the institutional standard patient.

TVs for $CTDI_{vol}$ and DLP were found to be 9,1 mGy and 492,8 mGy·cm for urolithiasis, 5,6 mGy and 231,8 mGy·cm for abnormal chest findings, and 49,8 mGy and 1062,9 mGy·cm for headache, respectively. Notably, the intra-institutional comparison revealed that one specific scanner delivered doses approximately double the institutional TV for urolithiasis (18 mGy vs. 9,1 mGy), while comparisons with published DRLs suggested excessive scan lengths in specific protocols. Consequently, the proposed CI-based methodology proved superior to broad anatomical surveys by pinpointing critical dose outliers that would otherwise remain masked. These findings triggered optimization plans, demonstrating that implementing CI-based DRLs is an essential strategy for overcoming the technological challenges of ensuring radiation safety during medical exposure in large academic hospitals with heterogeneous equipment fleets.

[1] E. Vañó, D. L. Miller, C. J. Martin, M. M. Rehani, K. Kang, M. Rosenstein, P. Ortiz-López, S. Mattsson, R. Padovani and A. Rogers, Ann. ICRP **46**, 1–144 (2017).

[2] J. Vassileva, V. Tsapaki, E. Vañó and M. M. Rehani, Phys. Med. **84**, 285–287 (2021).

[3] V. Tsapaki, J. Damilakis, G. Paulo, A. A. Schegerer, J. Repussard, W. Jaschke, G. Frija, Eur. Radiol. **31**, 4459–4469 (2021)

[4] P. R. Costa, J. C. de O. Castro, I. P. F. Nunes, D. Y. Nersissian, M. Y. Sawamura, H. L. Filho, A. Tomal, Radiat. Phys. Chem. **221**, 111669 (2024)

P16

Abstract template for College on Medical Physcis 2025 (smr 4232)

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Introduction
Since the advent of Computed Tomography (CT), the number of CT scans performed worldwide has steadily increased, leading to a growing impact on the collective dose received by the population. Although CT accounts for less than 10% of all radiological procedures, it contributes to over 40% of the total collective dose. Advances in CT technology have enabled the development of protocols for each type of examination and patient, allowing dose optimization. However, CT examinations still involve significant radiation doses, particularly concerning pediatric imaging. In these cases, lead aprons are commonly used to shield body regions not under examination, aiming to protect radiosensitive organs.
The objective of this study is to quantify the patients variation dose due to the scatter radiation using and not of a lead apron in CT procedures.

Materials y methods
A CT scanner, a lead apron, and an ionization chamber were used. A phantom was employed to simulate the presence of a patient. Scans were performed using different imaging protocols. The measurements were repeated for various shielding positions to evaluate the impact of apron placement on scatter radiation.

Results and conclusions
The results emphasize the importance of evaluating the use of lead aprons in CT scans. This study provides quantitative data on the variation in patient dose associated with the presence or absence of such protective measures, contributing to evidence-based decisions in radiological protection.

Key words: computed tomography, lead apron, radiological protection, ionizing radiation

P17

Characterization of 3D printed tissue equivalent plastic materials for radiotherapy quality assurance

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Patient-specific phantoms produced using 3D printing technology are important for radiotherapy quality assurance (QA). Compared to commercial phantoms, they are more cost-effective and can replicate individual patient anatomy. This can be particularly useful to test innovative techniques such as deep learning (DL)-based treatment monitoring [1]. A key challenge in the development of 3D printed phantoms is selecting suitable materials [2, 3]. This study evaluates various 3D printing materials for patient-specific QA in X-ray radiotherapy, with a particular focus on identifying a human soft-tissue-equivalent material.

Various small cubes of ABS, PET-G, PET-GF, PLA, PPA-GF, PA12 CF and ASA were printed at Laboratori Nazionali del Gran Sasso (LNGS) using Raise3D Pro printer. Moreover, ABS, PET G, PLA and TPU were printed at INFN Pisa using Bambu Lab printer, and 15 cubes were produced by BIO3DModel using Stratasys printer. To evaluate imaging response relative to human tissues, 120 kV CT images were acquired at the Careggi hospital in Florence. For each sample, the average Hounsfield Units (HU), mass density, electron density (ED), and relative electron density (RED) were determined and compared with ICRU reference data for human tissues. To assess the response under therapeutic (MeV) X-rays, point-dose measurements were performed using a micro-diamond ionization chamber, and were compared with the Monaco TPS predictions.

Materials from LNGS and INFN Pisa exhibited HU values ranging from –93.5 to 78.3, with the exception of PET GF, which showed an HU of 229.4, while Bio3DModel materials, HU values ranged from –16.8 to 804.5. The mass density of the LNGS and INFN Pisa samples ranged from 0.98 to 1.23 g/cm^3, the ED ranged from 3.13 to 3.80×10^{23} and the RED ranged from 0.94 to 1.23. The Bio3DModel materials showed mass densities between 1.02 and 1.26 g/cm^3. The deviation between the measured and the predicted dose by the TPS was between 0.9% and 1.2%. We identified various materials, that complied with ICRU soft tissue specifications, printed at INFN Pisa and LNGS, as well as the lightest Bio3DModel.

3D printing has an enormous potential in medical phantom development. Several candidate plastic materials were identified that realistically simulated soft tissues, many of which can be printed with moderately priced 3D printers. In the future, we will produce several 3D printed phantoms and use them to validate a DL-based treatment verification technique developed by our research group .

[1] L. Marini, M. Avanzo, A.C. Kraan, F. Lizzi, C. Mozzi, A. Retico and C. Talamonti, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. **169908**, 1069 (2024).

[2] K. Mei, M. Geagan, L. Roshkovan, H. Litt, G. J. Gang, N. Shapira, J. W. Stayman, and P. B. Noël, Med Phys. **2**, 49 (2022).

[3] S. A. Oh, M. J. Kim, J. S. Kang, H. S. Hwang, Y. J. Kim, S. H. Kim, J. W. Park, J. W. Yea and S. K. Kim, Prog Med Phys. **3**, 28 (2017)

P18

Deep learning-driven segmentation of ischemic stroke lesions using multi-channel MRI

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Ischemic stroke, caused by cerebral vessel occlusion, presents substantial challenges in medical imaging due to the variability and subtlety of stroke lesions. According to the World Health Organization (WHO), approximately 15 million people suffer from strokes each year, with ischemic strokes accounting for about 87% of all cases [1]. Magnetic Resonance Imaging (MRI) plays a crucial role in diagnosing and managing ischemic stroke, yet existing segmentation techniques often fail to accurately delineate lesions. This study introduces a novel deep learning-based method for segmenting ischemic stroke lesions using multi-channel MRI modalities, including Diffusion Weighted Imaging (DWI), Apparent Diffusion Coefficient (ADC), and enhanced Diffusion Weighted Imaging (eDWI). The proposed architecture integrates DenseNet121 as the encoder with Self-Organized Operational Neural Networks (SelfONN) in the decoder, enhanced by Channel and Space Compound Attention (CSCA) and Double Squeeze-and-Excitation (DSE) blocks. Additionally, a custom loss function combining Dice Loss and Jaccard Loss with weighted averages is introduced to improve model performance. Trained and evaluated on the ISLES 2022 dataset, the model achieved Dice Similarity Coefficients (DSC) of 83.88 % using DWI alone, 85.86 % with DWI and ADC, and 87.49 % with the integration of DWI, ADC, and eDWI. This approach not only outperforms existing methods but also addresses key limitations in current segmentation practices. These advancements significantly enhance diagnostic precision and treatment planning for ischemic stroke, providing valuable support for clinical decision-making.

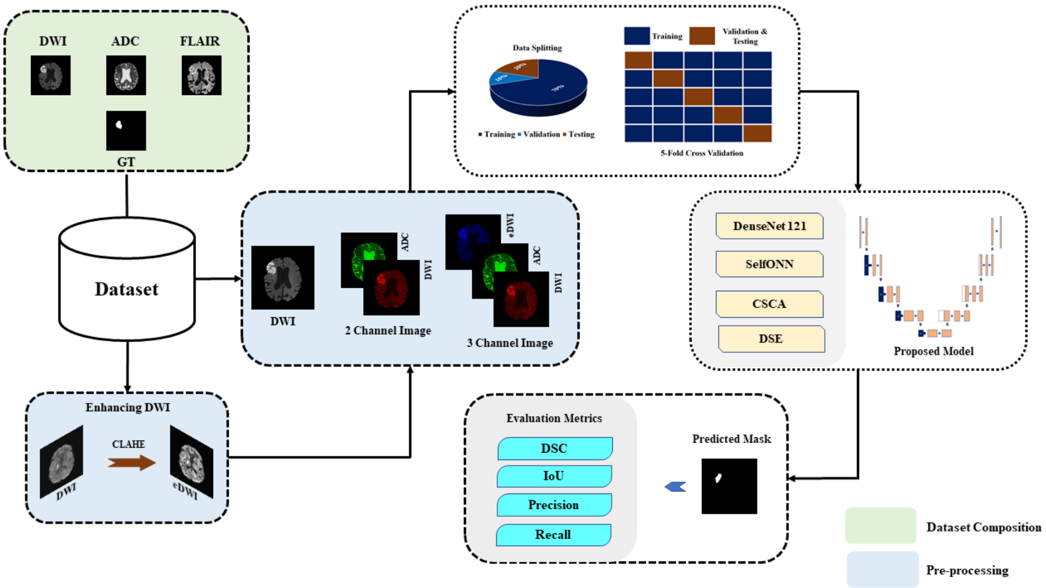

Figure 1: Schematic representation of the experimental pipeline for ischemic lesion segmentation.

[1] WHO Fact sheets, "The Atlas of Heart Disease and Stroke," 02 March 2026. [Online]. Available: https://www.who.int/cardiovascular_diseases/resources/atlas/en/.