Institute of Physics and Engineering in Medicine
Fairmount House, 230 Tadcaster Road, York YO24 1ES

POLICY STATEMENT: The Roles of the Scientist and Technologist in Radiotherapy Physics

1. Introduction

Radiotherapy (RT) is the targeting of tumour cells with ionising radiation, most commonly high energy (megavoltage) photon beams from a linear accelerator (linac). Radiotherapy is also performed using lower energy (kilovoltage) photons, electrons, and protons, as well as injected or implanted radionuclides, depending on the clinical requirements. It can be a stand-alone treatment, or combined with surgery, chemotherapy, hormone therapy, or a combination of these. Radiotherapy can target even undetectable microscopic disease, and is most often delivered in small daily doses of radiation called fractions over a period of a few weeks. About 40% of patients cured of their disease have radiotherapy as part of their treatment, second only to surgery [1].

This policy provides an overview of the roles of the Clinical Scientist and Technologist in RT physics. It should be noted that individual roles and responsibilities for specific appointments may vary in each centre Guidance on appropriate staffing levels are given by the IPEM policy statement *Recommendations for the Provision of a Physics Service to Radiotherapy* [2].

2. Scientists in radiotherapy physics

The scientific workforce in radiotherapy comprises Clinical Scientists (RT physicists) and technologists (often called RT dosimetrists) specialising in medical physics. RT physicists and RT dosimetrists are involved in all aspects of treating cancer patients with radiation. Although they might have less direct patient contact than a clinician or radiographer, RT physicists and RT dosimetrists are essential members of the multi-disciplinary team responsible for the design and delivery of radiotherapy treatment. The responsibility of this team is to ensure the highest quality of personalised radiation treatment for each patient. The RT physicists and technologists work closely with electronic and mechanical engineers who maintain treatment units or design and produce bespoke equipment for the radiotherapy service.

The scientific workforce will have an undergraduate degree related to their specialism, followed by further postgraduate study and practical clinical experience, as required by an accredited training programme [3]. Clinical Scientists are registered with the Health and Care Professions Council (HCPC). Much of the role of the RT physicist is in taking responsibility for implementation, maintenance, and development of systems for calculating or delivering radiation to patients, whether equipment-related or clinical techniques. This involves applying scientific principles and knowledge of radiation physics in particular to ensure the quality of these commissioned systems. Consultant Clinical Scientists leading specific RT physics sections take overall responsibility for scientific service. Training for leadership roles is now delivered through the Higher Specialist Scientist Training programme (HSST) [4], including equivalence routes.

Clinical Technologists also have a scientific background but will be more focused on technical tasks including those associated with individual patient treatments. They may specialise in dosimetry, planning, or mould room duties, along with information technology, electronic engineering or mechanical engineering. A number of different entry routes are available, including accredited training programmes, transfer from a related discipline such as treatment radiography, or direct entry with suitable science or information technology qualifications. Clinical technologists do not need to be professionally registered but registration with the Register of Clinical Technologists [5] is recommended.

RT physicists with a thorough and detailed understanding of RT physics, along with appropriate skills and experience, may act as a Medical Physics Expert (MPE). MPEs are legally required to be closely involved in radiotherapy, and take responsibility for aspects of treatment accuracy such as dosimetry, equipment management (including commissioning and quality assurance, QA), optimisation (including treatment planning), and consulting on situations that fall outside of standard protocols. Further descriptions of the role of MPE can be found in the UK Medical and Dental Guidance Notes [6] and European guidelines [7].

3. Scientific service provision

3.1 Optimisation (treatment planning and imaging)

Each patient receiving radiotherapy has their treatment individually planned, usually based on anatomical information from a computed tomography (CT) scan or other imaging modality. The position of the tumour is identified, as well as the healthy tissues to be avoided. The location of these anatomical structures determines the arrangement, energy and intensity of the radiation used to target the tumour, as simulated in the computerised treatment planning system. Radiotherapy treatment planning can range from simple manual calculation of open fields, to complex inverse-planned dynamic treatments involving sophisticated computational algorithms. The aim of the treatment is to deliver the maximum dose to the tumour without exceeding the tolerance of the healthy tissues.

Treatment planning is typically performed by specialist planning radiographers, RT dosimetrists or, particularly for new or complex techniques, RT physicists. It is the responsibility of the RT physicist to design and implement robust dose checking systems to ensure all patient treatments have been acceptably verified prior to treatment. Complex situations may arise, such as the need for off-protocol treatments or dose assessment of anatomical changes during treatment that require input from the RT physicist or MPE. The RT physicist is responsible for performing a radiation dose or radiobiological assessment in terms of achieving successful treatment outcome, and providing scientific advice. For example the RT physicist can advise on the dose tolerance of a patient who has had previous radiotherapy.

Technologists are responsible for practical aspects and development of computed treatment preparation, including patient immobilisation and plan verification. They may also be involved in developing these procedures. Mould room technologists manufacture custom immobilisation devices and shields.

MPEs have the overall responsibility for all scientific aspects of the treatment planning process, including designing protocols for standard treatments, introduction of new equipment or techniques, and advising on non-standard situations.

Imaging in radiotherapy has been one of the most rapidly advancing areas over recent decades. Linacs now have 'on-board imaging' capabilities as standard, used to confirm patient setup on a day-to-day basis. Imaging allows specific localisation of the tumour and surrounding anatomies. Capabilities such as deep-inspiration breath hold, 4D imaging over time, and respiratory gating with real time monitoring, allow precise treatment to be delivered in cases that are otherwise difficult.

Imaging parameters must be determined to achieve optimal quality and/or dose. It is the responsibility of the RT physicist to implement new imaging techniques in radiotherapy, to continually optimise imaging-dose settings, and to cascade training to all end-users.

3.2 Dosimetry

Linacs, typically mounted on a rotating or ring gantry with the patient centrally positioned, deliver high-energy photon or electron treatment beams. It is the responsibility of the RT physicist to calibrate these linacs so that the delivered radiation dose matches that simulated on the treatment planning system.

The radiation-measuring equipment used to calibrate a linac is regularly calibrated against the primary standard held at the National Physical Laboratory. It is the responsibility of the RT physicist to derive and validate equipment calibration factors via precise measurement.

Complex treatments are often verified on a per-patient basis to ensure accurate delivery, by RT physicists or technologists.

MPEs have the overall responsibility for accurate calibration of treatment equipment, including establishing dosimetry protocols, provision of beam data for calculations, and active involvement in definitive calibration.

3.3 Brachytherapy

Brachytherapy is the term for close-range or internal radiotherapy, where sources of radiation are placed (permanently or temporarily) in contact with the site to be treated to deliver a very high localised dose. Performed within an appropriately-shielded operating theatre environment, the RT physicist will be available for immediate advice and dose calculation. RT technologists may be involved in the preparation of sealed sources for treatment use or source holders for direct skin contact, and may assist in theatre.

3.4 Scientific computing

Radiotherapy departments may manage their own computer systems, separate from the main hospital network, because IT failures could adversely affect patient treatments. A close working relationship with hospital IT specialists should exist. All patient information and radiotherapy treatment records are contained on a 'Record and Verify' system enabling seamless data transfer with the treatment delivery system.

RT physicists and technologists often develop bespoke in-house software systems to address specific clinical requirements, and may provide technical support for computer hardware and a range of software related to scientific and clinical applications. Any computational system introduced with a clinical implication is appropriately risk-assessed and robustly tested. The RT physicist is responsible for the management, operation, and quality assurance of computer systems within the radiotherapy environment.

Some RT physicists and technologists manage the networked verification systems and dedicated computer systems used for treatment planning and other radiotherapy applications.

3.5 Equipment management (commissioning and quality assurance)

The RT physicist carries out the acceptance and commissioning of new treatment equipment. This involves undertaking precise and accurate measurements of the parameters required by the treatment planning system in order to correctly model the beam output of the linac. Prior to being released into clinical use, the entire system is rigorously tested end-to-end using ‘dummy’ patient data to ensure the process runs seamlessly.

Regular quality assurance checks are performed by the RT physicist or technologist in conjunction with RT engineers. It is the responsibility of the RT physicist to actively monitor all radiotherapy equipment, set tolerances for acceptable performance levels, critically assess faults, and act when remedial action is required. As well as linacs, radiotherapy equipment can include imaging systems (CT, MRI or PET scanners, ultrasound scanners, therapeutic or diagnostic X-ray machines), patient monitoring equipment, and patient safety systems.

The RT physicist works closely with electronic engineers who carry out repairs on therapy equipment. In-house engineering teams can provide the quick response necessary for minimum disruption of patient treatment in the event of a breakdown. In many departments, the linac engineers carry out all repairs, planned maintenance and electrical safety testing, which can maximise machine availability and save maintenance costs.

RT Physicists may also work closely with mechanical engineers for design and fabrication of treatment aids using machine tools, and in mechanical aspects of repair, maintenance, and safety of radiotherapy equipment. Such engineers often make modifications and improvements to the equipment and immobilisation to facilitate special techniques.

3.6. Safety

Radiation protection of staff and the public is governed by the Ionising Radiations Regulations. Every employer must appoint a suitably qualified Radiation Protection Adviser (RPA) to provide advice on the implementation of the regulations. RT physicists may be accredited RPAs and in this capacity will advise the employer on radiation safety matters such as the design of shielding and appropriate protection measures. RT physicists assist the employer to implement the regulations by carrying out a variety of tasks such as radiation risk assessments and radiation safety training.

3.7. Service design and development

The provision of high quality radiotherapy services in a safe and effective manner is of vital importance. The RT physicist has a central role in the provision of these services; they maintain and improve the quality, efficacy and safety of measurement and investigation techniques to ensure that technology is used appropriately and that services are provided in line with best practice. The RT physicist also has a role in the introduction and advancement of new techniques for the benefit of the patient.

The RT physicist will advise on the adoption of new techniques and service modifications where appropriate. This includes evaluation of clinical demand, assessment of clinical risk, resource management, critical evaluation of new techniques and the optimisation of existing techniques and clinical applications. This will invariably require liaison and cooperation with other stakeholders and may include the drawing up of Service Level Agreements. Services may also develop and improve through the medium of a quality management system and working under service accreditation such as ISO9001 [9].

4. Leadership

Consultant RT physicists have overall responsibility for system specification, procurement, acceptance testing and commissioning. They take responsibility for the technical and scientific work of others, and are likely to stimulate system replacements, introduce innovations, and make policy and service design proposals. They will work with other radiotherapy professionals to set the strategy for clinical service development. The Head of Radiotherapy Physics will be one of the Lead Scientists in the hospital.

5. Education, research and innovation

RT physicists & RT dosimetrists are regularly involved in the teaching and training of other staff, including trainee clinical scientists, clinical technologists, doctors, radiographers and nurses. They may also teach on university courses at undergraduate or graduate level.

RT Physicists often work closely with other disciplines to innovate and develop new radiotherapy techniques. Examples include the widespread implementation of Intensity Modulated Radiotherapy (IMRT), where the beam intensity is varied to more closely conform the delivered dose to the patient anatomy, and Stereotactic Body Radiotherapy (SBRT or SABR), where large doses of radiation are delivered to millimetre accuracy. For innovation support, RT physicists may work with commercial partners or be fully employed within commercial companies, to develop techniques before wider adoption. Recent developments have strengthened the need for sophisticated imaging as part of the therapeutic process to ensure accurate targeting of the tumour, minimising the impact of organ motion and positioning uncertainties. The latest innovations include use of MRI during treatment for visualisation of soft tissues and daily adaptation, the use of protons and other particles to deliver highly localised doses, and the combination of radiotherapy with sophisticated drugs in order to maximise the therapeutic outcome.

Innovation can also include trouble-shooting local challenges, streamlining workflows and adding value to all aspects of the process. Research and innovation may be disseminated through conference presentations, peer reviewed publications or professional guidance. The specialist scientific workforce in radiotherapy has an essential role in the translation of cutting edge research into clinical reality, and their combination of knowledge and skills makes them ideally suited to fulfil that role.

References

[1] Cancer Research UK (CRUK) (2009). Achieving a world-class radiotherapy service across the UK (CRUK: London).

[2] Institute of Physics in Engineering & Medicine (IPEM) (2017). IPEM Policy Statement: Recommendations for the Provision of a Physics Service to Radiotherapy (IPEM: York).
[3] Association of Clinical Scientists (ACS). Available at: http://www.assclinsci.org/acsHome.aspx (Accessed: 23 January 2017).
[4] National School of Healthcare Science (NSHCS). Available at: http://www.nshcs.hee.nhs.uk/join-a-programme (Accessed: 23 January 2017).
[5] The Register of Clinical Technologists. Available at: http://therct.org.uk/ (Accessed 23 January 2017).
[6] Institute of Physics in Engineering & Medicine (IPEM) (2002). Medical and Dental Guidance Notes: A Good Practice Guide on all Aspects of Ionising Radiation Protection in the Clinical Environment (IPEM: York).
[7] European Commission (2014). Radiation protection report 174: European guidelines on Medical Physics Expert (EC, Luxembourg).
[8] Ionising Radiations Regulations 1999. Available at: http://www.legislation.gov.uk/uksi/1999/3232/pdfs/uksi_19993232_en.pdf (Accessed: 31 May 2017).
[9] International Organization for Standardization. Available at https://www.iso.org/iso-9001-quality-management.html (Accessed: 31 May 2017).

Date first published: 1999 **Date reviewed: June 2017**

Next review date: 2020

Produced by a working party on behalf of the RTSIG; comprising:

Leila Shelley	Addenbrooke's Hospital and University of Cambridge
John Byrne	Northern Centre for Cancer Care, Newcastle
Katie Hutchinson	Addenbrooke's Hospital, Cambridge
Rosemary Hakes	Royal Devon and Exeter NHS Foundation Trust
David Eaton	Radiotherapy Trials QA group, Mount Vernon Hospital, London