Institute of Physics and Engineering in Medicine

IPEM

IPEM Recommendations for the Provision of a Physics Service to Radiotherapy

1. Introduction

This document reflects the impact of the technological, medical and regulative changes affecting radiotherapy since the publication of previous guidance over five years ago. The last five years has seen an increase in both the quality and quantity of radiotherapy treatment machines and associated equipment in departments throughout the UK. This trend is likely to continue with both the NRAG report[1] and The Cancer Reform Strategy[2] advocating an increase in radiotherapy provision for the UK. In addition the NRAG Technical Development Sub-Group[3] strongly endorsed advanced radiotherapy as the future standard of care with greater use of image-guided 4D adaptive radiotherapy and intensity modulated radiotherapy. Such advanced equipment requires an increased level of support by clinical scientists, physics and engineering technologists. Furthermore the Ionising Radiation (Medical Exposures) Regulations (IR(ME)R)[4] provide a statutory requirement for the availability of Medical Physics Experts (MPE), in addition to the long-standing requirement for Radiation Protection Advisers[5].

This document addresses the current issues and gives professional guidance on the provision of a physics service to radiotherapy. Although the document provides guidance on the number of clinical scientists, clinical and engineering technologists required to provide a safe radiotherapy service it should be understood that increased levels of skill mix can be applied to individual departments depending on local work practices and circumstances.

These guidelines supersede the previous IPEM policy statement: 'Guidelines for the Provision of a Physics Service to. Radiotherapy'[6] issued in 2002.

2. Minimum Physics Staffing Requirements for Radiotherapy

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

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 ten components should then be summed.

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

Unit	Item	WTE Clinical Scientists per unit item (see note a)	WTE Technologists per unit item		Notes
			Physics (see note a)	Engineering (see notes a,b)	
Equipment dependent factors					
1	Multi-mode accelerator	0.8	0.4	1.0	
1	Single mode accelerator	0.6	0.3	0.8	
1	Major item	0.2	0.2	0.2	c
1	Minor item	0.1	0.1	0.1	d
Patient dependent factors					
1000	New courses treated p.a. by external beam therapy	0.8	1.0		
100	New courses treated with 3D conformal planning	0.1	0.3		
100	New courses treated p.a. by brachytherapy	0.3	0.5		
100	Special Techniques	0.3	0.5		e
Departmental Factors					
	Radiation Protection	0.1			
	Established Quality System	0.5			

Notes

a. 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 technologists must be adequate to cover for absences.

b. The number of engineering technologists required will depend on the extent to which maintenance is carried out in-house. Even where there is a fully comprehensive, externally resourced, service contract it is recommended that a facility for first line repair and quality control is provided in-house.

c. Examples of major items include CT scanners, Simulators, treatment planning systems (TPS), HDR/PDR units and oncology management systems.

d. Examples of minor items include IGRT systems, advanced TPS features, othovoltage/superficial units, block cutting devices, stereotactic radiotherapy equipment.

e. Special techniques include TBI, stereotactic radiotherapy, total skin electron techniques, IMRT and prostate brachytherapy.

Equipment is considered to include all imaging, IT and treatment equipment, the range and complexity of which has increased significantly over the past few years. Equipment requires commissioning and maintaining throughout its lifetime. For major items of equipment this is usually considered to be 10 years. Radiotherapy Physics staff are involved from the initial procurement process through to de-commissioning. At the start of the procurement process a significant time is required to appropriately specify and evaluate a major piece of equipment and the resource required for this activity should not be underestimated. Once the equipment is installed, acceptance testing and commissioning is required. Two whole time equivalent staff are required to ensure this is undertaken in a timely manner and to ensure the integrity of the process[7]. Ongoing support for equipment will include maintenance and quality assurance, although maintenance may be provided under a contract with an external body.

IPEM believes that these recommendations reflect the factors currently recognized 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.

3. Additional Considerations

Minimum number of MPEs

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 Consultant Clinical Scientist level, to be Head of and be professionally accountable for, the service.

Extended Working

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.

Development of New Techniques

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.

In-Vivo Dosimetry

Towards safer radiotherapy[8] recommends '*that all radiotherapy centres should have protocols for in vivo dosimetry and this should be in routine use at the beginning of treatment for most patients'.* For many radiotherapy physics departments this recommendation requires a much greater provision of in-vivo dosimetry than traditionally provided. The recommended staffing required to support single mode and multi-mode linear accelerators in table 1 includes a limited provision for in-vivo dosimetry in line with the previous IPEM staffing document[6]. However, the staffing requirements per linac for a fully comprehensive in vivo dosimetry service have been outlined by Williams & McKenzie[9] and amount to 0.15-0.20 WTE staff per linac.

Teaching/Training

The figures given in table 1 are for fully trained staff. Staff that are not State Registered Clinical Scientists still require substantial supervision and additional staffing is required for this task. Where departments provide significant training in addition to that required for state registration or to ensure the competence of staff within the radiotherapy department, additional resources should be made available.

Satellites
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.

Clinical Trials
National and international trials involving radiotherapy require detailed implementation by a Medical Physics Expert (MPE) and draw on the resources of the general radiotherapy staffing. For the initial set-up and maintenance of clinical trials it is estimated that one WTE member of staff is required for every 8 clinical trials that a radiotherapy centre is involved in. Centres need to carefully consider the staffing requirements for trials on an individual basis.

Radiobiology Advice
Although not routinely covered in the training of clinical scientists, appropriately trained individuals can provide valuable advice on the radiobiological effects of gaps in treatment and alternative fractionation regimes. At all times the responsibility for changes in the fractionation schedule including compensation for treatment gaps resides with the clinical oncologist authorizing the treatment.

Information Technology
An appropriately trained clinical scientist can 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. However, given the highly specialized nature of the work, IT specialists should always be considered for this role.

Continuous Professional Development (CPD)
It is important for all healthcare professionals to maintain and develop their skills and knowledge throughout their career. In recognition of this the Health Professions Council requires all registrants to undertake a range of CPD activities. All staff should have within their job plans time allocated for CPD, although this may take the form of in-house training, technique and service development projects to meet the needs of the department.

Economy of Scale
In very large departments there MAY be economies of scale, but local conditions such as extended hours working, a significant Research or Teaching workload or a diverse equipment base will reduce the economies expected.

4. Skill Mix & the Role of the Medical Physics Expert (MPE)

Skill mix patterns in Radiotherapy Departments have evolved over many years and are largely based on the ease of recruiting different staff groups in different parts of the country as well as on the personalities who influenced the setting up of different departments. A joint document from the RCR, IPEM and CoR described some of the issues[10] and it should be noted that although table 1 above clearly demarcates the different staff groups, in practice radiographers, physics and engineering technologists can, with appropriate training and support, be employed to perform tasks traditionally associated with clinical scientists. Flexibility can be applied to the staffing numbers given by table 1 to provide an estimate of the size of the required workforce and then models of skill mix applied to the number of clinical scientists, radiographers, physics and engineering technologists employed in practice.

Given the potentially large range of skill mix scenarios special consideration should be taken of the role of the Medical Physics Expert in radiotherapy. The Ionising Radiation (Medical Exposures) Regulations 2000 follow the European Directive[11] in requiring a Medical Physics Expert (Qualified Expert in the EU documents) to be “closely involved” in all radiotherapy treatments. This expert must be specifically trained in Radiotherapy Physics and the implication of the requirement is that such a physicist should be available on site for at least part of the day, wherever radiotherapy is carried out. The role of the MPE in radiotherapy is set out in detail in the Medical and Dental Guidance Notes[12], but some comments on detailed arrangements are appropriate here.

The first role of the MPE is to ensure the accurate calibration of the treatment equipment. This involves the establishment of the protocols for dosimetry within the centre and an active involvement in the process of definitive calibration of the equipment as set out in appendix 15 of the Medical and Dental Guidance Notes[12]. The level of supervision that is required for calibrations carried out by others will depend to some extent on their individual competence. Therefore the MPE must be personally involved in the assessment of competence of staff carrying out the work. Calibration extends to the provision of beam data for all dose calculations. An MPE must supervise and take full responsibility for the measurement and analysis of these data.

The process of treatment planning is becoming increasingly complex and there are many examples of issues that can cause unforeseen problems. Ideally a Medical Physics Expert should have full responsibility for the scientific aspects of the treatment planning process including setting up protocols for standardized treatments[13]. It is in the introduction of new equipment and techniques that it is particularly important to have input from an MPE. An MPE must be closely involved in the establishment of all new techniques and with any deviation from standard practice, including when an individual patient treatment requires an unusual setup. It is essential that sufficient time is given to examine new techniques carefully so that systematic errors are not introduced.

It must be emphasized that where functions are devolved to other staff groups it remains necessary for the MPE to provide appropriate supervision in order to be “closely involved” in the treatment. Such “supervision” is best applied when physicists work alongside their radiographic and technical colleagues so that they fully understand the detail of the processes being applied. It should be remembered that whatever the skill mix solution employed training is a key factor in its success. It is also important to remember that in order to become a Medical Physics Expert a considerable amount of practical experience is required and this can only be acquired by taking part in the various procedures. For this reason it is imperative that any skill mix project includes Medical Physicists in routine tasks to some extent.

5. Risks associated with reduced staffing levels

The Manual for Cancer Services[14] required that numbers of radiotherapy physicists should conform to IPEM recommendations as outlined in 2002[6]. However, an IPEM survey of radiotherapy centres in 2008 highlighted that only 21% had met the recommendations with 13% of departments having a deficit of 10 staff or more[15]. In addition, understaffing and inadequate skill mix were highlighted as contributory factors in a number of radiotherapy incidents reported to the Department of Health prior to IR(ME)R. As a result the report 'Towards safer radiotherapy'[8] recommends that departments review their staff levels at intervals of no more than two years and ensure compliance with national guidance. It should also be noted that achieving reasonable staff levels but without the appropriate level of experience and supervision is also likely to lead to an increased risk of failure in patient safety standards.

It is important to understand the consequences of inadequate staffing levels. For whatever size department the minimum service must be the provision of a radiation dosimetry service for radiotherapy, maintenance of the equipment and support of routine radiotherapy treatment planning. Inadequate staff resources may directly impact on the quantity and quality of the service provided to the patients, oncologists and radiographers within a department. In particular inadequate staffing may lead to increased waiting times for cancer treatments, thereby compromising an individual patient's probability of disease free survival. Where there is a shortfall of staff compared to the guidelines outlined above there is a potential for:

- 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[13,16].

Patients are put at an increased level of risk in departments operating at staff levels well below national guidance for prolonged periods of time. Departments in this situation should therefore ensure that robust risk management is in place to reduce the risk posed by understaffing over a reasonable timescale.

6. Example Staff Calculation

Consider a radiotherapy department comprising 4 multi-mode linear accelerators, 4 single mode linear accelerators, and 2 CT-Simulators. 50% of the linacs are equipped with IGRT systems. In total 4800 patients are treated per annum with 50% of patients treated palliatively and 400 treated with a mixture of special techniques such as IMRT, total body irradiation and total skin electron treatments. In addition the department treats 300 patients per annum with gynaecological cancer using HDR brachytherapy, 100 patients per annum with early prostate cancer using low dose brachytherapy seeds, and 50 patients per annum with prostate cancer using HDR brachytherapy alone.

Table 2: Example staffing calculation using the IPEM formalism.

Item	**WTE Clinical Scientists**	**WTE Physics Technologists**	**WTE Engineering Technologists**
4 Multi Mode Linear Accelerators	3.2	1.6	4.0
4 Single Mode Linear Accelerators	2.4	1.2	3.2
Major Item (2 CT-Simulators)	0.4	0.4	0.4
Major Item (treatment planning system TPS)	0.2	0.2	0.2
Minor Items (4 IGRT systems)	0.4	0.4	0.4
Minor Item (Advanced TPS - external beam therapy)	0.1	0.1	0.1
New courses treated pa by external beam therapy (4800 patients)	3.84	4.8	0
New courses treated with 3D conformal planning (2100 patients)	2.1	6.3	0
New courses treated pa by brachytherapy (300 + 100 patients)	1.2	2.0	0

Special techniques (400 patients)	1.2	2.0	0
Special techniques (50 prostate HDR patients)	0.15	0.25	0
Radiation Protection	0.1	0	0
Established Quality System	0.5	0	0
Total	**15.79**	**19.25**	**8.3**

7. References

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16. Report of the Committee of Inquiry into the Incident in the radiotherapy department. Exeter. Exeter Health Authority, 1988
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Appendix A. Specific Roles and Responsibilities of Clinical Scientists

The clinical scientist[A] 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 summarized 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 planning
- 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 including 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).

Clinical scientists are scientifically trained in the techniques for accurate measurement and numerical recording that underpin a well designed quality control system for the equipment used in radiotherapy. 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 judgment between the need to deliver treatment to patients and the need for treatment accuracy.

The training of a clinical scientist is designed to produce an individual who has a sound knowledge of the physical principles underlying radiotherapy treatment, and the skills necessary to perform scientific research. The training enables the clinical scientist to analyze 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 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 fully accredited Radiation Protection Adviser (RPA) should always be consulted when designing

[A] The term 'Clinical Scientist' is a protected title and may only be used by those registered as such with the Health Professions Council.

new radiotherapy facilities.

The training of a clinical scientist will also include extensive study of computing techniques including appropriate numerical methods and programming techniques. An appropriately trained clinical scientist can therefore make a major contribution to the management and operation of the many sophisticated computer systems likely to be used in radiotherapy as well as to the development of new software. However, given the highly specialised nature of the work IT specialists should always be considered for this role.

Appendix B. Specific Roles and Responsibilities of Technologists

Clinical technologists involved in the functions covered by these recommendations come from a variety of backgrounds, the main ones being electronic engineering, mechanical engineering and clinical physics. For the purposes of the IR(ME)R Regulations the clinical technologist may act as an operator. The employer must ensure adequate training is provided and the scope of practice is clearly documented.

Technologists in radiotherapy form part of the multi-professional team responsible for providing technical support service to radiotherapy. Their key roles may be summarised as:

- 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
- In-vivo dosimetry
- Control and quality assurance of dosimetry equipment and radiotherapy treatment systems
- Service development including R&D
- Hazard/risk analysis and safety testing
- Management of computer systems and software development

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 electronic engineering 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[17]. In many departments the engineering 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 ensure that maintenance methods and any modifications do not invalidate the CE marking of the equipment.

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.

Technologists with clinical physics training perform all aspects of computed treatment planning including patient immobilisation under procedures authorised by the MPE. They will also be involved in developing these procedures. They will manufacture custom immobilisation devices and shields (Mould Room work). Under the supervision an MPE, technologists will undertake both routine and complex quality assurance measurements on a wide range of radiotherapy treatment systems, including making adjustments to parameters that affect the radiation output. They may have responsibility for maintaining the performance and accuracy of radiotherapy dosimetry measuring equipment, including their compliance with national guidelines. With guidance from an MPE, they may undertake patient dose measurements and develop and implement systems for doing so. In brachytherapy they may prepare sealed sources for treatment use, including the development of devices, and may assist in theatre. Clinical technology specialists undertaking such roles may be better described as dosimetrists, although this is not a clearly defined profession within Medical Physics.

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.

July 2009