

Guidelines for the Provision of a Physics Service to Radiotherapy

Institute of Physics & Engineering in Medicine

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Executive Summary

This report gives professional guidance on the provision of a Physics service to radiotherapy. It makes reference to the statutory requirement for physics support to radiotherapy, identifies staff roles and provides a clear statement of duties and responsibilities (Appendix A). It also provides a framework to identify the minimum physics staffing requirements for radiotherapy (table 1).

Radiotherapy is delivered by multidisciplinary teams of professional staff. Clinical scientists and clinical technologists play a key part in the provision of a radiotherapy service as a whole, providing essential scientific and technical input. The specialist scientific training and expertise of physics staff means they are uniquely qualified to understand both the physical processes and technology that underpin the entire radiotherapy process. Clinical scientists design, build and develop the framework of radiation dosimetry, treatment planning algorithms and treatment machine quality assurance that enable the team of oncologists, radiographers, clinical scientists and clinical technologists to practise safe, state-of-the-art radiotherapy and, in addition, provide expert advice on the development of new treatment techniques.

The implementation of new techniques involving advanced equipment, while maintaining patient safety, is of paramount importance, and is fundamentally dependent upon the essential skills of medical physics staff. This is recognised in both EC Directives (1) and UK legislation (IRR99 and IR(ME)R) (2,3). As a result, there is a statutory requirement for clinical scientists in radiotherapy departments, both as Radiation Protection Advisers and Medical Physics Experts.

Cancer planning documents, such as the NHS Cancer Plan (4), have recognised the need for additional radiotherapy equipment, including linear accelerators, simulators, treatment planning computers and imaging equipment. This will make a major contribution to cancer treatment in terms of efficacy and access. The necessary investment in staff has also been identified in order to realise the benefits of these capital equipment initiatives.

Adequate staffing levels of both clinical scientists and clinical technologists will make a major contribution to:

- Reduced waiting times for cancer treatments
- State of the art care using sophisticated equipment and techniques
- Patient safety and the reduction of debilitating side effects. This was highlighted by the recommendations of the Exeter and North Staffordshire Royal Infirmary Enquiries (5,6).

1. Introduction

This document reflects the technological, medical and regulative changes affecting radiotherapy since the publication of previous guidance (7,8) over ten years ago. The timely National Cancer Plan (4) has led to a welcome increase in the quality and quantity of radiotherapy treatment machines so that departments throughout the UK are beginning to be able to offer radiotherapy of the highest standard. However, this new and more technologically advanced equipment requires an increased level of support by clinical scientists and clinical technologists. Furthermore the Ionising Radiation (Medical Exposures) Regulations (IR(ME)R) provide a statutory requirement for the availability of Medical Physics Experts (MPE), in addition to the long-standing requirement for Radiation Protection Advisers. This document addresses these current issues and gives professional guidance on the provision of a physics service to radiotherapy. Consideration has also been given to a number of previously published national and international documents on physics staffing levels (9-11)

These guidelines supersede the previous IPEM policy statements: *'The role of the physical scientist in radiotherapy'* and *'Recommended staffing levels for the medical physics support of radiotherapy'* (7,8) and the Association of Medical Technologists published statements: *'The role of the medical physics technician in radiotherapy'* and *'Recommended minimum staffing levels for the technical support of radiotherapy'* (12,13).

The NHS Plan (14) has promoted the concept of “working flexibly together across traditional boundaries” between different staff groups. The IPEM welcomes this approach, recognising the need for team working within a multidisciplinary NHS for the benefit of patients.

2. The Statutory Requirement for a Physics Service to Radiotherapy

There is a statutory requirement for a physics service to radiotherapy. This arises from European Directives (1) and UK legislation (2,3), which places a legal requirement on the employer to ensure that a Medical Physics Expert (MPE) is “closely involved” with radiotherapy treatment.

A Medical Physics Expert in Radiotherapy is defined as:

A state registered clinical scientist with MIPEM or equivalent and at least six years of appropriate experience in radiotherapy physics (15).

Close involvement is only realistically practicable with the full time on-site availability of an MPE, at least when patients are being planned for treatment. It is essential that an MPE has adequate backup. It is recommended that each department should have a minimum of two clinical scientists qualified as MPEs.

There is also the legal requirement on the employer to retain the services of a qualified Radiation Protection Advisor with experience in radiotherapy safety, who from 2004

must hold a valid certificate from an accrediting body such as RPA 2000. In a radiotherapy service this role is usually and most effectively fulfilled by a state registered clinical scientist employed within the NHS Trust.

In addition there is a legal requirement on the employer to appoint one or more Radiation Protection Supervisors (RPS) who have knowledge and understanding of the Regulations and Local Rules, and an ability to exercise a supervisory role. Both state registered clinical scientists and clinical technologists may act as RPS in a radiotherapy service.

IR(ME)R (3) also introduce the role of an ‘operator,’ and state that in radiotherapy the many operator tasks must be clearly defined, as must those qualified to undertake such tasks. For new techniques and new equipment all operators must be appropriately trained.

A clinical scientist operator is defined as having:

‘DipIPEM or equivalent and appropriate practical experience in the clinical speciality with in-house training on specific equipment, techniques and procedures.’ (15)

A clinical technologist operator is defined as having:

‘normally an HNC or equivalent qualification in science or engineering, and appropriate practical training in the clinical speciality, normally obtained through a designated programme of in-service training’. (15)

A named clinical scientist or clinical technologist may also act in the role of practitioner (where appropriate) for exposures concomitant to radiotherapy. Concomitant exposures are defined as all exposures within the course of radiotherapy other than the treatment exposures. These will include simulation, check simulation, CT localisation and portal localisation and verification images (when these are additional to the treatment exposure). All practitioners must be named in local protocols (16).

3. Changing Roles in Radiotherapy

The IPeM welcomes the review of the roles of staff working in radiotherapy and, in particular, it supports the development of the contribution of clinical technologists. It recognises the requirement of the Manual of Cancer Services Standards (17) that all staff working in a radiotherapy department shall be clinically accountable to the clinical director of the radiotherapy service. It is also appropriate that responsibility for scientific standards and scientific management should be vested in a grade C clinical scientist appointed as the Head of Radiotherapy Physics. However, any review of roles or of accountability structures must reflect the statutory requirements referred to in section 2 and recognise that each staff group involved in radiotherapy brings their own particular expertise to the speciality. These particular contributions should be used in the optimal multi-professional way.

Medical Physics Experts in Radiotherapy provide scientific advice to the multi-professional Radiotherapy team and are the only staff appropriately qualified to take ultimate responsibility and have authority for:

- a) ensuring that the equipment, data and calculation procedures used in all aspects of planning radiotherapy treatment are appropriate, accurate and correctly applied;
- b) the correct calibration of radiotherapy equipment, and the procedures which ensure that the prescribed therapeutic dose is correctly delivered;
- c) physics aspects of the implementation of new equipment and techniques.

This was highlighted in the Report of the Committee of Inquiry into the Conduct of Isocentric Radiotherapy at North Staffordshire Royal Infirmary (6) which recommended an organisational model such that those preparing treatment plans “*do so under the scientific supervision of the Radiotherapy Physicist in any respect which might involve the physics content of the plans; and that responsibility and authority entailed in this supervisory role would extend to the provision for their training, and if necessary retraining concurrently with significant technical developments in the physics content of treatment planning.*” (par. 11.15).

In addition, recommendation 7 of the Report states that “*It should be a duty of the [Head of Radiotherapy Physics] to institute such a programme of tests and checks, recurrent or otherwise, that each Clinical Oncologist in the department is continually assured that any dose of radiation which he or she prescribes is delivered to the tumour in precisely the manner and intensity prescribed by the clinician.*”

An appropriately qualified clinical scientist must be appointed as Radiation Protection Adviser (2).

Clinical technologists bring to radiotherapy a science/engineering-based education and training which ensures that they are competent to maintain and repair the high technology equipment used in radiotherapy, and to operate the advanced machine tools used in the preparation of machine-related accessories and treatment aids. Their skills are also of particular value in any area that requires precise measurement such as the quality control of radiotherapy equipment.

The dosimetrist is a new and evolving role in Radiotherapy. This term is being used to describe staff undertaking all aspects of treatment planning, including patient immobilisation and the preparation of patient related accessories. Dosimetrists may also undertake radiotherapy equipment dosimetry and quality control, and patient in-vivo dosimetry. This role may be undertaken by staff trained as clinical technologists, clinical scientists or radiographers, but the dosimetrist must be professionally accountable to a Medical Physics Expert (Radiotherapy) for the dosimetric aspects of the work. In the UK, the extent to which this role has been implemented varies from hospital to hospital. The IPEM considers that the development of the dosimetrist’s role is of benefit to the NHS and may help to alleviate the current crisis in staffing amongst both therapy radiographers and clinical scientists.

Outside the specific areas of expertise listed above, different professional groups should take on different roles as appropriate to deliver patient care. For example, in

treatment planning, contributions may be made by clinical scientists, clinical technologists and radiographers depending both on the hospital arrangements and on the particular requirements of the patient being treated. Ideally each of these staff groups will contribute their particular skills to the planning process in close co-operation, thereby ensuring that the treatment of the individual patient is optimised. The special skills that are brought by clinical scientists and clinical technologists are elaborated in Sections 4 and 5.

In each of these areas, the clinical scientist or clinical technologist must be accountable individually for their conduct. This accountability of the individual, whether acting as referrer, practitioner or operator in the restricted senses defined by IR(ME)R (3), is now a formal legal obligation and following the inappropriate instructions of a superior is unlikely to constitute an adequate defence in a court of law.

4. The Contribution of Clinical Scientists

4.1 Definition

A State Registered Clinical Scientist working in Radiotherapy Physics is a qualified physicist with an honours degree in a physical science or equivalent and extensive postgraduate experience in the application of physical science to Radiotherapy, with the skills and fundamental scientific understanding to provide leadership, advice and innovation in the planning and delivery of radiotherapy treatment.

4.2 Clinical Scientist Training

The postgraduate training of a clinical scientist initially involves a two year period of basic training, including the attainment of a Masters degree, leading to the Diploma of the Institute of Physics and Engineering in Medicine (DipIPEM). A minimum further period of 2 years of higher training is required before applying to become a State Registered Clinical Scientist. The minimum period of undergraduate and postgraduate training required to achieve State Registration is therefore 7 years. Corporate membership of the IPEM (MIPEM) requires a minimum of six years postgraduate training and experience. In addition to this vocational training many clinical scientists have research qualifications, often to Ph.D. level.

Occasionally an experienced clinical scientist will be recruited directly from industry or academia, and sometimes from overseas. In this case a period of familiarisation training is required before the individual can be registered as a clinical scientist and can practice independently. All clinical scientist appointments should be made with the guidance of the government appointed National Assessors.

4.3 Particular Skills and Roles of Clinical Scientists in Radiotherapy Physics

Details of the roles and responsibilities of clinical scientists in radiotherapy physics are given in Appendix A. The clinical scientist in radiotherapy physics is an essential

member of the multi-professional team responsible for the design and delivery of radiotherapy treatment whose key roles may be summarised as:

- Management, development and scientific direction of the radiotherapy physics service
- Ensuring the accuracy of radiotherapy treatment through scientific supervision of dose calculation procedures and of ongoing quality control of both equipment and treatment
- Design and implementation of new and innovative treatments,
- Leadership of research and development, especially in the technological basis of radiotherapy
- Providing advice on appropriate treatment techniques
- Ensuring radiation safety
- Management of computer systems and software design and development
- Equipment management and procurement of radiotherapy equipment
- Teaching and training of staff (including junior clinical scientists, clinical technologists, doctors, radiographers, nurses).

It must be emphasised that the accurate delivery of a radiation dose to a tumour requires complex calculations, the accuracy of which can only be guaranteed by a thorough understanding of the underlying physics and computer algorithms being used. The supervision of these dose calculations cannot therefore be delegated to other staff groups whose training in the physical sciences is less rigorous. One of the most critical factors in modern radiotherapy is the accurate localisation of the target volume at the isocentre of the treatment machine. The clinical scientist's skills, especially the understanding of error analysis, should be fully employed in ensuring that the methods used for patient positioning and portal verification are appropriate. It should be noted that the giving of appropriate advice often involves direct patient contact.

Clinical scientists in radiotherapy physics are scientifically trained in the techniques for accurate measurement and numerical recording that underlie a proper quality control system for the equipment used in radiotherapy. This also requires an understanding of the physical principles of the generation and shaping of photon and electron beams. Clinical scientists have the ability to critically assess faults, and assign tolerances, test frequencies and remedial action. The decision to hand over a piece of therapy equipment for clinical use after a repair which might affect the clinical accuracy of the equipment must be made by a clinical scientist in consultation with the clinical technologist or manufacturer's representative carrying out the repair. This may require a balanced judgement between the need to deliver treatment to patients and the need for treatment accuracy.

The training of a clinical scientist in radiotherapy is designed to produce an individual who has a sound knowledge of the physical principles underlying radiotherapy treatment, the ability to think independently, and the skills necessary to perform innovative scientific research. The training in physical science received enables the clinical scientist to analyse the important features of a process and to identify the potential causes and likely magnitude of any sources of error. The training incorporates an understanding of all aspects of medical physics including methods of

diagnosis and of other treatment techniques. The clinical scientist is thus well equipped to lead research aimed at improving the technological basis of radiotherapy and the development of new techniques.

Knowledge of treatment techniques, the capabilities of equipment and of the physical properties of radiation enables the clinical scientist to advise clinicians and other members of staff on appropriate treatment techniques. Provision of immediate advice and dose calculations in the operating theatre during brachytherapy is also an important aspect of the clinical scientist's work. This requires a thorough knowledge of and practice in the dosimetric principles of brachytherapy.

Training in all aspects of radiation safety and an understanding of the principles of radiation protection and of radiation shielding and a detailed knowledge of radiation protection legislation enables the clinical scientist in radiotherapy physics to advise on radiation protection of both staff and patients. A clinical scientist expert in the design of radiation shielding should always be consulted when designing new radiotherapy facilities.

The training of a clinical scientist in radiotherapy physics will also include extensive study of computing techniques including appropriate numerical methods, programming techniques and an understanding of computer hardware. An appropriately trained clinical scientist can therefore make a major contribution to the management and operation of the many sophisticated computer systems and networks likely to be used in radiotherapy as well as to the development of new software.

The Medical Physics Expert has a key contribution to make to the specification, evaluation and selection of new equipment and will usually lead the project team considering such purchases. The declaration of suitability for clinical use of the advanced radiotherapy equipment being brought into use at the present time is a complex task requiring alertness to all the potential problems with the equipment and must be the responsibility of a Medical Physics Expert.

The extensive academic training of clinical scientists enables them to take a lead role in the training of the other staff groups (including medical staff, radiographers and nurses) involved in radiotherapy, in matters associated with radiation physics and radiation protection.

5. The Contribution of Clinical Technologists

5.1 Definition

A clinical technologist working in radiotherapy normally holds a degree, HNC or equivalent qualification in science or engineering, and appropriate practical training, normally obtained through a designated programme of in-service training, and is involved in the application and

development of the principles and techniques of medical physics and clinical engineering to the diagnosis, treatment and prevention of human disease.

A Clinical Technologist is usually employed on a Medical Technical Officer grade.

5.2 Clinical Technologist Training

Qualified clinical technologists usually hold an appropriate degree, higher national diploma, higher national certificate or equivalent qualification. Four years of further post certification training are required to be eligible for assessment for Incorporated Membership of IPEM and where appropriate Incorporated Engineer status. Clinical technologists are also encouraged to register on the Voluntary Register of Clinical Technologists.

Clinical technologists involved in the functions covered by these recommendations come from a variety of backgrounds, the main ones of which are electronic engineering, mechanical engineering and clinical physics.

For the purposes of the IR(ME)R Regulations the Medical and Dental Guidance Notes recommend that the minimum requirement to be an operator for a task requiring a clinical technologist should normally be an HNC or equivalent qualification in science or engineering, and appropriate practical training in the clinical speciality, normally obtained through a designated programme of in-service training.

5.3 Particular Skills and Roles of Clinical Technologists

Details of the roles and responsibilities of clinical technologists in radiotherapy are given in Appendix A, however, the key roles are summarised below:

- Management and service development
- Equipment procurement
- Training of other staff (including junior clinical technologists, clinical scientists, doctors, radiographers, nurses)
- External beam treatment planning including treatment verification
- Brachytherapy treatment planning (including preparation of sources (sealed and unsealed), operation of remote afterloading machines, assisting in theatre)
- Preventive and corrective maintenance of radiotherapy equipment
- Manufacture of treatment aids
- Mould room work
- Research and development
- Quality control and assurance
- Safety testing
- Management of computer systems and software development

Clinical technologists with electronic engineering skills are primarily responsible for carrying out equipment management, which includes the repair and maintenance of radiotherapy equipment. Those from mechanical engineering repair and maintain the

mechanical aspects of the equipment, and fabricate machine related treatment aids. Clinical technologists in clinical physics prepare patient related treatment aids (including mould room work), perform treatment planning and verification. Clinical technologists with a background in information technology are highly skilled in the management of networked verification systems and dedicated computer systems used for treatment planning and other radiotherapy applications. They have skills in software development and they provide technical support for computer hardware and a range of software related to scientific and clinical applications.

Technologists with electronics skills are trained to carry out repairs on therapy equipment at all levels and it is recommended that, even if equipment maintenance is contracted to an external supplier, an in-house team is trained to carry out first line repairs. The in-house team can provide the quick response necessary for minimum disruption of patient treatment in the event of a breakdown. Engineering policies and procedures should be developed and maintained to national standards (18, 19). In many departments the clinical technologists are highly trained linear accelerator engineers who can carry out all repairs, planned maintenance and electrical safety testing. Such staff can improve machine availability and make a considerable saving on maintenance costs. Their understanding of the repair and maintenance requirements should be fully utilised when considering the purchase of new equipment. They also liaise with equipment manufacturers on mandatory safety modifications and to ensure that maintenance methods and any modifications do not invalidate the CE marking of the equipment.

Clinical technologists with training in mechanical engineering are highly skilled both in the design and fabrication of treatment aids using machine tools and in the mechanical repair, maintenance and the mechanical safety of radiotherapy equipment. They may also liaise with manufacturers and make modifications to the equipment to facilitate special techniques. A sound knowledge of the treatment techniques being used enables them to suggest improvements, e.g. in patient immobilisation.

Clinical technologists with clinical physics training perform all aspects of treatment planning including patient immobilisation under procedures authorised by the MPE. They will also be involved in developing these procedures. Clinical technologists may also be responsible, under an MPE, for Quality Control checks and dose measurement prior to treatment and for in-vivo dosimetry. Clinical technologists undertaking such roles may be better described as dosimetrists.

Clinical technologists from any of the specialities described above may be cross-trained to suit the needs of individual departments. For example an electronics specialist may be trained to carry out Quality Control checks and a clinical physics specialist may also support maintenance tasks.

6. Continuing Professional Development

Continuing professional development (CPD) is the planned acquisition of knowledge, experience and skills, and the development of personal qualities for the execution of professional and scientific duties throughout one's working life, encompassing

scientific, technical, clinical and professional matters. CPD is of vital importance for each clinical scientist and clinical technologist to ensure the efficiency and maintenance of competence of the physics service. To this end IPEM operates a continuing professional development scheme.

“Making the Change” (20, chapter 3.16) emphasises that “*CPD plays a crucial role in the maintenance of competence by individual practitioners and is likely to be increasingly important in the future for the maintenance of professional registration.*” Also as operators, under IRMER, (3) paragraph 4(4), both clinical scientists and clinical technologists have a duty to undertake “*continuing education and training after qualification including, in the case of clinical use of new techniques, training related to these techniques and the relevant radiation protection requirements*”. The employer is obliged to take steps to ensure that this happens. Clinical governance and the NHS cancer plan also highlight the need for CPD.

No allowance has been made in table 1 for staff time for CPD. However, it is essential that staffing levels provide the time for staff to meet the requirements of a CPD programme, and that adequate funding is provided. This will enable clinical scientists and clinical technologists to maintain the physics service, to keep abreast of developments, and to ensure staff have the skills and knowledge necessary to deliver the best health care.

7. Staffing Recommendations

7.1. Assessment of Workload

The staffing recommendations for clinical scientists issued in 1989 have been widely endorsed and have been incorporated in the Manual of Cancer Services Standards (17). Since the recommendations were issued, a number of developments have taken place in radiotherapy that have had staffing implications. IPEM considers that the original recommendations require clarification, amplification and revision. At the same time it is timely to issue recommendations for the number of clinical technologists that are required additionally.

The number of physics staff required for the provision of a physics service to radiotherapy departments depends upon

- the amount and complexity of equipment used
- the number of patients treated and the complexity of treatments
- departmental working arrangements

A framework to identify the minimum physics staffing requirements for radiotherapy is provided in Table 1. The factors in Table 1 include provision for the limited amount of development work that is necessary to provide a routine service. However, specific research and development programmes leading to new services or techniques will require additional resources, which should be specifically funded. Where departments

have a high workload in terms of teaching and training, additional resources should be made available.

Staffing level recommendations for physics support for therapeutic radionuclide services have been addressed elsewhere (21). Staffing figures recommended have been included in table 1 for completeness.

The figures derived from Table 1 represent the minimum number of staff to provide a safe service. The figures given are for trained staff. As already noted, staff who are not State Registered Clinical Scientists still require substantial supervision and additional staffing is required for the supervision and training of such staff.

No specific consideration has been given to local circumstances such as multi-sited organisations. In such arrangements it may be appropriate to treat each site as an independent centre for staffing calculation purposes. The advice of the local Head of Medical Physics should be sought.

It must be emphasised that these are **minimum** recommendations. Where there is a shortfall of staff compared to these numbers there is a potential for:

- increased waiting times for cancer treatments.
- under usage of expensive therapy equipment, thereby depriving patients of state of the art care.
- an increase in the likelihood of errors by a group of staff who have a determining effect on the accuracy and safety of radiation treatment to a large number of patients (5,6).

A physics service operating below these levels is likely to place an undue burden on the staff and expose the patients to unnecessary risk.

7.2. Minimum Physics Staffing Requirements for Radiotherapy

Staffing levels should be calculated from Table 1. For each component, the number of items applying to the department should be multiplied by the number of WTE staff per item to give the number of physics staff for that component. The number of staff for each of the eleven components should then be summed.

In all departments it is recommended that there must be at least two clinical scientists qualified as Medical Physics Experts (Radiotherapy). At least one of these should be appointed at grade C, to oversee co-ordination of, and be professionally accountable for, the service. Advice on the composition of grades within a department should be sought from the local Head of Medical Physics who may also seek guidance from national assessors.

If the number of clinical scientists calculated from the table is less than three then, in order to cover for absences, the establishment should be made up of at least three individuals. Each of these should be a radiotherapy physicist, but could have some responsibilities in other areas of medical physics.

The exact number of staff required will depend on the extent to which physics staff are involved in those processes where other staff groups may carry out the work. These processes are identified in Appendix A. This is largely in the area covered by the dosimetrists skills and the WTE for these activities may comprise clinical scientists, clinical technologists or radiographers.

In some departments the services of suitably trained electronic engineering and / or mechanical engineering staff are obtained from a medical equipment maintenance section of the medical physics department.

The numbers indicate staffing requirements to allow for provision of a service during a standard 8-hour working day. Additional resources are required to account for extended working hours and/or weekend working for treatment, planned preventative maintenance, repair or quality assurance work. Whilst it is not possible to provide a general recommendation, it should be noted that extended day working is potentially much less efficient. In addition, the need for senior staff cover at all times should be considered.

In very large departments there MAY be economies of scale. A formula to calculate economies of scale can be used such that where the number N, derived from the table is eight or more, the minimum number, M, of staff recommended, is given by $M=0.68N + 2$. This formula has been found to be appropriate in many centres, but local conditions such as extended hours working, a significant Research or Teaching workload or a diverse equipment base will reduce the economies expected. The formula may be employed for clinical scientists, engineering clinical technologists and clinical physics technologists..

The examples of major and minor items and special techniques in Table 1 do not constitute an exhaustive list. Those examples given represent the typical workload associated with such an item or technique. These factors must be applied according to the equipment within each department and must be applied to each staff group as appropriate.

IPEM believes that these recommendations reflect the factors currently recognised by the profession as constituting good practice in the UK. However, radiotherapy is associated with rapidly changing technologies and treatment techniques. Although account has been taken of recent developments, local circumstances should be evaluated and, where appropriate, modifications to these recommendations made.

Table 1. Minimum Staffing Requirements for a Routine Physics Service to Radiotherapy

Unit	Item	WTE Clinical Scientists per unit item (see notes 6,7,10)	WTE Technologists per unit item (see note 10)		Notes
			Clinical physics (see notes 6,7,8)	Engineering (see notes 6,7,9)	
Equipment dependent factors					
1	Multi-mode accelerator	0.7	0.3	1.2	1
1	Single-mode accelerator	0.5	0.2	0.9	
1	Major item e.g. Cobalt unit, HDR, CT scanner within radiotherapy, Simulator, TPS, IMRT, Radiotherapy data / image network.	0.4	0.15	0.2	2,11
1	Minor item e.g. MLC, EPID, Advanced features of TPS, Orthovoltage /Superficial unit, LDR afterloading, block cutting machine, automatic outlining device, Stereotactic radiotherapy, CT extension on simulator.	0.2	0.1	0.1	11
Patient dependent factors					
1000	New courses treated p.a. by external beam therapy	1.2	1.2	0.2	3,4
100	New courses treated with 3D conformal planning	0.2	0.2	0	3,5
100	New courses treated p.a. by brachytherapy	0.2	0.4	0	3
50	Special Techniques (fully developed routine service) e.g. TBI, Stereotactic radiotherapy, Total skin electron techniques, IMRT, Prostate brachytherapy.	0.4	0.6	0	11
100	New courses treated p.a. with unsealed sources	0.2	0.1	0	3
Departmental factors					

	Radiation Protection Advisor	0.1	
	Established Quality System	0.2	

Notes

1. A multi-mode accelerator is one that has more than one X-ray energy or has an electron facility. Additional features, such as multileaf collimators and electronic portal imaging systems and connection to a network, do require significant physics department time and should be recorded separately as minor items.
2. Intensity modulated radiotherapy is extremely demanding of physics input and the infrastructure and increased quality control required justifies it being regarded as a major item.
3. The 1989 recommendations referred to "New patients". This has more appropriately been replaced by "New courses".
4. The 1989 recommendations stated that the number of clinical scientists may be reduced by up to 0.4 according to the extent of the routine duties carried out by staff who are not supervised by the clinical scientist. However, IPEM considers that the requirements for close involvement in treatment planning by a Medical Physics Expert as required by IR (ME) R means that there is a requirement that clinical scientists do supervise such staff and this reduction is no longer considered appropriate.
5. This is a new category. Since the previous recommendations were introduced conformal planning has become more common and this has a significant impact on the workload of clinical scientists.
6. In very large departments there MAY be economies of scale. A formula to calculate economies of scale can be used such that where the number N, derived from the table is eight or more, the minimum number, M, of staff recommended, is given by $M=0.68N + 2$. This formula has been found to be appropriate in many centres, but local conditions such as extended hours working, a significant Research or Teaching workload or a diverse equipment base will reduce the economies expected. The formula may be employed for clinical scientists, engineering clinical technologists and clinical physics technologists.
7. If the number of clinical scientists calculated from the table is less than three then, in order to cover for absences, the establishment should be made up of at least three individuals. Each of these should be a radiotherapy physicist, but one may have some responsibilities in other areas of medical physics. Similarly, the number of clinical technologists must be adequate to cover for absences.
8. Staff numbers identified in this column may be applied to whichever staff group act in the role of dosimetrist. It is recognised that the role of dosimetrist may be carried out by suitably qualified and trained members of whichever staff group fit most easily into the existing management structure and the individual radiotherapy centre can recruit and retain.
9. The number of engineering clinical technologists required will depend on the extent to which maintenance is carried out in-house. Even where there is a fully externally resourced service contract it is recommended that a facility for first line repair and quality control is provided in-house.
10. The table indicates minimum staffing requirements to allow for provision of a service during a standard eight-hour working day.
11. The examples of major and minor items and special techniques in Table 1 do not constitute an exhaustive list. Those examples given represent the typical workload associated with such an item or technique. These factors must be applied according to the equipment within each department and must be applied to each staff group as appropriate.

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Appendix A: Specific Roles and Responsibilities of Clinical Scientists and Clinical Technologists

Fourteen broad areas in radiotherapy can be identified where clinical scientists and clinical technologists have a distinct role. Within these areas some tasks are clearly assigned to clinical scientists (radiotherapy physicist); these are in part associated with statutory requirements.

The broad areas are;

- Management, scientific responsibility, advice and direction
- Equipment procurement, acceptance and commissioning
- Radiation dosimetry
- External beam treatment planning, delivery and verification (including optimisation and safety)
- Radiation protection
- Quality control, safety and maintenance of radiotherapy equipment
- Specialised treatment techniques
- Brachytherapy
- Unsealed sources
- Mould room
- Computing and networking
- Quality Management
- Teaching and training
- Research and development

The exact role of the clinical scientist and clinical technologist is dependent on organisational structures and staff mixes within departments. The responsible staff group has been identified after each item as follows:

^a Clinical scientist

^b Medical Physics Expert

^c The clinical scientist is responsible for this area with the clinical technologist contributing as appropriate

^d Clinical scientist or clinical technologist

^e Clinical scientist, clinical technologist or other competent staff

A.1 Management, scientific responsibility, advice and direction

The exact organisational structure may vary from department to department. A Head of Radiotherapy Physics may be responsible for the entire provision of a physics service to radiotherapy. Alternatively this may be split between a number of sections of a medical physics department. In all cases clear lines of managerial control, roles and responsibilities should be defined. Furthermore, where there is no common line management for medical physics and radiotherapy, a service level agreement should exist between the two (17). In addition, the Head of Radiotherapy Physics is a member of a multidisciplinary management team and participates in the decision-making processes of the team. The managerial responsibility of clinical technologists for other

clinical technologists and other staff groups may also be significant. The responsible staff group has been identified after each tem. It is acknowledged in specific cases that this may be another staff group. However, in such cases it is important that the scientific, engineering and technical expertise provided by physics staff is available.

- Managerially responsible for overall physics service ^b
- Managerially responsible for department / section budgets ^c
- Managerially responsible for treatment planning ^e. (Overall scientific responsibility for treatment planning must be invested in an MPE)
- Managerially responsible for the integration of physics within the radiotherapy department ^a
- Managerially responsible for a mechanical workshop and its staff ^d
- Responsible for ensuring that a maintenance programme exists for radiotherapy equipment ^b
- Managerially responsible for mould room ^e
- Key role in strategic planning and policy making at a local, national or international level ^c

A.2 Equipment procurement, acceptance and commissioning

Physics staff play a key role in the team responsible for budgeting and procurement of new equipment. This includes input into the formation of a capital equipment replacement programme. Physics staff also play a key role in the planning and design of new installations, including taking responsibility for radiation protection aspects of design such as shielding requirements and safety features to comply with statutory regulations and good practice. The Medical Physics Expert (Radiotherapy) is responsible for the acceptance, commissioning and calibration of radiotherapy equipment. In addition, they have a lead role in the safe and effective implementation of new or modified equipment into clinical use.

The specific roles and responsibilities are listed below;

- Key role in the scientific justification and development of business plans for radiotherapy ^c
- Key role in the development of a capital equipment replacement programme ^c
- Key role in assessing service needs ^c
- Lead role in preparing radiotherapy equipment specifications ^c
- Lead role in evaluating radiotherapy equipment, treatment techniques and technologies ^c
- Advising on specifications for radiotherapy related imaging equipment e.g. CT scanners, MRI systems, PET systems ^c
- Advising on service effects of procurement options ^c
- Lead role in the planning and design of installations ^b
- Responsibility for the radiation protection aspects of design (RPA/MPE). ^b
- Responsible for co-ordination of the installation. ^b
- Responsible for liaising with manufacturer's installing engineers during installation ^b

- Responsible for acceptance testing of new or modified radiotherapy equipment ^b. This includes
 - Safety testing
 - Involvement in critical examination as required by the Ionising Radiation Regulations 1999
 - Stability testing
 - Performance acceptance testing against national standards and against selection and supply specifications
 - Establishing basic machine performance quality control baselines
 - Interfacing and integration into local computer networks
 - Accepting all modalities, functions, systems, options and accessories prior to clinical use
- Responsible for commissioning of radiotherapy equipment ^b. This includes
 - The measurement of all data required for the treatment planning computer
 - The measurement of data required for data tables and calculations
 - The measurement of check data to confirm the accuracy of the treatment planning computers and systems
 - The measurement of parameters to determine a baseline for ongoing quality assurance tests
 - The definitive calibration of treatment units. (15)

A.3 Radiation dosimetry

Radiation physics is the science of ionising radiation and its interaction with matter, with particular emphasis on the energy absorbed. Radiation dosimetry entails the quantitative determination of that energy and requires a thorough knowledge of the physical processes involved. The clinical scientist is responsible for the establishment and maintenance of all dosimetric standards, techniques and equipment. In addition, there is a requirement for radiotherapy centres to participate in the national dosimetry audit scheme (17). The requirement for accuracy and dosimetric precision in radiotherapy with regard to tumour control probability and normal tissue complication probability is well known (22-24).

The specific roles and responsibilities are listed below. Responsibility for each lies with the MPE, however, measurements other than Definitive Calibrations may be performed by clinical scientists and clinical technologists.

- Responsibility for calibration, including Definitive Calibration, of dosimeters
- Responsibility for regular quality control of dosimeters
- Responsibility for calibration, including Definitive Calibration, of treatment units, i.e. calibration of dose monitor or timer, traceable to national standards
- Responsibility for implementation of dosimetry Codes of Practice (e.g. 25-27)
- Responsibility for participating in the national dosimetry audit scheme
- Responsibility for participating in international dosimetry audits where applicable
- Responsibility for in-vivo dosimetry
- Responsibility for dosimetry measurements for calibration of brachytherapy sources

A.4 External beam treatment planning, delivery and verification.

The complexity of treatment planning is increasing, with 3D treatment planning and conformal therapy becoming standard. The use of new treatment planning optimisation techniques (inverse planning) leading to the delivery of complex treatments with Intensity Modulated Radiation Therapy beams (IMRT) is becoming increasingly common. Safe and effective treatment planning therefore relies on a thorough understanding of radiation and its interactions in and with patients' tissues, the dose calculation and optimisation algorithms, competence in the use of advanced software tools and knowledge and appreciation of the inherent limitations in accuracy of any treatment planning system. Therefore the clinical scientist must take overall scientific responsibility for the treatment planning process.

The specific roles and responsibilities are listed below;

- Commissioning of treatment planning systems, including establishment of accuracy and overall limitations of the systems^b
- Overall scientific responsibility for the treatment planning process, including advising on all aspects of patient dosimetry including the optimisation and safety of treatment and treatment planning^b
- Production of optimum treatment configurations, resultant dose distributions and setting up instructions (i.e. the treatment plan)^c
- Calculation of monitor units.^c
- Development of independent method of checking monitor unit calculations provided by the treatment planning computer^b
- Verification of patient treatment delivery using in-vivo dosimetry and portal imaging systems^c.
- Development, implementation and analysis of in vivo dosimetry and portal imaging systems^c
- Design and production of machine specific treatment accessories^c
- To provide advice on radiobiological models for alternative fractionation schemes and compensation for gaps in treatment^a
- A key role in the development and implementation of new treatment techniques^c

A.5 Radiation protection

There are legal requirements on a radiation employer, such as an NHS Trust, to ensure the radiation safety of patients, members of the public and staff by employing appropriately qualified and trained medical physics staff. The legal framework for these requirements is contained in the Ionising Radiation Regulations 1999 (2), the Ionising Radiation (Medical Exposure) Regulations 2000 (3) and the Radioactive Substances Act 1993 (28). Guidance on the implementation of these regulations and on good practice in the safe delivery of radiotherapy and other radiation-based techniques is given in the Medical & Dental Guidance Notes (15).

The main duty holders under these regulations are Medical Physics Experts, who are clinical scientists with considerable experience in the application of physics to radiotherapy. Details of the training and experience required are contained in the

Medical & Dental Guidance Notes. One or more, where appropriate, Medical Physics Experts in Radiotherapy must be closely involved in every radiotherapy practice or procedure. This will include :

- Advising on the radiation safety of individual patients undergoing radiotherapy. Particular emphasis is placed on minimising the dose to organs at risk, particularly the foetus, the gonads of patients of reproductive capacity and organs at particular risk such as the spinal cord and eyes.
- Responsibility for supervising the installation, safety testing, commissioning and calibration of new radiotherapy equipment
- Responsibility for ensuring the regular calibration of all dosimetry systems associated with radiotherapy equipment
- Responsibility for managing an appropriate quality control and preventative maintenance programme for radiotherapy equipment
- Advising on the safety and implementation of new radiation treatment techniques and imaging procedures
- Advising on the optimisation of treatment plans to achieve the best possible outcome for the patient
- Responsibility for maintaining an inventory of radiation equipment
- Responsibility for maintaining records of radionuclides used and for monitoring their safety.
- Responsibility for giving advice on the discharge of patients whom have been treated with radionuclides and advice on the disposal of corpses containing radionuclides.
- The administration of appropriate authorisations for the use of radionuclides within the radiotherapy department and giving advice on ARSAC applications.

In general one or more Medical Physics Experts in Radiotherapy will supervise these procedures assisted by other radiotherapy physics and technical staff.

The radiation employer must also appoint a Radiation Protection Adviser for radiotherapy. This is a medical physicist with appropriate training and considerable experience in radiotherapy safety. Details of the training and experience required are contained in the Ionising Radiations Regulations 1999 and the Medical & Dental Guidance Notes.

The Radiation Protection Adviser (RPA) in Radiotherapy must be consulted on:

- The design of radiotherapy treatment rooms and rooms where radionuclide sources will be used, prepared or stored. The RPA will also advise on the appropriate designation of the radiation areas in the department, as controlled or supervised areas, and any physical control measures that are required.
- In co-operation with the Medical Physics Experts and departmental management the RPA will advise on appropriate risk assessments prior to the use of radiotherapy equipment and appropriate emergency procedures and contingency plans.
- The RPA will ensure that a critical examination of new radiotherapy equipment is carried out by the installer. This is likely to be in collaboration with the Medical Physics Expert in Radiotherapy.
- The RPA will advise on requirements for the regular calibration and testing of radiation monitoring instruments
- The RPA will provide advice where required on the use of personal protective equipment and training of workers.

A.6 Quality control, safety and maintenance of radiotherapy equipment

A vital component of the physics service involves the provision of comprehensive quality control programmes to ensure the correct and safe functioning of all radiotherapy, or radiotherapy-related, equipment. This includes all treatment units, radiotherapy imaging devices such as simulators, CT equipment and MRI scanners, treatment planning computers, dosimetry equipment, brachytherapy devices, network systems, treatment verification systems, and in-house software. A comprehensive guide to physics aspects of quality control in radiotherapy has been published by IPEM (29). The physics service is also responsible for ensuring that effective planned preventative maintenance (PPM) and repair arrangements are implemented. This may be carried out by manufacturers or an in-house service. The Medical Devices Agency has published guidance on equipment management in Medical Devices and Equipment Management for Hospital and Community-based Organisations (DB9801) (18) and Medical Devices and Equipment Management: Repair and Maintenance Provision (DB2000(02)) (19). In all cases the Medical Physics Expert (Radiotherapy) is responsible for ensuring that adequate quality control checks are carried out following any PPM or repair work, prior to the equipment being handed back for safe clinical use.

The specific roles and responsibilities of the service may be listed as follows

- Responsibility for establishing a quality control baseline.^b
- Responsibility for establishing the quality control programme^b, including
 - frequency of checks
 - methodology, including equipment and personnel
 - provision of necessary instructions
 - tolerance and action levels

- actions resulting
- method of recording
- Responsibility for ensuring that all equipment associated with radiation simulation and treatment is safe for clinical use (*see note below)
- Responsibility for withdrawing from clinical use, or imposing restrictions on, equipment deemed unsatisfactory for clinical use(* see note below)
- Key role in establishing and carrying out a PPM and repair service (18,19)^d

*The clinical scientist has responsibility for those areas which have an effect on the delivery of radiation treatment to patients although measurements may be carried out by the clinical technologist, who may make an interim decision to withdraw equipment from clinical use. The clinical technologist carries responsibility for those areas where the safety of patients or staff may be compromised through the failure of components, systems or devices.

A.7 Specialised treatment techniques

Physics staff play a key role in the development, implementation, delivery, verification and maintenance of specialised treatment techniques.

Such specialised treatment techniques include

- Stereotactic radiotherapy
- Intensity modulated radiotherapy (IMRT)
- Total skin electron techniques
- Total body irradiation techniques
- Proton therapy
- Cardiovascular brachytherapy
- Ultrasound guided prostate brachytherapy
- Targeted radiotherapy using unsealed sources

A. 8 Brachytherapy

Clinical scientists and clinical technologists have a key role in the commissioning and use of sophisticated remote afterloading treatment hardware and software. To ensure accuracy and safety in brachytherapy treatment planning and delivery, clinical scientists and clinical technologists work in close collaboration with clinical oncologists, radiographic and nursing staff. The following lists specific responsibilities of a clinical scientist/clinical technologist in brachytherapy planning and delivery.

- Establishment of local procedures for the implementation of dosimetry systems for intracavity and interstitial brachytherapy treatments.^a
- Overall responsibility for radioactive source strength confirmation/calibration and issuing of appropriate source data for clinical use.^b
- Acquisition of patient data, computerised treatment planning and calculation of treatment times.^e
- Development of independent methods for checking treatment times.^a
- Manual handling of sources,^e

- Source custodian duties, including stock control, documentation, compliance with relevant legislation^e (Overall responsibility lies with the MPE)
- Responsibility for countersigning ARSAC certificate applications for brachytherapy procedures (RPA)
- Routine quality control checks e.g. positional accuracy (in the case of remote afterloading equipment) prior to patient treatment, source activity checks and leakage testing.^e
- Responsibility for quality assurance of planning system, and for imaging equipment used for source localisation (e.g. ultrasound, CT scanner etc)^c
- Radiobiological equivalence calculations of protracted brachytherapy to fractionated external beam treatments to assist clinical oncologists in their choice of treatment regime.^c
- Design of special brachytherapy treatment arrangements, such as ophthalmic treatments.^e
- Design and construction of sealed source applicators for specialised treatments or for individual patients.^e
- Development and introduction of new treatment techniques into clinical practice^e (MPE must always advise)

A. 9 Unsealed sources

The clinical scientist is responsible for the supervision of therapeutic uses of radionuclides as prescribed by the consultant oncologist. This will include

- Practical advice on radiation protection of other staff (especially nursing staff)
- Procurement and stock control
- Calibration and measurement of required radionuclides
- Advice on administration procedures
- Maintenance of records

Further guidance is available in Guidelines for the Provision of Physics Support to Nuclear Medicine (21)

A. 10 Mould Room

Optimisation of an individual patient's treatment often requires patient specific treatment accessories to be produced. Clinical technologists working in this area have close patient contact. Their roles include the design and construction of:

- immobilisation and positioning devices
- shielding blocks or masks
- compensators or bolus
- sealed source applicators

A. 11 Computing and networking

Computer networking provides the potential for significant improvements in the efficiency of the radiotherapy process, thereby helping to minimise the occurrence of errors. Such systems provide recording and verification of treatments; setting and verification of multileaf collimators and rotation therapy; transfer of patient and treatment planning data between machines, patient administration systems and databases; information transfer with hospital networks through dedicated gateways; archiving of data stored in the system; transfer of diagnostic, planning and verification images; and processing of portal images.

Physics staff are uniquely placed in having, not only a detailed knowledge of radiotherapy, but also an accurate understanding of what the network does and an understanding of network architecture and transmission standards necessary for understanding and developing a radiotherapy image and data network. Physics staff should therefore take overall responsibility for the safe and accurate implementation of such technology.

The specific roles and responsibilities may be listed as follows

- Responsibility for defining network pathways and developing network functions^c
- Responsibility for assessing and evaluating systems.^c
- Responsibility for installing, testing and commissioning systems.^c
- Responsibility for authorising such systems as safe for clinical use.^b
- To undertake system administrator roles^e
- To provide beta and gamma test site facilities and undertake software evaluation of pre-clinical releases of commercial software^c
- Development of in-house software to facilitate improvements in service or technique^c

A. 12 Quality Management

Radiotherapy departments in the UK are required to adopt the Quality Assurance in Radiotherapy (QART) standard (30) published by the Department of Health. This is a framework for a formal quality management system, based on the then British Standard BS5750 Part 2 (31), applied to the multidisciplinary field of radiotherapy. Physics staff have taken a key role in the development and introduction of the standard in radiotherapy departments nationally, in liaison with other staff groups. A member of the physics staff may have responsibility, as Quality Management Representative, for the development and maintenance of a quality system within a radiotherapy physics department. In many centres, a clinical scientist has the wider responsibility of quality manager for a radiotherapy department, including other staff groups.

A. 13 Teaching and training

Clinical and other staff groups rely heavily on appropriately qualified physics staff for their training in all areas of radiotherapy physics.

Physics staff provide teaching and training for

- Clinical scientists in training, particularly those enrolled in the training scheme for physical scientists in health care organised by IPEM
- Clinical technologists in training
- Clinical oncologists undertaking the examination for Fellowship of the Royal College of Radiologists
- Radiographers in training
- Other health service staff, for example, in aspects of radiation protection and the use of equipment or new procedures. In particular, training is given by clinical scientists to other health service staff in the core knowledge required by the Ionising Radiation regulations and of operators and practitioner under the IR (ME) R regulations.
- Supervision of M.Sc. and Ph.D. programmes
- Other relevant courses including update courses, as are established by local need

A. 14 Research and development

Clinical scientists within the UK are largely responsible for establishing the high standards of dosimetry now used throughout the world, and to the development, optimisation and advancement of radiotherapy treatment techniques. They also contribute vital work on the design and development of treatment machines, simulators, treatment planning systems and other ancillary equipment. The complexity and cost of modern equipment has resulted in much implementation of research and development now being undertaken by the manufacturer, although often in close collaboration with medical physics departments. However, in all cases clinical scientists continue to advise on the directions of these developments and their integration into the planning and delivery of the radiation treatment of the patient. This requires a close liaison with manufacturers and therefore the clinical scientist has a continuing role in the application of new technologies.

The clinical scientist will continue to contribute to the understanding of the interaction of radiation with patients, to the development of major changes in treatment modalities and, in conjunction with clinical and radiographic colleagues, to patient orientated research and health technology assessment. This may involve participation in clinical trials and statistical analysis of results and, increasingly, to the formal process of Health Technology Assessment, a key feature of the NHS Research and Development Strategy. IPEM aims to ensure that not only are medical physicists and engineers contributing to the development of new equipment and technology but also contribute, as part of a multi-disciplinary team, to the process of Health Technology Assessment. It therefore strives not only to support research programmes in physics and engineering in cancer, but also to ensure that genuine research skills, such as ethically approved clinical trial design, are part of a clinical scientists training and practice. In England, clinical scientists and clinical technologists also have a key role to play in the recently formed Cancer Research Networks.

In many departments, especially those associated with teaching hospitals, physics staff are involved in, or responsible for, major projects and academic research. IPEM encourages and supports close collaboration between NHS and academic centres to ensure effective and productive research programmes. Involvement in research and development is essential for continuous improvement in the radiotherapy service leading to improved clinical outcomes. Such activities are the basis for evidence based medicine and will increasingly inform National Service Frameworks and NICE guidelines. Attendance at, and contributions to, scientific and medical meetings and publications in high quality peer reviewed journals constitute important elements of this interchange of information. There is also a requirement for staff to maintain an awareness of the work in other institutions in the UK and abroad through reading appropriate scientific and clinical journals and effective use of the World Wide Web.

Glossary

Bolus

Material of density close to that of tissue placed either on the patient's skin or in cavities. When placed on the skin (such as on scars from surgery) the aim is usually to increase the dose to the skin.

Brachytherapy

The clinical use of radioactive sources placed at a short distance from the planning target volume for the irradiation of tumours or non-malignant lesions. It can be administered in the form of intracavity brachytherapy, when sources are placed in body cavities, or interstitial brachytherapy, when sources are implanted directly into the volume.

Cardiovascular (intravascular or endovascular) brachytherapy

The use of brachytherapy sources for the prevention of restenosis following angioplasty.

Compensator

A patient specific treatment accessory made of high-density material used for modifying the radiation beam intensity to obtain a more uniform dose distribution within the target volume.

Computerised Tomography (CT)

Section imaging in which the required image must be reconstructed from projection measurements, usually using a digital computer (Webb 1993). Most commonly, images of the body are acquired in transverse planes.

Conformal therapy

A treatment technique that aims to tailor the high-dose volume to the planning target volume whilst minimising dose to healthy tissue.

CT simulator

A specially designed CT scanner equipped with a flat top couch and a laser field positioning system, which can simulate a patient's treatment. It can provide good quality CT images for improved tumour localisation, but can also reconstruct an equivalent simulator radiograph, thus providing virtual simulation.

Dosemeters

Generally referring to the detector equipment (detectors and associated electronics) used in the measurement of radiation.

Dosimetry Codes of Practice

Scientific papers specifying national or international recommendations for absolute dose determination in hospitals.

Dosimetrist

Suitably trained staff, usually employed as a clinical technologist, that specialise in clinical physics. Their tasks include work for patient immobilisation, treatment planning, in-vivo dosimetry, general dosimetry etc.

Electronic Portal imaging Device (EPID)

An electronic system for acquiring verification images during treatment delivery. It can be a single detector or matrix of detectors and is usually designed as an accessory of the linear accelerator.

Fractionation

The process of delivering a radiation prescription in a series of small doses spread out over time (Webb 1993).

In-vivo dosimetry

The process of measuring the radiation dose given to the patient during treatment delivery.

Intensity modulated radiotherapy

A treatment delivery technique using beams with variable intensity. These are usually designed by treatment plan optimisation methods and delivered using a computer controlled multileaf collimator.

Inverse planning

A novel treatment planning process which begins with the specification of the optimum dose distribution in the patient and allows the treatment planning computer to generate a plan of beam directions and intensities that best satisfies the required dose distribution.

Isocentre

A single point on a machine through which the central axis of the radiation beam always passes. CT scanners, treatment simulators and linear accelerators all have a single isocentre and are described as being isocentrically mounted.

Machine dose monitor

The internal dosimeter of a linear accelerator used for monitoring its output.

Machine timer

The device which controls the time of radiation exposure from a Cobalt or superficial X-ray unit.

Magnetic Resonance Imaging (MRI)

An imaging technique based on the differences in magnetic properties of protons within living cells. MR images are used in treatment planning for tumour localisation as they provide superior soft tissue definition in comparison to images from CT.

Mould room

The name traditionally given to a room within the radiotherapy department where treatment preparation takes place. Treatment preparation primarily involves making patient related accessories used for treatment, such as immobilisation devices, shielding blocks, electron end-frames and shielding masks etc.

Multileaf Collimator

A collimation system on a linear accelerator, which uses a number of 'leaves' to create an irregularly shaped radiation beam. The multileaf collimator is also the primary instrument for delivery of Intensity Modulated Radiation Therapy (IMRT)

Normal tissue complication probability (NTCP)

The probability of inducing a complication in normal healthy tissue as a function of the applied dose. (Webb 1993)

Patient immobilisation techniques

The methods used for immobilising and positioning patients during radiotherapy treatment in order to reduce intra-treatment motion and ensure reproducibility of patient position between treatment fractions.(Van Dyk 1999)

Planning Target Volume (PTV)

The geometric volume within the patient used for treatment planning and specification of dose.

Portal imaging

Imaging of the region of the body being treated with megavoltage X-rays for the purpose of verifying the geometric, and sometimes dosimetric, accuracy of the treatment.

Positron Emission Tomography

Form of sectional imaging of a radiopharmaceutical, in which the radionuclide is a positron emitter (in contrast to a single-gamma emitter). (Webb 1993)

Quality assurance

All those procedures that ensure consistency of the medical prescription and the safe fulfilment of that prescription as regards to dose to the target volume, together with minimal dose to normal tissue, minimal exposure to personnel, and adequate patient monitoring aimed at determining the end result of treatment. (WHO 1988)

Quality control checks

Those planned activities where the performance of equipment is compared with reference standards and through which the actual quality performance is measured.

Radiation (absorbed) dose

The mean energy imparted by ionising radiation to matter of a given mass. (ICRU60 1998)

Radiobiological model

Mathematical models developed to assist in understanding the influence of different radiotherapy factors on treatment outcomes.

Record and Verify system

Hardware and software designed to record and verify treatment parameters during a patient's treatment simulation and delivery. The system (which is sometimes external to the treatment delivery system) may now comprise of software with extended capabilities, such as for electronic patient record and general database functionality.

Remote afterloading

A brachytherapy source-loading technique that avoids manual handling of radiation sources by staff, thus reducing their exposure to radiation. Sources in remote afterloading systems can be used for treatment at various dose rates (low (LDR), medium (MDR), high (HDR) and pulsed (PDR)).

Shielding blocks

Treatment machine or patient specific blocks of high-density material used to shield critical organs from the radiation and/or to shape the radiation beam more closely to that of the planning target volume.

Simulator

A machine with geometric movements similar to those of the linear accelerator, but which allows a patient's treatment to be simulated and imaged using kilovoltage X-ray systems. It is used for localisation of treatment disease and for the verification of treatment plans prior to the patient's treatment.

Stereotactic radiotherapy

A radiotherapy technique, which uses a very precise localisation/fixation system and a number of small radiation beams, for treating small lesions most commonly in the brain. Where the intent is to sterilise the target volume, the practice is termed stereotactic radiosurgery and radiation is delivered in only one or two fractions.

Teletherapy

Irradiation of a patient using external sources of radiation (as opposed to brachytherapy).

Treatment planning

The process whereby the therapeutic strategy of the clinical oncologist is realised as a set of treatment instructions together with a physical description of the distribution of the prescribed dose in the patient. (Williams and Thwaites 1993)

Treatment planning system (TPS)

The hardware and software used for simulating the irradiation geometry to be used for patient treatment and for calculating the distribution of dose within the patient. Modern TPSs comprise of software tools that employ patient data from CT and other imaging modalities to visualise volumes of interest and software that can design patient specific accessories, such as shielding blocks and compensators. The main function of a TPS is to help the user design the optimum dose distribution within the patient, with most systems now able to do this in 3D (for both display and

calculations). Treatment parameters for a particular plan can be transferred to the linear accelerator via a computer network system.

Total Body Irradiation technique

An irradiation technique using megavoltage x-rays for treating leukaemia or for eradicating bone marrow prior to bone marrow transplantation.

Total skin electron technique

An irradiation technique for treating large, whole body, superficial skin disease using electron beams.

Ultrasound guided prostate brachytherapy

The implantation of brachytherapy sources in the prostate gland with the aid of ultrasound images acquired through a rectal probe.

Tumour control probability (TCP)

The probability of killing the tumour as a function of the applied radiation dose. (Webb 1993)

Abbreviations

CPD	: Continuing Professional Development
CT	: Computerised Tomography
EPID	: Electronic Portal Imaging Device
HDR	: High Dose Rate
IRR90	: Ionising Radiations Regulations 1999
IR (ME) R	: Ionising Radiation (Medical Exposure) Regulations
IMRT	: Intensity Modulated Radiation Therapy
IPEM	: Institute of Physics and Engineering in Medicine
LDR	: Low Dose Rate
MLC	: Multileaf Collimator
MPE	: Medical Physics Expert
MTO	: Medical Technical Officer
MRI	: Magnetic Resonance Imaging
NTCP	: Normal Tissue Complication Probability
PET	: Positron Emission Tomography
PPM	: Planned Preventative Maintenance
QMS	: Quality Management System
RPA	: Radiation Protection Advisor
RPS	: Radiation Protection Supervisor
SRCS	: State Registered Clinical Scientist
TBI	: Total Body Irradiation
TCP	: Tumour Control Probability
TPS	: Treatment Planning System
TSEI	: Total Skin Electron Irradiation

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