Multidisciplinary Education & Training Programme on Radiation Protection and CT Optimisation for Paediatric and Young Adult Patients

RHYTHM (Radiation, Health, Safety and Quality for Youth: A Comprehensive Approach to Justification, Optimisation, and Education)

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This training curriculum has been endorsed by the following societies in July 2026:

European Association of Nuclear Medicine (EANM)

European Federation of Organisations For Medical Physics (EFOMP)

European Federation of Radiographer Societies (EFRS)

European Society of Paediatric Radiology (ESPR)

European Society of Radiology (ESR)

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Description of the project task:

Task 6.1: Development of a multidisciplinary education and training programme

Description: This task will develop the structure, content, and curricula for an E&T programme in radiation protection for paediatric and young adult patients.

The programme will be specifically tailored for a multidisciplinary group of professionals, including radiologists, medical physicists, radiographers, and other healthcare practitioners involved in paediatric imaging.

Building on the relevant outputs from European projects such as SINFONIA, iViolin, MEDRAPET, PiDRL, EUCLID, MEDIRAD, and EURAMED rocc-n-roll, the programme will incorporate the latest advancements and evidence-based practices in radiation protection.

The programme will be a living document and will be updated, as appropriate, to incorporate RHYTHM's findings as they become available. Responsibility for future updates, maintenance, hosting, and dissemination will be defined in consultation with the relevant project partners and professional societies.

Any substantial revisions to an endorsed version will be subject to renewed review by the relevant endorsing societies before being formally adopted or disseminated.

In addition to defining the E&T programme, this task will develop a comprehensive plan for the creation, deployment, dissemination, and long-term sustainability of the materials and tools to be produced in the other tasks of this WP.

This plan will outline the formats, content focus, target audiences, implementation strategies, potential deployment routes, dissemination channels, and sustainability arrangements for these resources, including potential routes such as on-demand resources, congress-based sessions or workshops, and dissemination through professional society communication channels, subject to further coordination with each society.

All T6.1 processes will be carried out in close collaboration with the relevant European professional societies, including ESR, ESPR, EANM, EFRS, EFOMP, and ESTRO, to ensure that the programme aligns with professional standards, addresses the practical needs of clinical practice, avoids duplication with existing educational resources and tools, and supports adoption, dissemination, and sustainable implementation across clinical and educational settings.

The programme will complement, rather than duplicate, existing educational resources, clinical guidance, and audit tools in radiation protection and imaging optimisation, while adding value through its specific multidisciplinary focus on paediatric and young adult CT optimisation.

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1. Programme Overview

This multidisciplinary education and training programme (E&TP) is designed to support the development and consolidation of professional competence in radiation protection and CT optimisation for paediatric and young adult imaging. It may be implemented both as an entry-level structured training pathway and as part of continuing professional development (CPD), recognising that competence in radiological protection requires ongoing maintenance and periodic updates in response to evolving technology, clinical practice, and regulatory expectations.

The E&TP therefore encourages participants and institutions to view optimisation as a sustained professional responsibility embedded within routine clinical governance and quality improvement processes. It is intended to strengthen the capacity of healthcare professionals to deliver safe, justified, and optimised imaging in paediatric and young adult populations, including CT for radiotherapy (RT) treatment planning. Its central focus is the reduction of avoidable radiation exposure while maintaining diagnostic imaging and RT treatment planning image quality and clinical effectiveness.

Children and young adults represent a particularly important group for radiation protection due to increased radiosensitivity and the longer time horizon over which radiation-related risks may manifest. For this reason, the programme places strong emphasis on the practical application of radiation protection principles and protocol optimisation approaches aligned with current international recommendations and regulatory expectations [1], [2].

The E&TP is designed for medical imaging and radiotherapy clinicians (MI&RC), namely radiologists, nuclear medicine physicians, and radiation oncologists, as well as radiographers and medical physicists.

Although the full E&TP is designed as a comprehensive multidisciplinary training pathway, its modular structure allows flexible implementation according to local needs, available time, and professional roles. The complete programme may be delivered as an extended training course, but shorter and more concise versions may also be developed, including introductory formats, selected module packages, and role-specific learning pathways. These pathways may be tailored to the responsibilities of different professional groups, such as radiologists, nuclear medicine physicians, radiation oncologists, radiographers, and medical physicists, while preserving the shared multidisciplinary foundation required for effective radiation protection and CT optimisation.

It adopts a team-based perspective, reflecting the reality that optimisation is achieved not through isolated decisions, but through coordinated practice across the imaging pathway: from referral assessment and justification to protocol selection and acquisition, to dose monitoring and quality assurance.

It supports participants in developing a shared understanding of the roles and responsibilities of each professional group across the imaging pathway, from referral assessment and clinical justification to protocol selection, acquisition parameter optimisation, dose monitoring, and post-examination quality assurance.

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In addition to technical competence, the E&TP is grounded in the promotion of a strong safety culture, recognising that sustainable optimisation depends on systematic learning, transparent communication, and shared responsibility across clinical teams.

In this context, the E&TP fosters evidence-based decision-making and reinforces the systematic application of justification and optimisation strategies, including the practical integration of the ALARA principle, the appropriate use of diagnostic reference levels (DRLs), and the adoption of structured dose reporting and dose management systems [1], [3], in particular automated dose monitoring, cumulative dose tracking, dose alerts, trigger levels and structured review of outliers as part of optimisation governance.

Furthermore, the E&TP addresses key clinical and organisational dimensions of paediatric CT optimisation, including clinical indication-based protocol adaptation, patient preparation and positioning, motion management, communication of radiation risks and benefits to patients and caregivers in a clear, transparent, and ethically appropriate manner [2], [4].

In response to ongoing technological developments, the E&TP also introduces participants to advanced optimisation tools and emerging artificial intelligence (AI)-supported approaches for dose reduction and image quality enhancement, while critically considering their limitations, validation requirements, and governance implications [5], [6].

The E&TP is built on relevant evidence [7], [8], [9], educational resources, harmonisation efforts, and research outputs developed through European research programmes such as SINFONIA, i-Violin, MEDIRAD, PiDRL, EUCLID, and EURAMED rocc-n-roll. This programme further contributes to strengthening multidisciplinary capacity, standardisation of best practices, and sustainable implementation of radiation protection and optimisation strategies across clinical environments [10], [11], [12], [13], [14], [15].

Overall, the programme aims to strengthen professional capacity for continuous quality improvement in paediatric and young adult imaging by equipping participants with the competencies required to evaluate current practice, identify optimisation opportunities, implement targeted protocol improvements, and contribute to a culture of safety and accountability within multidisciplinary imaging teams.

Through this integrated educational framework, the programme ultimately seeks to enhance patient-centred care, improve consistency and standardisation of practice, and support high-quality, safe, and sustainable imaging services [16], [17].

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Learning objectives

The general objective of this multidisciplinary E&TP is to strengthen the knowledge base, professional competencies, and practical skills of healthcare professionals involved in paediatric and young adult imaging, with the overarching aim of ensuring safe, justified, and optimised use of CT procedures, including CT for treatment planning, while maintaining image quality and clinical effectiveness.

Specifically, the programme aims to:

a. Enhance radiation protection competence by ensuring participants understand the biological effects of ionising radiation and the increased radiosensitivity of paediatric and young adult populations.
b. Promote evidence-based justification of imaging examinations**,** enabling participants to critically evaluate referrals, apply appropriateness principles, and select the most suitable imaging modality according to clinical indication.
c. Strengthen optimisation skills for CT protocols**,** supporting the adaptation of acquisition parameters to patient size, age, and diagnostic task in accordance with the ALARA principle.
d. Improve dose awareness and dose management practices**,** including the interpretation of CT dose metrics, implementation of dose monitoring systems, and use of diagnostic reference levels (DRLs) to benchmark and reduce unnecessary exposure.
e. Support quality assurance and continuous improvement**,** enabling participants to integrate protocol optimisation into structured QA programmes, audits, and multidisciplinary optimisation cycles.
f. Develop effective risk–benefit communication competencies, ensuring participants can communicate radiation-related information transparently, ethically, and appropriately to patients and caregivers.
g. Foster multidisciplinary collaboration, reinforcing the complementary roles of physicians, radiographers, and medical physicists in patient-centred imaging pathways and shared responsibility for radiation safety.
h. Develop ethical and patient-centred practice, enabling participants to apply core ethical principles to clinical decision-making in paediatric and young adult imaging and to engage transparently and appropriately with patients, caregivers, and multidisciplinary teams.
i. Introduce and critically assess advanced technologies, including iterative reconstruction and AI-supported tools, with a focus on safe implementation, validation, and governance in clinical practice.

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2. Target audience

This programme is primarily intended for healthcare professionals involved in the planning, performance, optimisation, and quality assurance of diagnostic and radiotherapy imaging procedures using ionising radiation, particularly in paediatric and young adult patients.

It is specifically designed for:

- Radiologists (including paediatric radiologists and general radiologists involved in paediatric CT practice).
- Nuclear Medicine Physicians involved in paediatric and young adult hybrid imaging using ionising radiation (e.g., PET/CT, SPECT/CT), including justification and protocol optimisation.
- Radiation Oncologists involved in paediatric and young adult RT pathways, with specific responsibility for the use of CT for treatment planning and verification imaging and for the integration of radiation protection principles.
- Radiographers responsible for CT acquisition, protocol implementation, optimisation and patient preparation.
- Medical Physicists involved in dose management, quality assurance, and radiation protection governance.

3. Programme structure

The programme consists of eight modules that may be completed as a full programme or combined into shorter thematic or role-specific pathways, depending on the needs of the target audience and the intended level of training:

MODULE 1: Foundations of Radiation Protection (paediatric & young adult imaging)

Learning Objectives

By the end of this module, participants will be able to:

a. Explain the fundamental purpose and principles of radiation protection in paediatric and young adult imaging, including justification and optimisation, focused in the ALARA, ALARP (As Low As Reasonably Practicable) and ALADA (As Low As Diagnostically Acceptable) principles.

b. Describe the biological effects of ionising radiation relevant to medical imaging, including the distinction between tissue reactions and stochastic effects, the mechanisms underlying radiation-induced carcinogenesis, and the factors that determine tissue radiosensitivity.

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c. Describe why paediatric and young adult patients require specific radiation protection approaches, considering age-dependent sensitivity and long-term risk perspective.
d. Interpret key dose concepts and operational CT dose indicators used in clinical practice ($CTDI_{vol}$, DLP, and SSDE where available) and recognise their practical limitations.
e. Identify common sources of avoidable radiation exposure in paediatric CT, including protocol mismatch, excessive scan range, unnecessary multiphase imaging, and repeat acquisitions, as well as suboptimal use of CT for RT treatment planning.
f. Outline core optimisation priorities that support dose reduction while maintaining diagnostic quality in paediatric and young adult CT imaging.
g. Explain the role of diagnostic reference levels (DRLs) as benchmarking tools for supporting optimisation and continuous improvement in clinical practice.

Content

- Conceptual framework of radiation protection in medical imaging, including the scientific rationale for justification and optimisation and the operational implementation of the ALARA principle in paediatric and young adult practice.
- Biological effects of ionising radiation in the context of medical imaging: distinction between tissue reactions and stochastic effects, their dose response relationships, and their relevance at diagnostic dose levels; mechanisms of radiation-induced carcinogenesis and the linear no-threshold (LNT) model; determinants of tissue and organ radiosensitivity and their role in the increased vulnerability of paediatric and young adult patients.
- Age-dependent susceptibility and risk context, addressing the determinants of increased sensitivity in paediatric and young adult populations and the implications of lifetime risk horizon and cumulative exposure for clinical imaging pathways.
- Radiation dose descriptors and exposure quantification in CT, including the interpretation and clinical utility of $CTDI_{vol}$ and DLP, and the role of SSDE (where available) in improving patient-size adapted dose assessment; limitations and uncertainties in translating dose indicators into individual risk.
- Dose-driving parameters and protocol-related determinants of exposure, including scan length, acquisition phases, tube voltage and current modulation concepts, and the relationship between parameter selection, patient attenuation, image noise, and diagnostic task requirements.
- Systematic identification of avoidable exposure mechanisms, including inappropriate protocol selection, such as adult-derived protocols, overscanning, non-indicated multiphase acquisitions, and repeat examinations associated with motion artefacts or workflow inefficiencies. In the context of RT, this also includes practices such as the use of CT planning protocols derived from adult patients in paediatric cases, as well as repeat CT planning examinations associated with inadequate immobilization or failures/changes in the initial treatment plan, among other factors.

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- Scientific basis for optimisation priorities in paediatric CT, focusing on size- and indication-based protocol adaptation, scan coverage standardisation, acquisition simplification, contemporary views on patient shielding and strategies to maintain diagnostic performance while reducing unnecessary radiation burden.
- Benchmarking principles and optimisation governance, including the function of diagnostic reference levels (DRLs) as population-based indicators for protocol evaluation, identification of outliers, and initiation of continuous quality improvement cycles within multidisciplinary imaging services. This includes an introduction to the different levels at which DRLs are established and applied, from local, regional, national, and European values and the implementation of trigger values as a practical mechanism to flag individual examinations exceeding a defined dose threshold, prompting timely clinical review and corrective action.

Learning Methodology

Module 1 will be implemented through a blended learning format with a total duration of approximately 3 hours.

- Participants will first complete 1.5 hours of self-paced e-learning, consisting of short-structured lessons covering the core principles of radiation protection in paediatric and young adult imaging, including justification and benefit-risk principle, optimisation (ALARA and ALARP), dose indicators, and common sources of avoidable exposure.
- This will be followed by a 30-minute formative online quiz with automated feedback to consolidate key concepts.
- The module will conclude with a 1-hour interactive session (live webinar or facilitated workshop), during which participants will work through short clinical scenarios to identify optimisation priorities (e.g., scan length control, phase reduction, protocol adaptation) and discuss multidisciplinary roles in safe imaging practice.

MODULE 2: Paediatric and young adult patient considerations for optimised imaging

Learning Objectives

By the end of this module, participants will be able to:

a. Explain how patient age, size, and body composition influence CT dose and image quality, including the role of tissue attenuation and organ dimensions in protocol performance.
b. Describe key developmental and physiological characteristics of paediatric and young adult patients that affect image acquisition, such as respiratory patterns, heart rate, and susceptibility to motion artefacts.

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c. Apply structured patient stratification approaches (e.g., age-, weight-, or size-based grouping) to support consistent protocol selection and standardised optimisation in clinical practice.
d. Analyse the impact of patient motion and limited cooperation on diagnostic and RT treatment planning image quality and identify strategies to reduce repeat acquisitions and avoidable radiation exposure.
e. Evaluate cumulative exposure considerations in longitudinal imaging pathways, particularly in chronic disease and oncology follow-up, and recognise the importance of sustained optimisation over time.
f. Integrate patient-specific risk factors into optimisation decision-making, including age-dependent sensitivity, organ susceptibility, and clinical urgency.
g. Recognise special clinical situations requiring enhanced radiation protection measures, including adolescent and young adult (AYA) imaging and pregnancy-related considerations in young female patients.

Content

- Patient-specific determinants of CT optimisation: influence of age, body size, and tissue composition on attenuation, dose delivery, and image noise, and implications for protocol adaptation.
- Developmental physiology and acquisition planning: age-related variation in respiratory mechanics and cardiac rate, and how these factors affect scan timing, motion sensitivity, and image quality.
- Patient stratification for standardised protocols: use of age, weight, and size-based categories (including effective diameter concepts) to support reproducible protocol assignment and harmonised practice.
- Motion management and reduction of repeat imaging: mechanisms of motion artefacts, factors influencing cooperation, and practical strategies to improve scan success and minimise repeat exposures.
- Longitudinal imaging and cumulative exposure: considerations for repeated examinations in chronic conditions and oncology surveillance, including optimisation priorities for follow-up protocols and the importance of maintaining justification over time. In RT, the implications of repeated CT planning examinations (for example, due to growth, weight loss, or tumour volume changes) will be addressed, with particular emphasis on strategies to minimise the cumulative imaging dose without compromising geometric accuracy and treatment safety.
- Patient-specific risk context and clinical decision-making: integration of age-dependent sensitivity, organ susceptibility, and diagnostic task requirements into optimisation decisions.
- Adolescents and young adults (AYA): transitional considerations between paediatric and adult services, including protocol harmonisation and consistent optimisation strategies.
- Pregnancy-related considerations in young adults: radiation protection priorities and structured safeguards in imaging pathways involving potential or confirmed pregnancy.

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Learning Methodology

Module 2 will be delivered using a blended learning format combining self-paced theoretical study with applied, case-based discussion to support clinical translation of patient-specific optimisation principles, with a total duration of 3.5 hours.

- Self-paced e-learning (2 hours): participants complete structured online lessons covering age- and size-dependent factors influencing CT optimisation, patient stratification approaches for protocol selection, and motion-related determinants of repeat imaging.
- Interactive case-based session (1 hour): a live webinar or facilitated workshop will be used to analyse representative paediatric and young adult scenarios, focusing on protocol selection, preparation strategies, and identification of avoidable exposure drivers.
- Formative assessment (30 minutes): a short quiz and/or structured reflection task will be used to consolidate learning and assess understanding of key concepts, including patient categorisation and optimisation priorities.

MODULE 3: Justification of medical exposures and clinical appropriateness

Learning Objectives

By the end of this module, participants will be able to:

a. Explain the concept of justification as a fundamental principle of radiation protection and clinical governance in diagnostic imaging, with specific relevance to paediatric and young adult populations.
b. Describe how justification is embedded within international radiation protection guidance and national regulatory requirements, including the need for documented appropriateness, professional accountability, and clinical audit of medical exposures.
c. Define and differentiate the responsibilities of the referrer, radiologists, nuclear medicine physicians, radiation oncologists, and radiographers within the justification process, and explain how multidisciplinary collaboration supports safe, appropriate and consistent decision-making.
d. Apply imaging referral guidelines and appropriateness criteria to determine whether CT is clinically indicated and identify circumstances in which alternative non-ionising modalities (e.g., ultrasound or MRI) represent the preferred diagnostic pathway.
e. Apply justification principles to the use of CT for treatment planning in paediatric and young adult RT, by defining transparent criteria for requesting repeat CT planning examinations (for example, in the presence of clinically relevant anatomical changes).
f. Formulate the diagnostic task and anticipated clinical impact of an imaging examination by linking the referral question to expected benefits in diagnosis, management, or patient outcome.

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g. Critically evaluate common causes of unjustified or insufficiently justified imaging, including lack of adherence to established decision support, incomplete clinical information, duplication of examinations, defensive practice, and variability in local referral habits.
h. Explain the role of clinical decision support approaches in improving referral quality, standardising appropriateness, and strengthening justification practices within routine workflow.
i. Describe how clinical audit and continuous improvement mechanisms can be used to monitor justification performance, identify gaps in practice, and implement corrective actions.
j. Demonstrate communication principles consistent with justified imaging practice, including the ability to explain the rationale for imaging decisions in a transparent and proportionate manner to referring physicians, patients, and caregivers.

Content

This module addresses justification as a central requirement for safe imaging practice and a key determinant of population-level exposure reduction. It is aligned with relevant international radiation protection guidance, European and national requirements, and recognised imaging referral guidelines.

- Justification in diagnostic imaging - definition and clinical rationale: conceptual basis of justification and its relationship to clinical effectiveness, patient safety, and radiation protection.
- International and national frameworks supporting justification: overview of how justification is addressed within international guidance and national regulatory systems, including expectations for documentation, accountability, and audit.
- Professional roles and responsibilities in the justification process: the contribution of referrers, practitioners, and operators; multidisciplinary coordination in paediatric and young adult imaging pathways.
- Appropriateness criteria and referral guideline implementation: use of imaging referral guidelines, appropriateness criteria, and structured clinical information to support consistent decision-making and reduce variability in practice.
- Alternative imaging strategies and pathway selection: selection of ultrasound and MRI as non-ionising alternatives where appropriate, including consideration of diagnostic performance, availability, and clinical urgency.
- Diagnostic task definition and clinical value: linking the clinical question to the imaging strategy; evaluation of incremental value; avoidance of unnecessary repeat or low-impact examinations.
- Drivers of unjustified imaging and practice variation: system-level and behavioural contributors to inappropriate imaging, including workflow constraints, limited guideline integration, and incomplete referral information.

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- Decision support approaches in clinical workflow: principles of clinical decision support and its role in improving referral quality, standardisation, and compliance with justification requirements.
- Clinical audit and continuous quality improvement: audit models for justification, performance indicators, feedback processes, and corrective action cycles.
- Communication aligned with justification decisions: clear and proportionate explanation of imaging decisions, including managing expectations and supporting patient- and caregiver-centred care in paediatric contexts.

Learning Methodology

Module 3 will be delivered using a blended learning format that combines structured theoretical preparation with applied guideline-based decision-making exercises, supporting the translation of justification principles into routine clinical practice, with a total duration of 4 hours.

- Self-paced e-learning (2 hours): participants complete online learning units introducing the concept of justification, professional responsibilities, and the use of imaging referral guidelines and appropriateness criteria in CT decision-making.
- Interactive workshop/webinar (1.5 hours): a live session will focus on case-based referral assessment, where participants apply appropriateness frameworks to determine whether CT is indicated, identify alternative imaging pathways, and discuss multidisciplinary roles in justification.
- Formative assessment and reflection (30 minutes): A short quiz and a structured referral-review exercise will be used to consolidate learning, evaluate understanding, and promote reflective practice.

MODULE 4: CT optimisation techniques for paediatric and young adult patients

Learning Objectives

Upon successful completion of this module, participants will be able to:

a. Explain the fundamental relationship between CT acquisition parameters, radiation dose, and diagnostic image quality, with emphasis on clinically based image quality requirements in paediatric and young adult imaging.
b. Describe the influence of key CT protocol parameters (including tube voltage, tube current, pitch, collimation, rotation time, scan length, and reconstruction settings) on radiation exposure and image quality outcomes.
c. Interpret and apply practical CT dose descriptors to evaluate protocol performance and identify opportunities for optimisation in paediatric and young adult examinations.

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d. Apply patient-size and indication-based optimisation strategies to adapt CT protocols to paediatric and young adult patients while maintaining diagnostic adequacy.
e. Evaluate the clinical and technical appropriateness of multiphase acquisitions, including the impact of phase selection, scan range overlap, and contrast timing on cumulative dose.
f. Explain the principles and clinical relevance of automatic exposure control (AEC), including tube current modulation and voltage selection strategies, and the importance of accurate patient positioning and centring.
g. Describe the role of reconstruction methods in optimisation, including iterative reconstruction approaches and their influence on noise characteristics and diagnostic performance.
h. Integrate optimisation strategies into multidisciplinary protocol management, recognising how MI&RC, radiographers, and medical physicists contribute to safe and standardised protocol implementation.
i. Apply optimisation principles to CT planning protocols in paediatric and young adult RT, balancing image quality requirements for target and organ-at-risk delineation and localisation with rigorous minimisation of radiation dose.

Content

This module provides an advanced and practice-oriented overview of CT optimisation, focusing on the scientific basis of dose reduction strategies and their implementation in paediatric and young adult imaging.

- CT image quality fundamentals for optimisation: clinically based concepts of image quality, including noise, contrast resolution, spatial resolution, artefacts, and diagnostic acceptability.
- Dose/image quality relationships in CT: principles governing dose efficiency, signal-to-noise considerations, and the trade-offs inherent to protocol optimisation.
- CT acquisition parameters and dose drivers: scientific and operational impact of protocol parameters, including tube voltage and current, pitch, rotation time, collimation, scan length, and phase selection.
- Patient-size adaptation and protocol stratification: size-based protocol selection principles, age/weight/effective diameter approaches, and harmonisation strategies for paediatric and young adult populations.
- Automatic exposure control (AEC) and patient positioning: principles of modulation systems, impact of patient centring on dose and image quality, and practical approaches to consistent positioning.
- Scan range optimisation and overscanning control: strategies to standardise anatomical coverage, minimise unnecessary exposure, and avoid overlap between phases or adjacent acquisitions. Optimisation of CT planning protocols in paediatric and young adult RT, with particular focus on tailoring craniocaudal scan length to the tumour localisation and adjacent structures requiring accurate delineation, in order to avoid unnecessary anatomical coverage.

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- Multiphase CT and contrast-enhanced protocols: clinical indication-based phase selection, contrast timing considerations, and strategies to reduce cumulative dose while maintaining diagnostic image quality.
- Reconstruction strategies for dose optimisation: role of iterative reconstruction and advanced reconstruction settings in noise reduction, image quality preservation, and clinical indication performance.
- Integration into protocol governance and optimisation cycles: multidisciplinary protocol review, documentation of protocol changes, evaluation of outcomes, and alignment with benchmarking approaches (e.g., DRLs).

Learning Methodology

Module 4 will be delivered using a practice-oriented blended learning format, combining structured theoretical instruction with applied protocol optimisation exercises to ensure that participants can translate optimisation principles into routine clinical CT practice, with a total duration of 6 hours.

- Self-paced e-learning (2.5 hours): participants complete online learning units covering the scientific basis of CT optimisation, including dose/image quality relationships, protocol parameters, automatic exposure control, scan range management, and reconstruction strategies.
- Interactive optimisation workshop / webinar (2 hours): a live session will focus on applied optimisation activities, where participants review representative paediatric and young adult CT protocols, analyse parameter choices, and discuss strategies to reduce dose while maintaining diagnostic image quality.
- Guided practical assignment (1 hour): participants complete a structured protocol optimisation task (e.g., adjustment of scan range, phase selection, and parameter settings for a given clinical indication), supported by a standardised template and peer/facilitator feedback.
- Formative assessment (30 minutes): a short quiz or a decision exercise based on acquisition parameters will be used to consolidate key concepts and assess understanding of optimisation strategies.

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MODULE 5: Advanced technologies and innovation for dose reduction and quality improvement

Learning Objectives

Upon successful completion of this module, participants will be able to:

a. Describe current and emerging technological developments in CT imaging that support radiation dose reduction and diagnostic quality improvement in paediatric and young adult practice.
b. Explain the principles, clinical rationale, and limitations of advanced reconstruction techniques, including iterative reconstruction and deep learning–based reconstruction methods, and their influence on image quality characteristics and diagnostic performance.
c. Evaluate the role of automation and intelligent scanner functionalities (e.g., automatic patient centring, automated kV selection, tube current modulation enhancements) in standardising optimisation and reducing variability in clinical practice.
d. Assess the potential of emerging CT hardware technologies (such as spectral imaging and photon-counting CT) for improving dose efficiency and diagnostic performance in paediatric and young adult imaging.
e. Identify and analyse common sources of image artefacts (e.g., motion, metal artefacts, beam hardening, attenuation correction artefacts in hybrid imaging) and discuss modern technical strategies for artefact mitigation.
f. Critically appraise the safe clinical implementation of innovative tools, including requirements for validation, performance evaluation, quality assurance, and clinical governance.
g. Discuss the role of artificial intelligence (AI) in radiation protection and optimisation, including its applications in protocol selection, dose monitoring, image reconstruction, and workflow decision support, while critically assessing the need for paediatric and young adult specific validation, particularly where tools have been developed or trained primarily using adult data.
h. Integrate innovation into multidisciplinary optimisation practice, ensuring that new technologies are adopted in a manner that supports patient safety, clinical effectiveness, and continuous quality improvement.

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Content

This module explores technological innovation as a driver of sustainable optimisation in paediatric and young adult imaging, focusing on advanced CT capabilities, automation, and AI-supported tools for dose reduction and quality enhancement.

- Innovation landscape in CT optimisation: overview of emerging technological trends and their relevance to paediatric and young adult imaging.
- Advanced reconstruction methods: iterative reconstruction and deep learning-based reconstruction: principles, image noise/texture effects, and diagnostic task considerations.
- Automation and protocol standardisation tools: automated exposure selection, automatic kV optimisation, patient centring technologies, and workflow-based decision support mechanisms.
- Emerging CT hardware developments: spectral CT and photon-counting CT, dose efficiency, contrast performance, and potential clinical applications in paediatric imaging.
- Artefacts and mitigation strategies: mechanisms of artefact generation (motion, metal, beam hardening) and modern correction methods; relevance to hybrid imaging systems.
- AI applications in optimisation and dose management: AI-based approaches for protocol selection, dose prediction, dose outlier detection, reconstruction enhancement, and workflow support.
- Paediatric-specific validation of AI-supported tools: assessment of whether AI-based tools have been adequately validated in paediatric and young adult populations before clinical implementation, including their impact on image quality, diagnostic performance, dose, and local governance requirements.
- Validation, quality assurance, and governance for innovation: requirements for safe adoption, acceptance testing, clinical validation, performance monitoring, and risk management.
- Implementation into clinical practice: multidisciplinary strategies for integrating new tools into protocol governance, training, and continuous improvement cycles.

Learning Methodology

Module 5 will be delivered using a blended learning format combining technology-focused theoretical instruction with critical appraisal and applied discussion activities, enabling participants to understand and evaluate innovation in dose optimisation and image quality improvement, with a total duration of 6 hours.

- Self-paced e-learning (3 hours): participants complete online learning units introducing advanced reconstruction methods, automation tools, emerging CT hardware, and AI-supported approaches relevant to paediatric and young adult optimisation.

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- Interactive seminar / webinar (1.5 hours): a live session will be used to review clinical examples and discuss the practical implications of innovation, including benefits, limitations, and variability in implementation across imaging systems.
- Critical appraisal activity (1 hour): participants complete a guided evaluation exercise (e.g., structured review of a reconstruction or automation tool) focusing on image quality impact, dose implications, and implementation requirements.
- Formative assessment (30 minutes): a short quiz or scenario-based decision task will be used to consolidate learning and assess understanding of technology-driven optimisation principles.

MODULE 6: Quality assurance, audit and safety learning systems

Learning Objectives

Upon successful completion of this module, participants will be able to:

a. Explain the role of quality assurance (QA) in CT imaging as a structured approach to ensure consistent equipment performance, stable protocol implementation, and reliable diagnostic and RT treatment planning image quality in paediatric and young adult practice.
b. Describe the key components of CT QA programmes, including routine performance testing, protocol verification, dose monitoring procedures, and image quality evaluation, including objective and subjective methods.
c. Interpret dose monitoring outputs and benchmarking indicators to identify protocol drift, dose outliers, and variability in practice requiring investigation and corrective action.
d. Apply the principles of clinical audit to evaluate compliance with justification and optimisation requirements, including the selection of audit criteria, data collection methods, and performance indicators.
e. Explain the function of safety learning systems, including incident reporting, event classification, root-cause analysis, and implementation of corrective and preventive actions in imaging services.
f. Perform structured analysis of repeat and reject imaging events, identifying workflow, patient-related, and technical contributors to avoidable exposure and reduced efficiency.
g. Propose evidence-informed improvement actions based on QA, audit, and safety learning outcomes, supporting sustainable optimisation and patient safety culture.
h. Demonstrate an understanding of multidisciplinary governance mechanisms required to implement QA and audit findings into routine protocol management and continuous improvement cycles.

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Content

This module provides a comprehensive overview of quality assurance and clinical governance mechanisms that support sustainable radiation protection and optimisation in paediatric and young adult imaging services.

- Quality assurance as a component of clinical governance: definition, objectives, and scope of QA in CT imaging; relationship between QA, optimisation, and patient safety.
- CT equipment performance and routine QA testing: principles of acceptance testing, routine constancy testing, and performance evaluation; key parameters relevant to image quality and dose stability.
- Protocol verification and protocol drift management: importance of protocol consistency, documentation, change control, and monitoring for unintended deviations over time.
- Dose monitoring systems and benchmarking approaches: use of dose management systems, analysis of $CTDI_{vol}$/DLP distributions, identification of outliers, interpretation in relation to diagnostic reference levels (DRLs), and implementation of corrective actions.
- Clinical audit methodology in imaging practice: audit cycle design, selection of standards, data collection, evaluation of compliance, reporting, and implementation of corrective actions.
- Safety learning systems and incident reporting: reporting frameworks, classification of events, investigation processes, and translation of learning into risk reduction measures.
- Reject/retake analysis and repeat exposure reduction: identification of causes of repeat imaging (motion, protocol selection, positioning, planning errors), performance indicators, and strategies to reduce avoidable exposure.
- Continuous quality improvement and multidisciplinary governance: integration of QA and audit outputs into protocol optimisation committees, staff training, and structured improvement cycles in paediatric and young adult imaging.

Learning Methodology

Module 6 will be delivered using a blended and practice-oriented learning format, combining structured theoretical preparation with applied quality and safety exercises.

The module is designed to strengthen participants' ability to translate QA and audit principles into routine optimisation governance in paediatric and young adult imaging services, with a total duration of 6.5 hours.

- Self-paced e-learning (2.5 hours): participants complete online learning units covering the principles of CT quality assurance, dose monitoring, benchmarking, clinical audit methodology, and safety learning systems.

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- Interactive workshop / webinar (2 hours): a live session will focus on applied interpretation of QA and dose monitoring outputs, identification of outliers and protocol drift, and discussion of corrective actions within a multidisciplinary governance context.
- Applied practical exercise (1.5 hours): participants complete a structured activity such as a mini-audit plan, a dose outlier investigation scenario, or a reject/retake analysis task, supported by templates and guided instructions.
- Formative assessment (30 minutes): a short quiz and/or scenario-based questions will be used to consolidate learning and assess understanding of QA and audit principles.

MODULE 7: Multidisciplinary collaboration and workflow integration for optimisation

Learning Objectives

Upon successful completion of this module, participants will be able to:

a. Explain the rationale for multidisciplinary collaboration in paediatric and young adult imaging optimisation, including how coordinated decision-making improves radiation protection, diagnostic quality, and consistency of practice.
b. Define the complementary roles and responsibilities of MI&RC, radiographers, medical physicists in the optimisation process across the imaging pathway.
c. Describe workflow components and decision points that influence radiation exposure and image quality, from referral assessment and protocol selection to acquisition, reconstruction, reporting, and follow-up.
d. Apply structured communication and documentation principles to support harmonised protocol implementation, clear task definition, and effective escalation of dose or quality concerns.
e. Evaluate organisational factors affecting optimisation performance, including protocol standardisation, staffing models, training needs, equipment variability, and local governance structures.
f. Propose multidisciplinary optimisation workflows that integrate justification, protocol review, dose monitoring, and quality assurance into routine clinical practice.
g. Demonstrate the ability to participate in protocol management processes, including protocol development, revision, change control, and periodic review based on clinical and technical evidence.
h. Identify strategies to support sustainable implementation and cultural change, promoting accountability, continuous improvement, and patient-centred safety within imaging services.

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Content

This module focuses on the organisational and professional integration required for sustainable optimisation in paediatric and young adult imaging.

It emphasises workflow-based decision-making, multidisciplinary governance, and structured collaboration across imaging services.

- Multidisciplinary optimisation as a clinical governance requirement: scientific and organisational rationale for team-based optimisation; impact on patient safety, quality, and standardisation.
- Professional roles and responsibilities across imaging pathways: contributions of MI&RC, radiographers, medical physicists, including shared accountability and interfaces between roles.
- Workflow mapping and optimisation touchpoints: identification of key workflow stages influencing dose and image quality, including referral, justification, protocol assignment, acquisition planning, patient preparation, reconstruction, reporting, and follow-up.
- Communication, documentation, and standardisation mechanisms: protocol documentation standards, diagnostic task definition, structured reporting elements, and escalation pathways for dose outliers and image quality issues.
- Protocol governance and change management: protocol committees, multidisciplinary review processes, version control, training updates, and evaluation of outcomes following protocol modifications.
- Integration of optimisation tools into routine practice: incorporation of DRLs, dose monitoring systems, QA outputs, and audit findings into structured workflow and governance cycles.
- Organisational determinants of optimisation performance: variability across equipment, staffing, workload pressures, and resource constraints; strategies to maintain quality and safety in diverse settings.
- Sustainable implementation and continuous improvement culture: building accountability, promoting shared ownership of optimisation, and embedding continuous improvement as a routine standard of clinical practice standard.

Learning Methodology

Module 7 will be delivered using a collaborative and workflow-oriented blended learning format, designed to strengthen multidisciplinary integration and support the practical implementation of optimisation governance in paediatric and young adult imaging services, with a total duration of 6.5 hours.

- Self-paced e-learning (2 hours): participants complete online learning units introducing multidisciplinary roles, workflow-based optimisation principles, protocol governance structures, and communication /documentation requirements.

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- Interactive multidisciplinary workshop / webinar (2 hours): a live session will focus on structured discussion and workflow mapping exercises, where participants analyse optimisation touchpoints across the imaging pathway and identify team-based strategies to improve consistency, safety, and protocol implementation.
- Group-based applied activity (1.5 hours): participants complete a guided task (e.g., development of a multidisciplinary optimisation workflow or protocol review pathway) using templates that can be adapted to local institutional practice.
- Formative assessment (30 minutes): a short scenario-based quiz and reflection task will be used to consolidate learning and assess understanding of workflow integration and governance principles.

MODULE 8: Ethics and patient-centred care

Learning Objectives

Upon successful completion of this module, participants will be able to:

a. Critically explain the ethical foundations of radiation protection in medical imaging, demonstrating how the principles of beneficence, non-maleficence, respect for autonomy, and justice inform decision-making in paediatric and young adult imaging practice. This includes ethical considerations specific to paediatric and young adult RT, such as communication with patients and caregivers about the need for additional CT planning examinations.
b. Analyse the integration of patient-centred care within imaging pathways involving ionising radiation, with emphasis on safeguarding patient welfare, promoting dignity, and supporting informed participation in clinical processes.
c. Evaluate the ethical dimensions of justification and optimisation, recognising these as professional and moral obligations aimed at preventing unnecessary exposure while maintaining diagnostic effectiveness and clinical value.
d. Interpret paediatric-specific ethical considerations, including the role of caregivers in decision-making, the concepts of assent and consent, the protection of vulnerable populations, and the requirement to act in the best interests of the child.
e. Demonstrate competence in communicating radiation-related information in an ethically appropriate manner, including the ability to present risk–benefit information clearly, proportionately, and transparently, while acknowledging uncertainty where relevant.
f. Identify and address common sources of misunderstanding, anxiety, and misperception associated with radiation exposure, applying evidence-informed communication strategies that support trust and reduce avoidable distress.

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g. Examine the ethical implications of variability in clinical practice, including disparities in access to non-ionising alternatives, differences in optimisation resources, and the potential impact of institutional variation on equity and patient outcomes.
h. Apply ethical reasoning to clinical scenarios, integrating diagnostic necessity, patient-centred values, and radiation protection principles in a balanced and defensible decision-making process.

Content

This module addresses ethics and patient-centred care as essential dimensions of high-quality imaging practice in paediatric and young adult populations. It explores how ethical principles support justification and optimisation, guide professional responsibilities, and strengthen communication and trust in contexts involving ionising radiation.

- Ethical principles underpinning medical imaging practice: core ethical frameworks relevant to healthcare and their application to diagnostic imaging, with particular reference to radiation protection and the prevention of avoidable harm.
- Patient-centred care in paediatric and young adult imaging services: concepts of dignity, respect, empathy, and responsiveness to patient and caregiver needs, including cultural and developmental considerations.
- Ethical foundations of justification and optimisation: justification as an ethical requirement for clinical appropriateness and proportionality; optimisation as a commitment to minimising radiation burden while preserving diagnostic and RT treatment planning image quality.
- Paediatric-specific ethical and safeguarding considerations: best-interest decision-making, vulnerability, caregiver involvement, assent and consent processes, and ethical responsibilities in complex clinical situations.
- Risk–benefit communication and ethical transparency: approaches to communicating radiation risk and diagnostic benefit, including proportional framing, avoidance of misleading comparisons, and management of uncertainty.
- Addressing caregiver concerns and radiation-related misconceptions: common questions and concerns in paediatric imaging and structured communication approaches to support understanding, reassurance, and informed engagement.
- Equity, practice variation, and ethical governance: ethical implications of variation in access to imaging resources and optimisation tools, and the importance of standardisation and governance in promoting fairness and quality of care.
- Applied ethics through case-based discussion: structured analysis of representative scenarios (e.g., emergency imaging, repeated follow-up, complex chronic conditions) to support ethical reasoning and multidisciplinary reflection.

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Learning Methodology

Module 8 will be delivered using a blended, discussion-oriented learning format that integrates conceptual ethical frameworks with applied clinical reflection, supporting the development of ethically robust and patient-centred decision-making in paediatric and young adult imaging, with a total duration of 4.5 hours.

- Self-paced e-learning (1.5 hours): participants complete online learning units introducing ethical principles relevant to medical imaging, the patient-centred care framework, and the ethical dimensions of justification, optimisation, and communication in paediatric and young adult practice.
- Interactive seminar / facilitated discussion (1.5 hours): a live webinar or workshop will be used to explore ethical challenges through guided discussion, enabling participants to examine professional responsibilities, caregiver involvement, and practical approaches to transparent risk/benefit communication.
- Case-based reflection activity (1 hour): participants complete structured scenario analysis exercises focusing on ethically complex situations (e.g., emergency imaging decisions, repeated follow-up examinations, caregiver refusal or anxiety), with emphasis on defensible decision-making and multidisciplinary perspectives.
- Formative assessment (30 minutes): a short reflective assignment and/or scenario-based quiz will be used to consolidate learning and assess the ability to apply ethical reasoning and patient-centred communication principles.

4. Final remarks

This multidisciplinary education and training programme has been developed to support the implementation of safe, justified, and optimised CT practice, including CT for RT treatment planning, for paediatric and young adult patients.

By integrating radiation protection principles with evidence-informed optimisation strategies, the programme aims to strengthen diagnostic effectiveness while reducing avoidable radiation exposure in routine clinical pathways. By explicitly integrating both diagnostic imaging and RT contexts, the programme promotes a coherent approach to radiation protection across the entire clinical pathway, including the treatment planning of RT treatments in paediatric and young adult patients.

The programme is explicitly underpinned by an ethical approach to radiological protection, recognising that justification and optimisation extend beyond technical requirements and constitute fundamental professional responsibilities. In this context, the programme aligns clinical decision-making with established ethical principles, including beneficence and non-maleficence, respect for patient dignity, and the promotion of equitable and high-quality care.

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Particular emphasis is placed on the heightened vulnerability of paediatric populations and the need for transparent, proportionate, and patient-centred communication with patients and caregivers.

Sustainable optimisation is addressed as a shared multidisciplinary process, requiring coordinated contributions from radiologists, nuclear medicine physicians, radiation oncologists, radiographers and medical physicists, across the imaging pathway.

Through structured learning, applied clinical examples, and governance-oriented implementation perspectives, the programme supports participants in translating knowledge into practice improvements, including enhanced referral appropriateness, protocol standardisation, dose awareness, and quality assurance integration.

Overall, the programme contributes to strengthening a culture of continuous improvement within paediatric and young adult imaging services, supporting professional accountability and promoting alignment with relevant international guidance and recognised imaging referral recommendations.

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