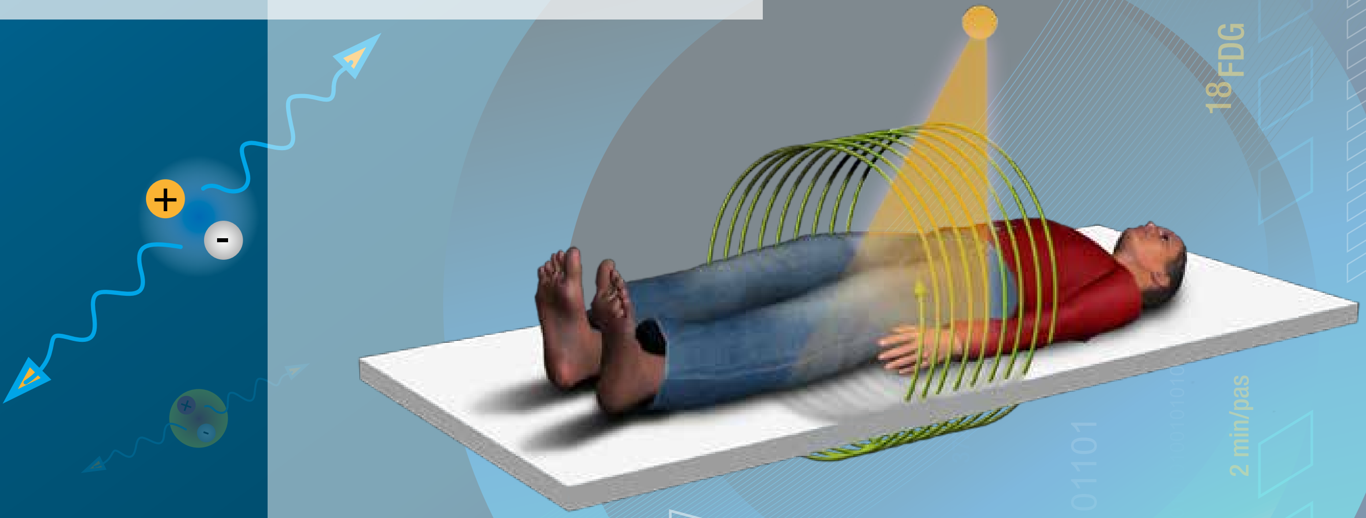
ASN/SFPM RECOMMENDATIONS

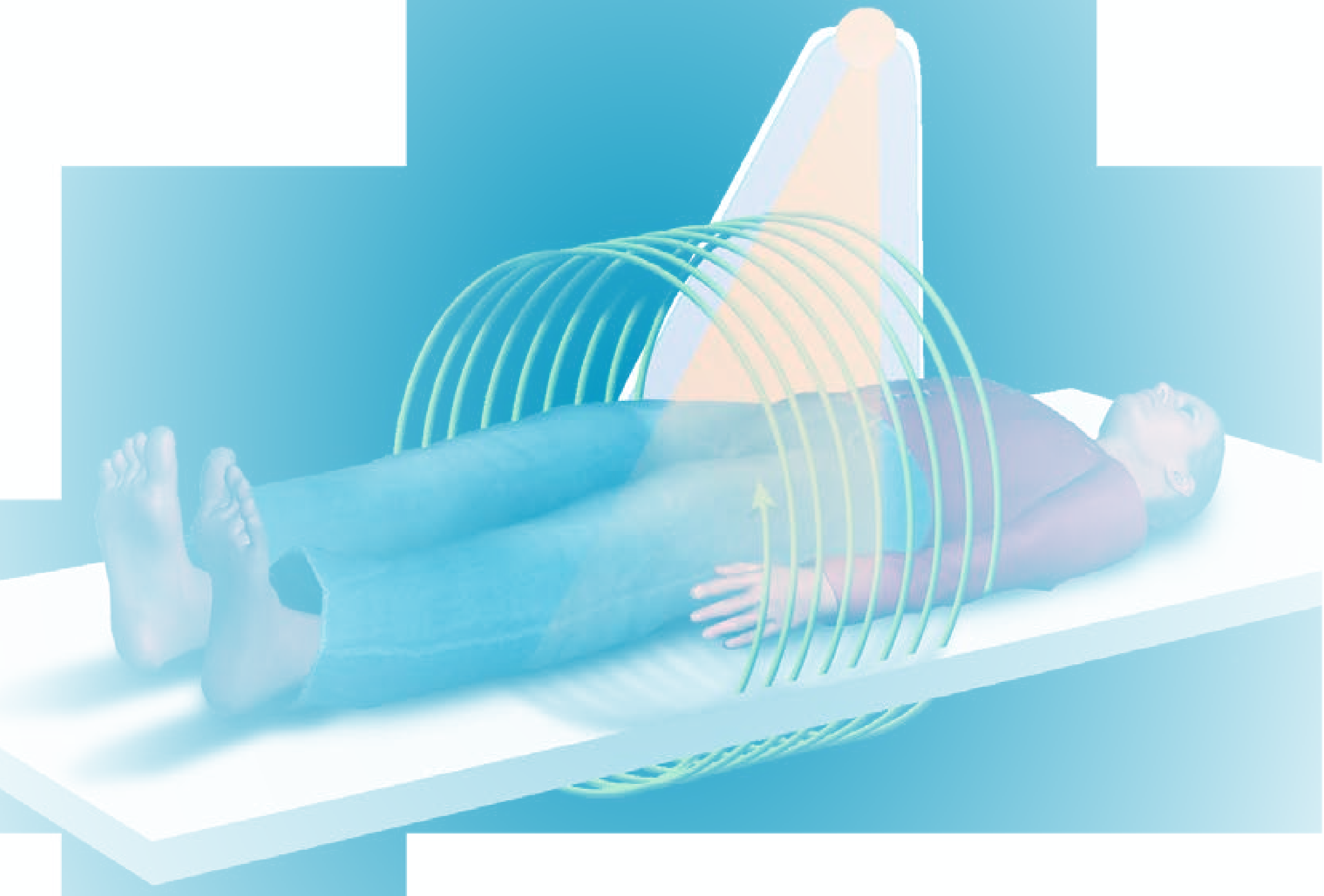
Medical Physics Personnel for Medical Imaging Requirements, Conditions of Involvement and Staffing Levels

APRIL 2013



asn AUTORITÉ DE SÛRETÉ NUCLÉAIRE

sfpm SOCIÉTÉ FRANÇAISE DE PHYSIQUE MÉDICALE



PREFACE

ASN, the French Nuclear Safety Authority, has been regulating medical applications of ionising radiation since 2002. Between 2002 and 2005, ASN worked on the publication of new regulations governing the radiation protection of patients and transposing directive Euratom 97/43[1] in particular. During that period, ASN intensified its oversight by carrying out inspections chiefly in radiotherapy, nuclear medicine and radiology (for computed tomography) departments, addressing the subjects of occupational radiation protection, the technical conformity of the facilities with authorisation requirements and radioactive source management rules. As of 2007, further to radiotherapy accidents, ASN refocused its inspection programme on the safety of radiotherapy treatments and oriented its inspections towards checking patient radiation protection requirements.
Since 2008, interventional radiology and the various procedures that make increasing use of ionising radiation to guide the medical practitioner (in surgery, cardiology and neurology, for example) have become priority inspection areas.
ASN's inspections in the field of imaging, combined with experience feedback from events notified to it, have revealed shortcomings in the optimising of practices, due in particular to the lack of involvement of medical physicists.

In June 2011 ASN published two deliberations, one concerning the increase in doses delivered to patients during computed tomography (CT) and conventional radiology examinations, the other relative to the improvement in radiation protection in interventional radiology. In these deliberations, apart from the questions concerning the training of professionals, the optimising of doses delivered during examinations thanks to better quality assurance at all levels, and reinforcement of the effective application of the principle of justification for the radiological examinations, particular emphasis is placed on the major role of the medical physicists in optimising procedures, evaluating and monitoring delivered doses and ensuring image quality.
In the field of medical physics, ASN considers that the efforts made since 2007 to boost the numbers of medical physicists must be continued in order to cover the needs in medical imaging.

The SFPM (French Society of Medical Physics) considers that the optimising of doses delivered during imaging examinations – in the same way as for doses delivered for therapeutic purposes – is an area in which the involvement of medical physicists must be increased and more widely developed.
Thanks to their specialised training in ionising radiation metrology among other things, medical physicists can evaluate the doses delivered during the various diagnostic procedures, link them to the image quality required and expected by the practitioner, and make recommendations to optimise the delivered doses. The SFPM has long been aware of the shortage in France of the human resources in medical physics required to apply the principle of optimisation and perform all the associated tasks, and this shortage can have a significant impact on patient radiation protection, particularly in medical imaging applications.

Given these findings, ASN and the SFPM have decided to issue recommendations to help the medical institutions define their medical physics requirements.

This guide entitled « *Medical Physics Personnel for Medical Imaging - Requirements, Conditions of Involvement and Staffing Levels* » made available in all the medical institutions that use ionising radiation for medical purposes, whatever their status, provides information on the medical physics tasks to be carried out and their quantification. It contains recommendations concerning the involvement of medical physicists (with or without supporting staff) and the personnel numbers required in nuclear medicine (PET CT, targeted internal radiotherapy, radioembolisation, etc.) and more generally in imaging (interventional radiology, computed tomography, conventional radiology).

This guide supplements the existing guides, and notably the « *Guide to good practices in medical physics* » produced by the SFPM and published in 2012. It is the result of an innovative approach which to our knowledge has never before been applied - including in other countries - with such a degree of exhaustiveness and precision. It is intended that the guide should evolve by integrating experience feedback from users. With this in view, we would ask you to inform us of any difficulties you might encounter when using the guide.

We hope that this guide will help medical establishments define their needs in medical physics and ultimately contribute to improving patient radiation protection through the optimisation of practices.

The Director-General
of ASN (French Nuclear
Safety Authority)

Jean-Christophe NIEL

The President of the SFPM
(French Society of
Medical Physics)

Dominique LE DU

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[1] Directive 97/43/Euratom of 30th June 1997, on health protection of individuals against the dangers of ionising radiation in relation to medical exposure.

SUMMARY

Medical applications of ionising radiation occupy an important position in patient healthcare. The ever-increasing performance of medical imaging improves the quality of diagnosis and allows therapeutic strategies to be better oriented and treatment effectiveness to be evaluated.

Medical exposure to ionising radiation is the second source of exposure of the French population after exposure to natural radiation and has been increasing over the last few years. The joint IRSN and InVS report published in 2010 [IRSN-2010] underlines that the doses associated with the use of diagnostic imaging increased by 57% between 2002 and 2007. In 2007, computed tomography represented 10% of the medical imaging procedures but contributed 58% to the average effective dose.

ASN's inspections in the field of imaging, combined with experience feedback from events notified to it, have revealed shortcomings in the optimising of practices, due in particular to the lack of involvement of medical physicists.

In this context, controlling the increase in doses is a priority in patient radiation protection. Ensuring radiation protection requires knowledge of the doses delivered, the development of procedures to optimise these doses and quality control of the imaging equipment.
The role of the medical physicist is vital for the management and performance of these tasks. However, as the French regulations concerning the involvement of physicists in medical imaging procedures are relatively vague, it was deemed necessary to help medical establishments determine their needs.

As part of this report, an assessment of the involvement of medical physicists in imaging in France was carried out on the basis of the findings of ASN and a survey conducted by the SFPM (French Society for Medical Physics) (chapter II).

The report also contains a review of the European and French regulatory requirements in effect at the beginning of 2013 and of the international and French recommendations (chapter III).
Among the situations in several countries, three countries drew particular attention because they tend to be in advance of the others and display strong points in terms of medical physics training and organisation, particularly in imaging.

The various areas of activity of medical physicists in imaging have been identified and described (chapter IV). Criteria for quantifying medical physics personnel requirements are thus proposed (chapter V and appendix 2).

The result of this work is an aid available to each medical establishment so that they can determine their own needs in terms of medical physics. These needs are defined according to the technical platform, the procedures and techniques practised on it, the number of patients treated and the number of persons in the medical and paramedical teams requiring periodic training.
Making a «calculation aid» available on the SFPM website in the months following the publication of this report will simplify the calculation of the medical physics personnel requirements, which remains a complex exercise, even though all the necessary data figure in this report.

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CONTEXT

Medical applications of ionising radiation hold an important position in patient healthcare. The increasingly good performance of medical imaging improves diagnostic quality, thereby helping optimise therapeutic strategies and evaluate treatment effectiveness.
Therapeutic procedures can also be carried out in interventional radiology and nuclear medicine. To give an example, in 2009 the interventional radiology activity in France taken as a whole represented 545,000 procedures (interventional cardiology excluded), comprising 315,000 diagnostic procedures and 230,000 therapeutic procedures.

Medical exposure to ionising radiation is the second source of exposure of the French population after exposure to natural radiation.
In 2010, IRSN and InVS published a joint report [IRSN-2010] which underlined that doses associated with the use of diagnostic imaging increased by 57% between 2002 and 2007. In 2007, computed tomography represented 10% of the medical imaging procedures but contributed 58% to the average effective dose.

The accidents that occurred in the United States (at the Cedar–Sinai Medical Center between February 2008 and August 2009, when performing computed tomography (CT) brain perfusion scans, and at the Mad River Community Hospital where a child was accidentally subjected to 1 hour of CT scans in January 2008) made people realise that in these two cases the use of CT imaging could lead to the delivery of high radiation doses.

During the last few years, significant radiation protection events have been notified to ASN, underlining the strong radiation protection implications for both the patients (deterministic effects have been observed following particularly long and complex interventional procedures) and the medical staff (dose limit exceedances have been observed). One of these events in interventional radiology was notified by the Strasbourg University Hospitals in 2009 [HUS-2009]. Following this notification, ASN took several steps, including the publication of recommendations to optimise the radiological procedures in interventional neuroradiology circulated by letter to the managing directors of the regional hospitals and universities and to the heads of interventional vascular neuroradiology departments[22], and the referral to the Advisory Committee of Experts in radiation protection for medical and forensic applications of ionising radiation (GPMED) in order to issue recommendations on the application of radiation protection principles in interventional radiology [AvisGPMED-RI2010]. Subsequently, in June 2011, ASN published a deliberation relative to the improvement in radiation protection in interventional radiology [DL-14juin2011-RI].

Moreover, ASN organised a seminar on 16th September 2010 on the theme of «the increase in doses delivered to patients during medical imaging examinations», attended by all the stakeholders concerned. At the end of this seminar, 12 recommendations and lines for progress were published and taken up in the ASN deliberation of 14th June 2011 [DL-14juin2011-imagerie].

In this context, controlling the increase in doses is a priority in patient radiation protection. Ensuring radiation protection requires knowledge of the doses delivered, the development of procedures to optimise these doses and quality control of the imaging equipment.
The role of the medical physicist is vital for the management and performance of these tasks.

In the remainder of this document, the term « medical physics » designates all the human resources assigned to that discipline, including the medical physicists and the supporting staff.
Recommendations concerning the organisation of medical physics are provided in another report[3].

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2. *http://www.asn.fr/index.php/S-informer/Actualites/2010/Retour-d-experience-de-l-evenement-en-radiologie-au-CHU-de-Hautepierre*
3. ASN Guide N°.20

I. OBJECTIVES AND WORK METHODS

During the meeting between ASN and the SFPM on 12th October 2010, it was agreed to set up an ASN/SFPM working group to identify the tasks of medical physicists in imaging departments and their conditions of involvement (the composition of the working group is described in appendix 1). Recommendations concerning the quantification criteria were also established to help the departments define the medical physics personnel needs.

The aim of this WG is to propose a substantiated document with recommendations concerning the involvement of medical physicists in imaging departments[4] .

For all the imaging fields (diagnostic and therapeutic nuclear medicine, conventional radiology, interventional radiology, etc.), the working group has identified:

- the areas of activity of the medical physicist;
- the medical physics tasks by area of activity and the time necessary for each of these tasks;
- the involvement of the medical physicist in the procedures and their monitoring;
- the conditions of involvement.

This report is intended for all medical establishments using ionising radiation for medical purposes or medical research, whatever their status. It constitutes an aid for determining the medical physics needs of medical establishments.

In an approach to enhance the quality and safety of the treatment of patients receiving ionising radiation, identifying the risks associated with medical practices is fundamental for determining the needs that can optimise practises. To achieve this, appropriate objectives must be defined within each structure according to their practice and their medical projects.

The aim of this report is to describe the medical physics tasks and to issue recommendations for determining the medical physics staffing requirements with respect to the quality and safety objectives specific to each site.
Thus, depending on these objectives, this report is a methodological aid to the identification of tasks and the quantification of the human resources in medical physics required to achieve them.

The radiologist physicians (French professional council for radiology - G4) and nuclear medicine physicians (French professional council for nuclear medicine) were consulted concerning the recommendations of the working group in March 2012.

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[4] With the possibility of delegating certain tasks, subject outside the scope of the report

II. SITUATION IN FRANCE IN 2012

The information presented in this chapter is based on three information sources: the results of inspections performed by ASN in the medical sector, the opinion of the Advisory Committee of Experts reporting to ASN (GPMED), the ASN deliberations and a survey conducted in 2011 by the SFPM with the medical physicists working in imaging departments.

II.1. Findings made during ASN's radiation protection inspections

II.1.1. Results of radiation protection inspections in nuclear medicine

ASN inspected all the nuclear medicine units over the 2009-2011 period. 89% of them state that they call upon a medical physicist whenever necessary.

II.1.2. Results of radiation protection inspections in interventional radiology

In 2010 and 2011, ASN inspected 260 departments practising fluoroscopy-guided interventional procedures. The results reflect the general trend for radiation protection in interventional radiology.

Dose optimisation is the responsibility of the machine operator, assisted by the medical physicist. However, the medical physicist is rarely asked to assist in this activity. The result of the inspections and experience feedback from the significant radiation protection events notified to ASN show that a true optimisation procedure is rarely implemented.

In 2009 only 40% of the medical institutions had defined a medical physics organisation plan (as required in article 7 of the order of 19th November 2004).

On the whole, the results of radiation protection inspections in interventional radiology reveal the lack of medical physicists in the field of patient radiation protection.

II.2. GPMED opinion of 23rd November 2010 concerning the « Recommendations on the application of the principles of radiation protection in the field of interventional radiology » and ASN deliberations of 14th June 2011

In its opinion of 23rd November 2010 [AvisGPMED-RI2010], the GPMED recommends defining – with the representatives of the professionals concerned – the role of medical physicists in interventional radiology and the human and organisational means devoted to it, particularly at the time of:

- purchase,
- equipment acceptance, maintenance and quality control,
- optimising procedures,
- establishing reference dose levels, and
- defining the doses that require subsequent patient monitoring.

The GPMED based this opinion on the report of a working group (called «GT RI», the French acronym for «interventional radiology working group») which issued 42 recommendations concerning radiation protection in interventional radiology, including the following 8 recommendations [GT-RI2010] that directly concern medical physicists:

« **6.** *Reassert the role of the persons competent in radiation protection (PCR) and the medical physicists in the acquisition process for interventional radiology facilities (medical devices, radiological protection equipment, etc.).*

10. *Oblige the users, aided by the medical physicist, to define optimised protocols as soon as the medical device emitting ionising radiation is put into service.*

15. *Draw the attention of the competent authorities to the lack [5] of medical physicists in interventional radiology.*

16. *Adjust the requirements to have the assistance of a medical physicist in the units according to the risks associated with the procedures.*

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[5] « Lack » in the sense that the number of physicists effectively involved in imaging is currently low (note from the SFPM-ASN working group).

26. *Ensure that the training of medical physicists gives an equitable share to all the areas of medical physics that use ionising radiation, including interventional radiology, and that courses are opened in interventional radiology departments.*

32. *Aided by the medical physicist, determine an alert threshold for the appearances of any tissular reactions induced by the ionising radiation and the conditions for the follow-up of patients that exceed this threshold. The «GT RI» recommends heightening practitioners' awareness of the importance of the follow-up of patients who have exceeded the alert threshold.*

41. *Bring together the medical physicists, the technicians working under their authority, and the PCRs in a radiation protection and medical physics department that is independent of any medical department and placed under the direct responsibility of the head of the medical establishment.*

42. *Develop and give recognition to a position of technician in physical radiation protection measures. Like the dosimetrists, these technicians will be able to work under the authority of the medical physicist.* »

One 14th June 2011, ASN published a deliberation relative to the improvement in radiation protection in interventional radiology [DL-14juin2011-RI], based on the recommendations of the GPMED and the results of the inspections carried out in 2009. In this deliberation ASN states that it considers that urgent steps must be taken to improve the radiation protection of patients and workers in interventional radiology, particularly for fluoroscopy-guided interventional procedures in operating theatres. ASN underlines two essential points that require specific measures, one of which concerns the medical physicists. ASN considers that the efforts initiated in 2008 to train medical physicists to meet the urgent needs in radiotherapy must be continued for at least 5 consecutive years for there to be sufficient medical physicists to fulfil medical imaging needs, especially in interventional radiology.

In ASN deliberation 2011-DL-0019 of 14th June 2011 relative to the increase in doses delivered to patients during CT and conventional radiology examinations [DL-14juin2011-imagerie], ASN supplements this recommendation by specifying that continuing the efforts to train and recruit medical physicists will enable real progress to be made in the optimisation of procedures and the monitoring and evaluation of doses delivered to patients, while guaranteeing the necessary diagnostic image quality.

II.3. Survey carried out with medical physicists involved in imaging

At the beginning of 2011, the SFPM conducted a survey of the medical physicists working in medical imaging (see appendices 3 and 4).

II.3.1. Results of responses for nuclear medicine

At the end of 2011, this sector totalled 236 in vivo and in vitro nuclear medicine units in operation, 60% of them installed in public or quasi-public structures and 40% in private structures.

This was broken down into (ASN 2011 figures):
- 466 gamma-cameras, of which 150 are coupled to a CT scanner and 103 to a PET-CT scanner;
- 166 radiation-protected rooms for targeted internal radiotherapy (40 sectors equipped).

Out of the 26 replies received for the SFPM's survey, 6 were from cancer centres, 19 from public hospitals and 1 from a private centre.
There are on average 0.8 contractual full-time equivalent (FTE) (for 0.7 actual FTEs[6]) medical physicists per nuclear medicine department that replied, for an average equipment pool of 2 SPECT, 0.9 SPECT-CT, 0.8 PET-CT, 3 dose calibrators and 2.3 probes per department.

It is noteworthy that these replies come from centres using state-of-the-art technology (total of 22 PET-CT machines, 23 SPECT-CT machines, 44 SPECT machines among the 26 centres that replied) and advanced medical practices (22 centres performing therapy, 17 of them using Zevalin®, 9 centres for which the medical physicists participate in the drafting of the Hospital Clinical Research Programme - PHRC).

For the ***activities associated with the equipment*** (administrative management, quality control, evaluation of performance, implementation and utilisation of complex techniques, optimisation, radiation protection of patients and people spending time with them, manufacturer interface, image processing, etc.), the FTE varies from 0.1 to 0.95 depending on the equipment pool in the department.

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[6] 6. Contractual FTE means the theoretical number of FTE medical physicists assigned to nuclear medicine with respect to the effectively assigned number of FTEs.

These activities depend little if at all on the number of patients, but concern 100% of the medical physicists.

For the ***therapy activities***, a distinction has been made between:

- highly standardised non-cancer therapy[7] in which the medical physicist's involvement is low;
- systemic cancer therapy[8] for which French legislation requires that the treatment preparation be validated by a medical physicist;
- selective cancer therapy[9] for which a personalised dosimetry must be calculated and validated by a medical physicist.

Consequently, the replies depend on the type of therapy and the number of patients treated. 85% of the respondent sites have a therapy activity to which the time devoted ranges from 0.02 to 0.5 medical physicist FTEs, with an average of 0.2 FTE.

The medical physicists also have a ***teaching activity*** in 88% of the cases and a ***clinical research and/or medical physics research activity*** in 50% of the cases (0.06 to 0.5 FTEs, with an average of 0.16 FTEs).
14 of the 26 respondent centres take in DQPRM (Qualifying Diploma in Medical & Radiological Physics) students.

In addition, 61% of the medical physicists said they had an activity linked to the ***radiation protection of the personnel*** in the nuclear medicine department and/or the management of radioactive waste[10].

The questionnaire also revealed large differences in hierarchical attachment, but with roughly equal proportions attached either directly to an administrative department (quality and risk management, human resources, etc.), or to a nuclear medicine department or unit, or to a medical physics and radiation protection unit attached to an administrative department.

II.3.2. Results of responses for radiology

At the end of 2011, the French pool of radiological devices included 1109 computed tomography facilities (ASN figures).

Out of the 19 replies received for the SFPM's survey, 6 were from cancer centres, 12 from public hospitals and 1 from a private centre. For the respondent centres, an average of 0.24 FTE medical physicists are working in radiology.
It can be noted that the replies to the questionnaire come from establishments in which at least one medical physicist is present and working in radiotherapy and/or nuclear medicine and/or radiology.

The medical physicists working in radiology have practically no teaching activity (3 respondents overseeing Master's degree year 1 and year 2 students) apart from overseeing DQPRM students (7 centres out of 19).
Among the 0.24 FTEs in radiology, the medical physicists who take on DQPRM students devote 0.11 FTEs on average to their supervision.
The medical physicist's time in radiology is essentially devoted to the CT scanner (including optimising doses delivered to patients), and then to strictly regulatory duties in conventional radiology (IQC, EQC and DRL). In cancer centres, more tasks are devoted to mammography than in public hospitals. The interventional radiology tasks, more numerous in the public structures, are also limited to regulatory duties, but with optimisation still being particularly insufficiently catered for owing to the expertise it requires and the lack of human resources.

The average FTE of medical physicists was analysed according to hierarchical attachment. If a physicist working in radiology is attached to:

- a radiotherapy supervisor, the average FTE is 0.16;
- a medical imaging supervisor, the average FTE is 0.21;
- an administrative department supervisor, the average FTE is 0.35.

Attachment of the medical physicist to an administrative department therefore seems to favour the time devoted to radiology assignments.

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[7] Example: hyperthyroid treatment by I-131, synoviorthesis, etc.
[8] Example: treatment of thyroid cancers, treatment of lymphomas by Zevalin®, treatment of endocrine tumours by Octreoscan®.
[9] Example: treatment of hepatocarcinomas by resin or glass microspheres marked with yttrium 90. The prescription can be based on a dose to a target volume
[10] This management is nevertheless not part of the specified tasks of a medical physicist, in accordance with ASN resolution 2008-DC-0095, any holder of a license who produces contaminated waste is responsible for that waste right up to its final disposal. The licensee must also establish and implement a management plan for the contaminated effluents and wastes he produces.

III. REGULATORY REQUIREMENTS AND RECOMMENDATIONS

III.1. Regulations

III.1.1. Regulations in effect at the beginning of 2013

Directive 97/43/Euratom [Directive 97/43]

Article 6 of Directive 97/43/Euratom, «Procedures», 3rd paragraph, states that:

«*In radiotherapeutic practices, a medical physics expert shall be closely involved. In standardised therapeutical nuclear medicine practices and in diagnostic nuclear medicine practices, a medical physics expert shall be available. For other radiological practices, a medical physics expert shall be involved, as appropriate, for consultation on optimisation including patient dosimetry and quality assurance including quality control, and also to give advice on matters relating to radiation protection concerning medical exposure, as required.*»

This directive defines the term Medical Physics Expert (MPE) as: «*an expert in radiation physics or radiation technology applied to exposure, within the scope of this Directive, whose training and competence to act is recognized by the competent authorities; and who, as appropriate, acts or gives advice on patient dosimetry, on the development and use of complex techniques and equipment, on optimization, on quality assurance, including quality control, and on other matters relating to radiation protection, concerning exposure within the scope of this Directive*».

In the French regulations these provisions have been transposed in the Public Health Code (Article R.1333-60) and the Order of 19th November 2004 [Order of 19.11.2004] and the Order of 6th December 2011 [Order of 06.12.2011] relative to the training, the duties and the conditions of involvement of the medical physicists.

Orders of 19th November 2004 and 6th December 2011

Pursuant to Article R.1333-60 of the Public Health Code and the Orders of 19th November 2004 and 6th December 2011 relative to the training, the duties and the conditions of involvement of medical physicists, the use of radiological facilities requires the involvement of a medical physicist for questions such as dosimetry, optimisation, quality assurance (including quality control) and patient radiation protection.

Section 2, Article 6.2 of the Order of 19th November 2004 indicates: «*In nuclear medicine departments, in healthcare structures practising interventional radiology and in radiology departments, a medical physicist must be called upon whenever necessary in accordance with the requirements of Articles R. 1333-64 and R. 1333-68 of the Public Health Code*».

The training of medical physicists is also defined in the Order of 6th December 2011. The specialist training leading to the qualification in medical physics is only open - unless a waiver is granted - to holders of a master's degree that includes specialised courses in ionising radiation and dosimetry physics for medical applications and figuring in a list established by the Ministry of Health. This specialised training, lasting a minimum of one year, must cover the disciplines of radiotherapy, brachytherapy, radiology, nuclear medicine and patient radiation protection. It shall include courses in the true working environment in health-care facilities. These health-care facilities and the associated clinical departments are approved by the training organisation if the SFPM gives a favourable opinion.

In January 2013, 7 master's degrees delivered by the Universities of Toulouse, Paris, Grenoble, Nantes, Lille, Rennes and Clermont-Ferrand give the right to sit the competitive entrance exam for the specialised training detailed in the Order of 3rd March 1997 (called Qualifying Diploma in Medical & Radiological Physics – DQPRM – created in 1995) and which to date is dispensed solely by the INSTN (National Institute of Nuclear Sciences and Techniques).

At the beginning of 2013, the course syllabus comprises:

- theory classes lasting 7 weeks minimum,
- a 52-week internship comprising 36 weeks in radiotherapy, 10 weeks in nuclear medicine and 6 weeks in radiology. These internships are carried out in physics departments approved by the SFPM.

As at the beginning of 2013, this professional training of medical physicists (DQPRM) - which lasts just one year - is the shortest in Europe. It must be increased to 2 years when the new academic year begins in September 2013 (recasting of the syllabus and internship courses).

III.1.2. Prospects of change in the regulations: draft Euratom Basic Safety Standards (BSS) Directive

Directives 96/29 and 97/43 have been undergoing a revision process since September 2011, which includes updating of the provisions of directive 97/43 relating to medical physics. Several successive versions of the Council directives setting out the basic standards for health protection against the dangers arising from exposure ionising radiation have been proposed in the interim[11].

More specifically, the new directive, which is not expected to be published before 2014, updates the duties of the medical physicists in the fields of radiotherapy and medical imaging. It redefines the notion of Medical Physics Expert (MPE) and the conditions of involvement of the MPE. More precise notions of the duties of the MPE are introduced and the recognition of MPEs becomes mandatory.

III.2. International and national recommendations

III.2.1. Recommendations of the learned societies at international level

AAPM Report No.33, 1991

In 1991, The American Association of Physicists in Medicine (AAPM) published a report [AAPM report No.33] on the number of medical physicists and their responsibilities in diagnostic imaging (radiology, nuclear medicine, ultrasounds, MRI).

This report reviews the medical physics service requirements in diagnostic imaging departments. The AAPM has developed recommendations concerning the needs for medical physicists and the associated personnel to manage the questions of diagnostic image quality, safety in the use of ionising radiation and the responsibilities with respect to patient care and treatment.

The AAPM has based its recommendations in terms of staffing on the number and type of imaging machines used in a centre and the priority tasks relating to radiological safety, quality control and equipment acceptance.
For one full-time equivalent medical physicist, the AAPM report recommends also having 1.5 FTEs of «support» staff (technicians in charge of quality control, for example).
These recommendations do not include any needs associated with research activities or specific involvement in teaching tasks, and do not describe the needs associated with PET-CT scanners.
The report recommends that small facilities which do not need to employ a full-time medical physicist should employ one on a part-time basis or as a consultant to supervise operations relating to medical physics.
Similarly, AAPM report No.42 [AAPM report No.42] recommends that all departments having diagnostic facilities should have at least one qualified and experienced medical physicist.

EFOMP policy statement, 1997

In 1997, The European Federation of Medical Physics (EFOMP) published a report [EFOMP PS 7] proposing criteria for determining the staff numbers required in a medical physics team working in the fields of radiotherapy, nuclear medicine and radiology.

This report points out that generally the total number of staff required in a Medical Physics Department depends upon:

- the range of applications of physics services to medicine;
- the scale of organisational and management responsibilities (number of hospitals, population served);
- the amount and complexity of equipment and procedures used in related clinical specialities;

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[11] *http://ec.europa.eu/energy/nuclear/radiation_protection/radiation_protection_en.htm*

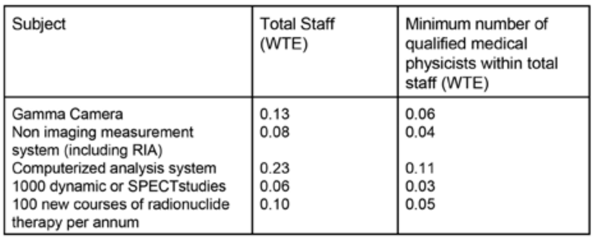
- the number of patients examined and treated with the relevant modalities and the complexities of these examinations or treatments;
- the workload for formal teaching and training;
- the level of involvement in maintenance, development, research and clinical trials.

The figures indicated in this report (dating from 1997) show wide disparities between European countries in the number of medical physicists per million inhabitants.

This report underlines that the proposed figures serve as a guideline for determining the staffing level of a medical physics team on a minimum basis to cover the routine tasks common to any type of centre. The figures do not take into account the additional personnel required if complex techniques are implemented or the time required for research or teaching activities.

With regard to the field of nuclear medicine, the following criteria are proposed:

Table 1. Extract from the EFOMP 1997 report.



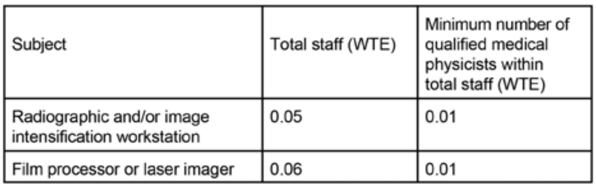
Subject	Total Staff (WTE)	Minimum number of qualified medical physicists within total staff (WTE)
Gamma Camera	0.13	0.06
Non imaging measurement system (including RIA)	0.08	0.04
Computerized analysis system	0.23	0.11
1000 dynamic or SPECTstudies	0.06	0.03
100 new courses of radionuclide therapy per annum	0.10	0.05

The figures given in table 1 must be multiplied by the number of items concerned and summed to calculate the minimum staff numbers required in the medical physics team concerned.
(WTE = Whole (Full) Time Equivalent)

Additional personnel are required if the medical physics team works on machines such as PET-CT scanners or cyclotrons, if the centre has a PACS (Picture Archiving and Communication System) or if team member involvement in management tasks is high.

With regard to the field of diagnostic radiology, the following criteria are proposed:

Table 2. Extract from the EFOMP 1997 report.



Subject	Total staff (WTE)	Minimum number of qualified medical physicists within total staff (WTE)
Radiographic and/or image intensification workstation	0.05	0.01
Film processor or laser imager	0.06	0.01

The figures given in table 2 must be multiplied by the number of items concerned and summed to calculate the minimum staff numbers required in the medical physics team concerned.
(WTE = Whole (Full) Time Equivalent)

The report emphasises that the number of medical physicists will largely depend on:

- the quality assurance programme implemented in the centre in question and the involvement of the radiographers or other staff in that programme;
- the involvement in the optimisation process, which was not quantifiable when the report was written;
- the involvement in non-ionising imaging techniques, not considered in this report.

IPEM, BNMS, BIR recommendations 1999

A joint report published in 1999 by several organisations in the United Kingdom (IPEM - Institute of Physics and Engineering in Medicine, BNMS - British Nuclear Medicine Society and BIR - British Institute of Radiology) formulates recommendations concerning the field of nuclear medicine [Williams 1999] (see table 3).

This publication is a revision of the recommendations published in 1991 by the IPSM (Institute of Physical Sciences in Medicine).

It provides recommendations for the number of medical physicists necessary for the tasks relating to nuclear medicine for five types of hospital structure (from a small unit to a large-sized university department).

The presence of PET cameras or PET-CT scanners is not considered in these recommendations.

Table 3. Extract from Williams and al, 1999 [Williams 1999].

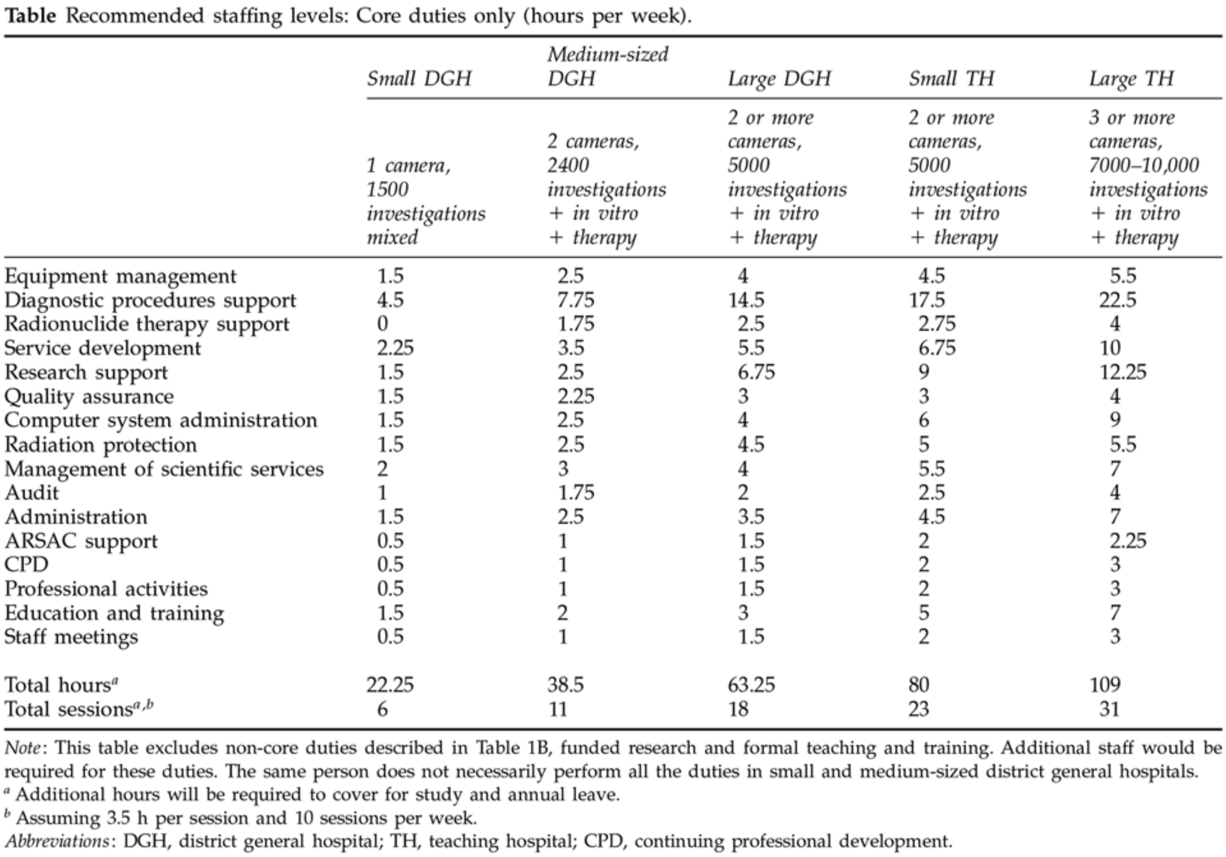


Table Recommended staffing levels: Core duties only (hours per week).

	Small DGH	*Medium-sized DGH*	*Large DGH*	*Small TH*	*Large TH*
	1 camera, 1500 investigations mixed	*2 cameras, 2400 investigations + in vitro + therapy*	*2 or more cameras, 5000 investigations + in vitro + therapy*	*2 or more cameras, 5000 investigations + in vitro + therapy*	*3 or more cameras, 7000–10,000 investigations + in vitro + therapy*
Equipment management	1.5	2.5	4	4.5	5.5
Diagnostic procedures support	4.5	7.75	14.5	17.5	22.5
Radionuclide therapy support	0	1.75	2.5	2.75	4
Service development	2.25	3.5	5.5	6.75	10
Research support	1.5	2.5	6.75	9	12.25
Quality assurance	1.5	2.25	3	3	4
Computer system administration	1.5	2.5	4	6	9
Radiation protection	1.5	2.5	4.5	5	5.5
Management of scientific services	2	3	4	5.5	7
Audit	1	1.75	2	2.5	4
Administration	1.5	2.5	3.5	4.5	7
ARSAC support	0.5	1	1.5	2	2.25
CPD	0.5	1	1.5	2	3
Professional activities	0.5	1	1.5	2	3
Education and training	1.5	2	3	5	7
Staff meetings	0.5	1	1.5	2	3
Total hours[a]	22.25	38.5	63.25	80	109
Total sessions[a,b]	6	11	18	23	31

Note: This table excludes non-core duties described in Table 1B, funded research and formal teaching and training. Additional staff would be required for these duties. The same person does not necessarily perform all the duties in small and medium-sized district general hospitals.

[a] Additional hours will be required to cover for study and annual leave.

[b] Assuming 3.5 h per session and 10 sessions per week.

Abbreviations: DGH, district general hospital; TH, teaching hospital; CPD, continuing professional development.

IPEM recommendations 2008

In November 2008, the Institute of Physics and Engineering in Medicine - IPEM, United Kingdom, published recommendations focusing on the role of medical physicists in departments equipped with a PET-CT camera [IPEM 2008].

This publication recommended the involvement of at least 1 FTE medical physicist in the departments operating a PET-FDG unit. It also stressed that this recommendation is a minimum requirement for a unit that is already installed and functioning. This recommendation did not cover the needs specific to the setting up of a new facility, new treatment techniques (markers other than FDG for example) or substantial research and development activities.

Recommendations of the Swiss Society of Radiology and Medical Physics (SSRPM, 2009) and of the Swiss Federal Office of Public Health (FOPH, 2011)

In October 2009, the Swiss Society of Radiology and Medical Physics (SSRPM) and the Swiss professional association of medical physicists published a report entitled «Medical physicist staffing for nuclear medicine and dose-intensive X-ray procedures» [SSRPM 2009].

The Swiss regulations indicate that a medical physicist should be contacted on a regular basis to ensure the radiation protection of nuclear medicine and dose intensive X-ray procedures (radiological examinations that include computed tomography and the use of fluoroscopy). The main task of the working group that produced this report was to propose a strategy to clarify the meaning of "regular basis".

The working group studied several approaches in order to propose an optimal strategy that puts the priority on situations where radiation risks are the highest.

It proposes acting on two levels:

- the «large centres» that use complex procedures and sophisticated equipment;
- the «smaller centres» where the need for medical physics expertise is certainly important but not on a continuous basis since most of the procedures used are standardized.

For the «large centres», the report proposes recommendations in FTE per unit available in a hospital, clinic or private practice. The authors of the report consider that a medical physicist is required when the resulting FTE is 0.8 or higher (a result of 1.8 would require the presence of two medical physicists, and so on). The responsibilities cover all the technical aspects of radiation protection, excluding research duties, associated with the use of all CT, fluoroscopy, mammography units, gamma camera and SPECT/CT, PET/CT units at the centre.

For the «smaller centres», the report proposes less stringent radiation protection requirements by ensuring continuous training of the team and organising audit/advisory visits. The working group proposes that in specified regions at least one senior medical physicist be involved in the use of X-ray units and that a senior medical physicist be involved in the centres that practice nuclear medicine examinations. A contract could be drawn up with each «small» centre to finance the work of the medical physicist who is administratively assigned to a «large» centre.

Following the publication of the report [SSRPM 2009] in June 2011, a working group comprising representatives of several learned societies, including the Swiss societies of nuclear medicine, radiology, radiopharmacy, radiobiology and medical physics, and representatives from the OFSP (Swiss Federal Office of Public Health), issued directives and recommendations for application of the radiation protection edict article 74 of the Swiss regulations [WG RP Switzerland 2011].

This document concerning medical physics is accompanied by two other documents that synthesise the functions, tasks and contribution of the manufacturers on the one hand and the technologists on the other.

The multidisciplinary working group nevertheless did not manage to reach a consensus on the recommendations and the report did not receive the formal approval of the different learned societies involved in its drafting. Furthermore, as the report might undergo future amendments and revisions, the data it contains are not reported herein.

European project for *Guidelines on Medical Physics Expert* (in progress at the start of 2013)

In 2009, a European call for proposals was launched on the theme «*Guidelines on Medical Physics Expert*» (contract TREN/09/NUCL/SI2.549828).

The aim of this contract is to provide elements to improve application of the provisions relative to the Euratom MED directive concerning medical physics experts (MPEs) and to facilitate the harmonisation of the training and the recognition of MPEs between member states with a view to encouraging cross-border mobility. To achieve this aim, the contracting party has undertaken to perform three main tasks:

- conduct a pan-European study of MPEs;
- organise a European workshop on the subject (this was held in Seville on 9-10 May 2011);
- develop recommendations concerning the MPEs.

At the beginning of 2013, the date of publication of the final version of the project report was not known.

The draft version of this report proposes criteria for quantifying medical physics personnel requirements (medical physicists and supporting staff) for radiotherapy, nuclear medicine and diagnostic radiology.

This report underlines on several occasions that the proposed data are indicative and that it is difficult to compare them with data proposed in various other reports (see references in paragraph III.2. above). In effect, each report proposes different calculation methods and lists functions, equipment items and tasks for the calculation of the FTEs which are not directly comparable.

III.2.2. Recommendations in France (SFPM)

In 1992, the SFPM published a report concerning the role and needs for medical physicists in nuclear medicine units, which was updated in 2006 [SFPM n°22].

The SFPM report recommends a required number of medical physicists taking into account the various areas of activity in which they participate (table 4). Examples are given for different types of nuclear medicine unit.

These recommendations include information for units that have PET cameras.

Table 4. Extract from SFPM report No.22 SFPM [SFPM No.22]

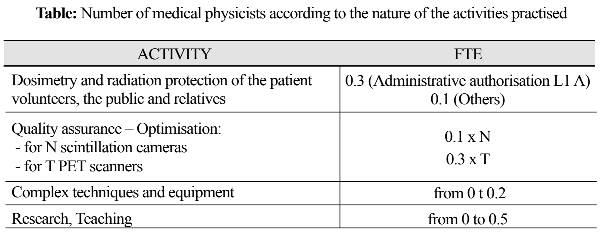


Table: Number of medical physicists according to the nature of the activities practised

ACTIVITY	FTE
Dosimetry and radiation protection of the patient volunteers, the public and relatives	0.3 (Administrative authorisation L1 A) 0.1 (Others)
Quality assurance – Optimisation: - for N scintillation cameras - for T PET scanners	0.1 x N 0.3 x T
Complex techniques and equipment	from 0 t 0.2
Research, Teaching	from 0 to 0.5

L1 A : nuclear medicine for diagnostic or therapeutic purposes, utilisation in vivo and in vitro.

As at the beginning of 2013, there are in principle no French recommendations concerning the medical physicist staffing levels for radiology departments.

The recommendations made in the various documents presented in this chapter have not been synthesised due to their diversity and their insufficient level of detail to allow an in-depth comparison. Furthermore, it is extremely difficult to correlate the situation of each of the countries studied with that of France. This is because it depends among other things on the tasks the medical physicists have to perform (radiation protection of patients and workers, management, training, teaching, etc.).

III.3. Involvement and training of medical physicists in imaging in three other European countries

III.3.1. Spain

Hierarchical dependency, status and organisation of medical physics

The majority of medical physicists in Spain are grouped in an independent department or unit, at the same level as the medical departments, and are usually called «Servicio de radiofisica y proteccion radiologica» (SRPR - radiological physics and radiation protection service). The medical physicists are independent of the operational departments and report directly to the medical management of the facility.

Their status is equivalent to that of the other medical specialists (cardiologists, oncologists, radiologists, etc.).

The management of radiation protection in centres that do not have full-time SRPR depends on an SRPR from a large hospital or a radiation protection technical unit (UTPR), a private unit created to provide the regulatory radiation protection services. These units are authorised and monitored by the Consejo de Seguridad Nuclear (CSN) [Arranz2009].

Training

The training of medical physicists in Spain is common to all areas of medical physics: radiotherapy, radiodiagnostics, nuclear medicine and radiological protection (of patients, workers and the public). It lasts three years and takes place in a physics department accredited by the Ministry of Health and the Ministry of Education under an internship system (the same system as applies to doctors training to become specialists).

This training lasts 3 years after 5 years of university studies. The training (practical and theory) over the 3 years is divided up as follows:

- Radiotherapy: 18 months;
- Imaging (radiology and nuclear medicine): 6 months + 6 months;
- Radiation protection and others: 6 months.

This training gives the title of «especialista en radiofisica hospitalaria» (specialist in hospital radiological physics) and allows the holder to practise as a medical physicist in all the areas of competence.

Access to the training is by a national competitive examination for 33 places per year in 2009 [Arranz2009].

The training centres must satisfy several accreditation criteria and the following two in particular:

- the hospital must have radiotherapy, nuclear medicine and diagnostic radiology departments;
- the medical physics department must have at least 4 medical physicists of whom 2 have at least 5 years' experience.

Delegation of tasks

In Spain there are professionals called «tecnicos» who can assist the medical physicists in routine tasks such as the quality checks.
These people have followed specific (non-university) professional training. They have a diploma that gives them the title of «técnico superior en radioterapia» or «técnico superior en diagnóstico por la imagen» (higher technician in radiotherapy or higher technician in diagnostic imaging». The training, which lasts 2 years for each speciality, is specific and depends on the area of work (radiotherapy or imaging).

The imaging technicians are those who work more in the diagnostic departments (radiology, nuclear medicine) performing diagnostic explorations on patients, but some also work in the hospital physics departments, ensuring equipment quality control above all. These professionals («tecnicos») always work under the supervision of a medical physicist who holds ultimate responsibility for the measurements and results.

Current regulations

Two royal decrees have been established to transpose European directive 97/43/Euratom:

- for radiodiagnostics: «REAL DECRETO 1976/1999, de 23 de diciembre, por el que se establecen los criterios de calidad en radiodiagnóstico»;
- for nuclear medicine: «REAL DECRETO 1841/1997, de 5 de diciembre, por el que se establecen los criterios de calidad en medicina nuclear».

A third royal decree concerns the creation of the speciality of hospital physicist («Radiofisica hospitalaria»- medical physics):

- "REAL DECRETO 183/2008, de 8 de febrero, por el que se determinan y clasifican las especialidades en Ciencias de la Salud y se desarrollan determinados aspectos del sistema de formación sanitaria especializada".

III.3.2. Belgium

Hierarchical dependency

In Belgium the hierarchical attachment of medical physicists depends on each centre and is not specified in the regulations.

Training

➜ Mandatory approval of medical physics experts (article 51.7.2)
Prior to exercising their functions, medical physics experts (MPE) must be approved by the FANC (Federal Agency for Nuclear Control), in one or more of the following areas of competence: radiotherapy, in vivo nuclear medicine, radiology.

➜ Approval criteria for medical physics experts (article 51.7.3)
The candidate for approval as an MPE must hold a university degree in physical or chemical sciences, a diploma in civil engineering or industrial engineering in nuclear energy, or a diploma that is recognised or declared equivalent in Belgium.
Holders of other diplomas can submit their candidacy for approval if they provide proof of the equivalence of their qualification.

The candidate for approval as an MPE in a particular field of competence must moreover have carried out:

- Higher university or inter-university training in medical radiation physics that meets the following criteria: the training lasts at least two years, including at least 600 hours of theory and practical teaching, covering the three areas, namely radiotherapy, in vivo nuclear medicine and radiology – and at least one year of clinical internship in the area of competence for which the approval is postulated.
- A person who is candidate in several areas of competence must, in addition to the training described above, perform an additional internship of at least one year for radiotherapy and six months at least for radiology or in vivo nuclear medicine.

In the case of medical exposures of children carried out as part of a medical screening program or involving high doses for the patient, such as interventional radiology, computed tomography and radiotherapy, including nuclear medicine for therapeutic purposes, specific appropriate training must also have been followed.

The internship program in the different areas is defined by the FANC.
http://www.fanc.fgov.be/GED/00000000/1500/1583.pdf

➜ Conditions of approval of medical physics experts
The approval defines the conditions concerning the validity period and the type of facilities or equipment used; the approval can be limited to certain classified medical establishments.

➜ Continuous training
The MPE is obliged to maintain and develop his/her knowledge and competence through university-level continuous training.
The FANC defines, after consulting the jury provided for in article 54.9., the minimum rules for continuous training and checks whether these criteria have been satisfied.

➜ Activity report
The MPE submits an activity report to the FANC after a first period of activity of 3 years, and thereafter, unless otherwise decided by the FANC, after each subsequent period of activity of 6 years. The content and form of the activity report are determined by the FANC. The jury gives an opinion on the quality of the activity reports.

➜ Composition and rules of functioning of the jury
The jury is made up of representatives of the FANC and personalities chosen for their scientific competence: specialists in radiation protection, medical physics experts in the three targeted areas (radiotherapy, in vivo nuclear medicine, radiology), physicians approved as holders of the specific professional title of specialist in radiotherapy-oncology, specialist in radiodiagnosis, specialist in nuclear medicine, specialist in clinical biology and in vitro nuclear medicine and pharmacist biologists or equivalent authorised for in vitro applications of radionuclides.

The list of MPEs approved in the different areas of competence is published by the FANC.
http://www.fanc.fgov.be/fr/page/liste-d-experts-agrees/452.aspx

➜ Current regulations
20 July 2001 — Royal order on the general regulations for the protection of the population, workers and the environment against the danger of ionising radiation (p 28931).
http://www.vbs-gbs.org/downloads/mn/lex_10916_part_1.pdf
It transposes directives 96/29 and 97/43 into the Belgian regulations.

➜ Definitions
• Qualified expert in physical surveillance:
Person having the necessary knowledge and training to perform in particular the physical, technical or radiochemical examinations necessary to evaluate doses and to give advice to ensure effective protection of individuals and correct functioning of the means of protection.
The qualified experts in physical surveillance are approved by the FANC.

• Medical physics expert (MPE):
Expert in physics or radiation technology applied to exposure for medical purposes, who, depending on the case, acts or gives advice concerning patient dosimetry, the development and use of complex techniques and equipment, optimisation, quality assurance, including quality control, and other questions associated with radiation protection relating to medical exposure.
The MPEs are approved by the FANC.

➜ Duties
• Quality assurance:
For the types of practice or radiological examination defined by the FANC, written procedures are established and available for each item of equipment under the responsibility of the practitioner. Clinical audits are conducted in the radiological facilities defined by the FANC and under the conditions set or approved by the FANC.

The licensee ensures that the following are implemented for the radiological facilities in his establishment:

- appropriate quality assurance programmes including quality control measures;
- evaluations of the doses or activities administered to the patient;
- development of measures to reduce the probability and amplitude of accidental or unintentional doses received by the patient;
- verification of the implementation of these measures.

In accordance with the provisions of article 51.7, the licensee shall ensure that an MPE actively participates in the preparation and performance of this task (article 51.4. Procedure).

- The acceptance testing of devices emitting ionising radiation is carried out by an MPE before the equipment is first put into service for medical purposes (51.6.4).

- Annual verification of devices emitting ionising radiation:

An MPE performs an annual verification of the conformity of each device used in the medical centre against the criteria of acceptability set or approved by the FANC.
The MPE draws up a report on this verification of conformity with the criteria of acceptability and sends it to the physical surveillance service which keeps it in the physical surveillance register (51.6.5).

- Assistance of MPEs for the radiation protection of patients (51.7):

The management of establishments operating radiodiagnostic, radiotherapy or in vivo nuclear medicine devices ensures that it has the assistance of MPEs to organise and monitor the measures necessary to ensure patient radiation protection and quality control of the devices.

Such measures include in particular:
- the dosimetry associated with the device;
- where appropriate, participation in collaboration with the medical team in the dosimetry associated with the patient;
- where appropriate, consultation for the preparation of specifications for the purchase of new devices;
- the selection, acceptance testing and calibration of dose and activity measuring instruments and devices;
- the preparation, implementation and monitoring of quality control procedures;
- participation in collaboration with the medical team in projects to optimise doses received by patients;
- quality control of the devices.

As a general rule, the number of MPEs, their area of competence, their level of availability and the conditions of assistance shall depend on the type and number of duties to accomplish, and in particular on the number of equipment items, the nature and complexity of the procedures requiring the involvement of an MPE, the number of patients and the potential risks for the patients.
More particularly:
- in each **radiotherapy** department, the presence of at least one MPE competent in the subject concerned is required on a **full-time basis**;
- for standard practices in therapeutic **nuclear medicine** and for diagnostic nuclear medicine practices, an MPE competent in the subject concerned must be **available**;
- for the **other radiological practices**, an MPE competent in the subject concerned must be **involved**, depending on the needs resulting from the present regulations and in particular for the purpose of optimisation, patient dosimetry and quality assurance.

Each intervention of an MPE shall be recorded in a register which shall be kept in the medical establishment for thirty years and can be consulted at any time by the FANC.

- Increased application of the optimisation principle:

Any dose further to medical exposure for radiological purposes, with the exception of radiotherapy procedures, must be kept at the lowest reasonably achievable level that allows the required diagnostic information to be obtained. Doses to patients must be evaluated and compared with reference levels, quality assurance procedures must be established and, with the active collaboration of MPE, written procedures must be drawn up and kept available for each device and type of examination.

III.3.3. Germany

Hierarchical dependency

There are very few medical physics departments. Most of the physicists are under the authority of a medical department.

Training

To obtain a certificate to practice as a medical physics expert (MPE) it is necessary to provide proof of the following qualifications: a master's degree in sciences (physics for example) or equivalent, have followed a training course in radiation protection applied to medicine (1 to 2 weeks) and have at least 2 years' practical experience, with a minimum of 6 months in each area for which the certificate is requested.

Current regulations

«Strahlenschutzverordnung», «Röntgenverordnung» and «Richtlinie Strahlenschutz in der Medizin» (texts concerning radiation protection in medicine and radiology).

A directive was published on 30th November 2011 by the German Minister for the Environment Protection of Nature and Nuclear Safety, concerning radiation protection in medicine (*http://www.bmu.de/files/pdfs/allgemein/application/pdf/rl_strlschv_strlschmed_en.pdf*).

Duties and staffing levels

The degree of involvement of medical physics experts varies according to the field.

In diagnostics (nuclear medicine and radiology), each department has at least one contract with an MPE who is available to provide technical support and answer questions. The duties are chiefly centred on quality control tasks, but also on radiation protection (measurements, calculations, teaching, etc.).

In nuclear medicine (therapy), an MPE must be present in the unit for a minimum length of time each day. Two MPEs are required, with a third MPE if the unit has more than 10 hospitalisation rooms.

In nuclear medicine (diagnostic), one MPE is required, with a second MPE if there are more than 4 cameras.

Delegation

Some medical physics tasks can be delegated (such as quality control tasks) but the MPE retains responsibility for them.

III.3.4. The strong points of these 3 countries

In Spain, the status and the organisation of medical physics into independent departments or units that are hierarchically equivalent to the medical departments are strong points, as is the sound training through an internship system. Furthermore, the Spanish regulations, unlike the French regulations, explicitly provide for the notion of the delegation of tasks to personnel with recognised qualification and training. These strong points result from the strategies adopted by this country further to the events it has experienced, particularly in Zaragoza (Radioprotection 2009, Vol. 44, No.4, pages 405 to 416).

In Belgium, apart from the training required to obtain approval as an MPE, especially in the fields of imaging, particular emphasis is placed on the maintaining of the skills of medical physicists during their career.

In Germany, the need for MPEs in all the areas of intervention is formalised, with staffing levels defined in nuclear medicine (diagnosis and therapy). As in Belgium, the notion of medical physics expert (MPE) has been adopted.

IV. AREAS OF INVOLVEMENT OF MEDICAL PHYSICISTS IN IMAGING AND IDENTIFICATION OF THE ASSOCIATED TASKS IN FRANCE

In France, the medical physicist – which in this report refers solely to what the French call a «Person Specialised in Medical Radiation Physics» (PSRPM) - intervenes in the areas where physics is associated with medical practice. The medical physicists activities are turned chiefly towards the sectors using ionising radiation for diagnostic or therapeutic purposes.

Having received specialised professional training in ionising radiation, the medical physicist takes part in the organisation and the technical and functional supervision of standard and/or innovative radiological procedures leading to the exposure of patients to ionising radiation, ensures safety, guarantees dose levels and examination quality and participates in project management. Trained in research, the medical physicist is also a scientist who helps develop the techniques of tomorrow, and ensures - along with the other professionals - a scientific, technological and safety watch over the medical devices and their utilisation.
The medical physicist participates, within his/her area of competence, in the training of other health professionals.

The practice of medical physics aims at mastering and using the fundamental concepts and principles of the physics of radiation and the recognised medical physics protocols to ensure patients are delivered optimum doses during the medical procedures involving exposure to ionising radiation. This is the specificity and added value that the medical physicist brings to medical establishments.
It also guarantees the quality (of imaging examinations in particular), the safety and the integration of developments in these examinations or therapeutic practices. Patient radiation protection is thus omnipresent in the practice of medical physics, guaranteeing the appropriate dose levels, both in the treatment of patients and in the development and management of projects.

The duties of medical physicists respond to public health and safety needs. In accordance with the order of 19th November 2004, any medical establishment operating medical devices that use ionising radiation for therapeutic or diagnostic purposes must call upon a medical physicist.

Today, the state-of-the-art technology and the specific operating aspects associated with the numerous clinical applications of imaging equipment require the active contribution of the medical physicist in the application and the updating not only of the radiological procedures but also of user professional training.
The details of these needs and conditions of involvement are set out in the remainder of this document through the cross-cutting duties of the medical physicist: quality assurance, safety, clinical dosimetry, ionising radiation metrology, radiological risk management, etc.

In the more specific area of imaging, the medical physicist's knowledge is applied firstly to achieving the best possible image quality for the lowest possible dose delivered, and secondly to guiding the medical practitioners in the choice of exploration or treatment techniques. **In the context of patient radiation protection, this optimisation necessitates precise knowledge of the clinical applications that are increasingly specialised per organ, specific expertise in metrology, quantification, dosimetry, ionising radiation detection and signal and image processing.**

The skills of the medical physicist in imaging are absolutely essential in the steps described in paragraphs IV.1 to IV.6.

IV. 1. When purchasing equipment

The medical physicist, in collaboration with the biomedical department, the holder of the authorisation and the person competent in radiation protection (PCR), participates in the drafting of the initial applications for ASN and ARS authorisations and authorisation renewals, declaring X-ray generators to ASN, drafting specifications, choosing equipment and options (for reducing doses and enhancing image quality in particular).

At the request of the PCR, the medical physicist participates in the studies necessary for the designing and fitting out of the premises in conformity with the radiation protection regulations concerning workers and the public. The medical physicist's expertise can be used in the calculation of radiological protections (see standard NFC 15-160) and the choice of measuring equipment for monitoring the facility.

IV. 2. When installing equipment

Working in collaboration with the biomedical department, the medical physicist performs and validates the equipment acceptance tests.
The medical physicist can moreover schedule and manage the performance of external quality controls on the equipment and performs the initial internal quality controls (as required by the AFSSAPS and ANSM decisions).

The medical physicist works with the medical teams in developing image acquisition, reconstruction and/or processing protocols in application of the principle of optimisation and sets up the internal image quality and dosimetry protocols to ensure long-term stability of equipment performance.

At the request of the PCR, the medical physicist can provide technical and scientific assistance to optimise worker radiation protection (devices, methods, etc.).

IV. 3. After putting equipment into service, as part of its routine clinical utilisation

After an item of equipment is put into service, the medical physicist's tasks are based on those carried out for equipment acceptance: they constitute an inseparable complement that serves to check the stability of the machine's performance throughout its clinical utilisation, particularly following maintenance work or when modifications are introduced.
Working in collaboration with the biomedical department, the medical physicist takes part in the control and analysis of maintenance operations and software updates.

The medical physicist takes part in the scheduling and management of the equipment internal and external quality controls. S/he finalises and draws up the internal quality control procedures specific to each facility and defines their frequency in compliance with the AFSSAPS /ANSM decisions and the recommendations of the manufacturers and the learned societies in this respect. S/he performs or delegates performance of the periodic internal quality controls (IQC) and the other stability tests, ensures the traceability and analysis of the IQC results and the external quality controls (EQC).

The medical physicist is also in charge of ionising radiation metrology. S/he participates in the development of acquisition protocols when new examinations or therapy protocols are established, and in monitoring them in application of the optimisation principle. The physicist also interfaces with the manufacturer, in collaboration with the biomedical department.

At the request of the PCR, the medical physicist can provide his/her expertise to reconstruct and evaluate the doses received by a worker in the event of accidental exposure further to a significant radiation protection event.

IV. 4. In the care and treatment of patients

The medical physicist helps collect the diagnostic reference levels (DRL), analyse the dosimetric indicators and implement any necessary corrective actions. The medical physicist also organises the «patient dosimetry» studies and calculates the doses received in the event of an incident or an unknown pregnancy. S/he participates in the monitoring of the cumulative doses (dose reconstruction, etc.), organises the statistical analysis of doses received by the patients (per protocol, per machine, etc.) and of the alert thresholds per protocol. S/he helps define the measures to be considered if the predetermined thresholds are exceeded. S/he helps produce the information sheets for

the patients and/or their family circle and the management of adverse events (significant radiation protection events, medical device surveillance) and quality management.

In the framework of interventional radiology and further to incidents in France, ASN and IRSN have published many recommendations involving the medical physicist over the last few years in order to prevent and monitor any cutaneous lesions in patients [IRSN-2009; HUS-2009].

In nuclear medicine, the medical physicist and the radiopharmacist work together to define the optimum conditions of use of dose calibrators.

IV. 5. Therapeutic nuclear medicine (targeted internal radiotherapy)

Although this medical physics activity is strictly speaking not an imaging activity, it is included in this assessment of needs because it is carried out on the nuclear medicine technical platforms. Article R.1333-64 of the public health code states that «*For therapeutic nuclear medicine procedures, tissue and organ exposures are determined on a case-by-case basis*». In 2013, selective treatments[12] were the first concerned.

Two types of therapeutic nuclear medicine can be distinguished: non-cancer treatments and cancer treatments. The degree of involvement of the medical physicist can vary depending on the case.
Thus, for non-cancer treatments (treatment of hyperthyroidism, synoviorthesis), due to the techniques used at present there is no particular need for involvement of the medical physicist other than for monitoring the consistency of the dose calibrator and preparing radiation protection instructions for people in the vicinity of the patient and for the environment.

Several types of cancer treatment can be identified:

- systemic treatments (thyroid cancer by iodine-131, non-Hodgkin lymphoma by Zevalin® with yttrium-90 as a marker, etc. …) ;
- selective treatments (treatment of liver cancers with yttrium-90 microspheres).

With treatments of this type, the medical physicist guarantees the conformity of the delivered dose with the medical prescription (validation); in certain cases s/he can help choose the method of calculation of the activity to inject and calculate the dose to the target and the organs at risk (OAR). This internal dosimetry can be part of treatment planning in the case of selective treatments. The medical physicists' expertise in quantification, thanks to their knowledge in ionising radiation metrology, image processing and their mastery of the use of dosimetric models produced by the MIRD (Medical Internal Radiation Dose) of the SNM (Society of Nuclear Medicine), is an advantage in the application of cancer treatments. The use of these skills will increase in the short to medium term due to the development of these new techniques, which include selective treatments by yttrium 90 microspheres.

IV. 6. Training of all the personnel concerned

The medical physicist helps train the personnel to ensure optimal utilisation of the radiological equipment, particularly the implementation of new protocols or during major interventions (hardware, software), and on the procedures relating to the exceeding of dosimetric alert thresholds.

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[12] Example: treatment of hepatocarcinomas by resin or glass microspheres marked with yttrium 90. The prescription can be based on a dose to a target volume.

V. QUANTIFICATION CRITERIA: THE WORKING GROUP'S RECOMMENDATIONS

To allow each medical establishment or imaging department to evaluate its medical physics personnel needs, the working group (WG) has proposed FTEs in the areas of work of the imaging medical physicist and the associated tasks listed in section IV and appendix 2. The calculation takes into account the size of the establishment's equipment pool and the number of patients in care (Equation 1).

The SFPM will also propose (during 2013) a «calculation aid» on its website to simplify the quantification task appropriately for each site.

To evaluate the medical physics staffing requirements, several elements must be taken into account:

- the scope of activity of the department, including its organisation and management;
- the number and complexity of the equipment and procedures used;
- the number of patients cared for and the complexity of their treatments;
- the involvement in training and teaching;
- the level of participation in research and development.

To establish the medical physics staff quantification criteria it is also necessary to know the tasks to be carried out and the time required to perform them. The staff numbers required will also fluctuate if new teaching or research programmes are introduced.
Another factor to be considered is the level of training, experience and skills of the personnel.

For each imaging equipment category (gamma-camera, hybrid gamma-camera, PET-CT, dose calibrator, peroperative and thyroid probes, mobile radiography units, C-arm units, conventional radiography or interventional radiography room, computed tomography, mammography, MRI, etc.) and for each therapeutic method using unsealed radioactive sources (targeted internal radiotherapy), the WG has evaluated the time necessary to carry out the medical physics duties.

These times enable an «**equipment FTE**» to be defined for each type of equipment and each method of targeted internal radiotherapy (non-cancer treatments, systemic or selective cancer treatments). In the framework of the specific tasks associated with the purchase and installation of an equipment item, this time has been divided over five years (licensing duration of major medical equipment items).
An **equipment complexity factor (Factor A)** has been introduced to take account of the constraints of particular applications, specific equipment configurations and/or technology.
A **Factor D is also introduced to take into account the diversity of the equipment pool** (different makes) for each imaging method (D equals 1 for equipment of the same make and 1.2 for different makes).

Alongside this, the WG has defined a «**clinical FTE**». It integrates the time spent on activities linked to the number of patients concerned by each equipment item or each targeted internal radiotherapy method. **Two «clinical» factors** have been introduced to take into account firstly the complexity of the clinical activities **(Factor B)** and secondly the «patient activity» relative to a reference activity **(Factor C)**.

For A and B, the factors relative to a same given machine are not summed, it is the maximum value that applies.

Equation 1: Calculation of the medical physics FTE per machine

For each machine in the imaging pool (radiology and nuclear medicine), the following formula is to be applied:

$$\mathrm{FTE}_{\text{Physics/machine}} = \mathrm{FTE}_{\text{equipment}} \times A \times D + \mathrm{FTE}_{\text{clinical}} \times B \times (\text{number of patients}/C)$$

The $\mathrm{FTE}_{\text{medical physics}}$ is the sum of the $\mathrm{FTEs}_{\text{physics/machine}}$

When the medical physicist or the supporting staff intervene on other geographical sites by agreement with the main employer, a factor of 1.2 is applied to the total imaging FTE for each site remote from the main activity.

The WG's recommendations in terms of FTEequipment and FTEclinical for quantifying staff numbers in *medical physics* are detailed in appendix 2.

The complexity factors A, B, C and D are detailed in the tables below.

Table 5. Complexity factors in nuclear medicine

Complexity linked to the equipment (Factor A)	Factor
Innovative techniques	1.2
Number or type of collimators: > 3 sets of collimators, fanbeam collimators	1.2
Complexity linked to the diversity of the equipment pool (different makes) (Factor D)	
Where different makes are involved, for each imaging method	1.2
Clinical complexity (Factor B)	**Factor**
Paediatrics	1.2
Large medical and paramedical team (>25 persons)	1.2
High rate of personnel renewal, university role of the centre - training of interns, heads of clinics, etc.	1.2
Innovative protocols in terms of acquisition and/or reconstruction, treatments	1.2
Patient activity (Factor C)	**Reference activity value in number of patients per year**
Camera or dedicated camera	1 000
SPECT-CT	1 000
PET-CT	1 000
Dose calibrator	none
Peroperative or thyroid probe	none
Non-cancer treatment*	100
Systemic cancer treatment**	50
Selective cancer treatment***	50

* Example: hyperthyroid treatment by I-131, synoviorthesis, etc.

** Example: treatment of thyroid cancers, treatment of lymphomas by Zevalin®, treatment of endocrine tumours by Octreoscan®.

*** Example: treatment of hepatocarcinomas by resin or glass microspheres marked with yttrium 90.

For targeted internal radiotherapy, the complexity of the technique and the regulatory requirements (article D. 6124-133 of the Public Health Code: treatment preparation must be validated by a qualified physician specialised in nuclear medicine and by a medical physicist) have been taken into account.

Table 6. Complexity factors in radiology

Complexity linked to the equipment (Factor A)	Factor
Suspended mounting with second X-ray tube	1.3
Biplanar vascular operating theatre	1.5
Dual-source scanner	1.5
Facility with several sensors	1.5
Innovative technique in mammography	1.5
Equipment used 24h/24, 365 days/year	1.5
Complexity linked to the diversity of the equipment pool (different makes) (Factor D)	**Factor**
Where different makes are involved, for each imaging method	1.2
Clinical complexity (Factor B)	**Factor**
Paediatrics	1.5
Large medical and paramedical team (>25 persons)	1.5
High rate of personnel renewal, university role of the centre - training of interns, heads of clinics, etc.	1.5
Innovative or complex protocols in terms of acquisition and/or reconstruction: rotational angiography, dual-energy CT acquisition, interventional CT procedure, embolisation, etc.	1.5
Shared utilisation of a small item of equipment (e.g. C-arm unit, mobile radiography units) between two different medical applications	1.5
Examinations in vital emergency	1.5
Patient activity (Factor C)	**Reference activity in number of patients per year**
CT scanner	10 000
Interventional radiology room	1 000
Conventional radiology room	7 500
C-arm unit	note*
Mobile radiography unit	
Mammography	1 500

* By default in equation 1 the value of the ratio between the number of patients and the factor C equals 1 because the activity is generally not known.

The FTE estimations are given in tables 7 and 8. These data were calculated on the basis of 1600 hours of work per year (which explains the figures with 4 decimals proposed in these tables). They take into account regulatory constraints and good practices associated with medical physics duties in imaging departments. **They correspond to FTEs in *medical physics*, that is to say the necessary time dedicated to medical physics tasks whether carried out by a medical physicist or delegated to a technician or a technologist under the responsibility of a medical physicist.**

For tables 7 and 8, the last column gives, for information only, an interval of the FTE per reference activity in number of patients per year for each method.

Table 7. Recommended medical physics FTEs in nuclear medicine

Nuclear medicine method	Equipment FTE	Equipment complexity factor (A)	Clinical FTE	Clinical complexity factor (B)	Reference activity value (patients/ year) (C)	FTE per reference activity
Camera or dedicated camera	0.14	1 or 1.2	0.004	1 or 1.2	1 000	0.144-0.173
SPECT-CT	0.19	1 or 1.2	0.005	1 or 1.2	1 000	0.195-0.234
PET-CT	0.2	1 or 1.2	0.005	1 or 1.2	1 000	0.205-0.246
Dose calibrator	0.034	1 or 1.2	0	1	none	0.034-0.041
Peroperative or thyroid probe	0.011	1 or 1.2	0	1	none	0.011-0.013
Non-cancer treatment	0.003	1 or 1.2	0.016	1 or 1.2	100	0.019-0.023
Systemic cancer treatment	0.006	1 or 1.2	0.032	1 or 1.2	50	0.038-0.046
Selective treatment	0.009	1 or 1.2	0.158	1 or 1.2	50	0.167-0.200

Table 8. Recommended medical physics FTEs in radiology

Radiology method	Equipment FTE	Equipment complexity factor (A)	Clinical FTE	Clinical complexity factor (B)	Reference activity value (patients/ year) (C)	FTE per reference activity
CT scanner	0.084	1 or 1.5	0.05	1 or 1.5	10 000	0.134-0.201
Interventional radiology room	0.075	1 or 1.5	0.059	1 or 1.5	1 000	0.134-0.201
Conventional radiology room	0.033	1 or 1.3 or 1.5	0.011	1 or 1.5	7 500	0.044-0.066
C-arm unit	0.02	1 or 1.5	0.006	1 or 1.5	note*	0.026-0.039
Mobile radiography unit	0.01	1 or 1.5	0.001	1 or 1.5		0.011-0.165
Mammography	0.035	1 or 1.5	0.0063	1 or 1.5	1 500	0.041-0.062
MRI	0.053	1	0.0031	1	not applicable	0.0561

* By default in equation 1 the value of the ratio between the number of patients and the factor C equals 1 because the activity is generally not known.

For nuclear medicine departments having an oncological targeted internal radiotherapy activity and for medical establishments with a substantial interventional radiology activity, the WG specifically recommends allocating at least 1 FTE medical physicist to each of these 2 areas for the establishment.

When the medical physics FTE reaches 0.8, the WG recommends that a full-time medical physicist be assigned to the establishment.

The nuclear medicine figures in table 7 have been compared with the answers obtained during the survey conducted with the members of the SFPM. In radiology, this comparison corresponds to what is felt by the physicists who currently work in radiology. In both cases, the figures have been compared with true situations in several establishments.

To take into account the **supervision of trainees**, the WG recommends 0.2 medical physicist FTEs for the months where master's degree students are being supervised. For example, for a 4-month internship, the calculated annual FTE is 0.067 per student.

For the students studying for the DQPRM[13] diploma, the DGOS and the INCa base themselves on one FTE for 3 students during 12 months. In nuclear medicine, as in radiology, the calculation was based on the pro rata of the number of weeks of internship of the DQPRM students. This calculation also takes into account the diversity of the equipment (0.01 additional FTEs) and the procedures to be learned by the student. The WG thus recommends 0.07 medical physicist FTEs in nuclear medicine (for 10 weeks) and 0.05 FTEs in radiology (for 6 weeks) per DQPRM student.

With regard to the **research activity**, the time allocated to the medical physicist depends on the extent of the medical establishment's research role and its projects.

A calculation aid based on the WG's recommendations, an extract of which is shown in appendix 2, will be provided by the SFPM. It will allow the research and training activities to be integrated into the final calculation of the medical physics FTEs.

Examples. Calculation of medical physics FTEs in nuclear medicine and radiology

Nuclear medicine
Example 1 - Department equipped with 1 SPECT camera (4 sets of collimators, 2500 patients per year), 1 PET/CT scanner (2500 patients per year) and 2 dose calibrators
FTE = [0.14*1.2 + 0.004*1*2500/1000] + [0.2*1 + 0.005*1*2500/1000] + [0.034*2] = 0.459
Example 2 - Department equipped with 1 SPECT camera (2500 patients per year), 1 SPECT/CT scanner (2500 patients per year), 1 PET/CT scanner (2500 patients per year, large medical team as there is an agreement between several medical centres) and 2 dose calibrators
FTE = [0.14*1 + 0.004*1*2500/1000] + [0.19*1 + 0.005*1*2500/1000] + [0.2*1 + 0.005*1.2*2500/1000] + [0.034*2] = 0.636
Example 3 - Department equipped with 1 SPECT camera (2500 patients per year), 1 SPECT/CT scanner (2500 patients per year), 1 PET/CT scanner (2500 patients per year), 2 dose calibrators, a therapeutic activity (60 patients per year in non-cancer therapy and 60 patients per year in systemic cancer therapy)
FTE = [0.14*1 + 0.004*1*2500/1000] + [0.19*1 + 0.005*1*2500/1000] + [0.2*1 + 0.005*1*2500/1000] + [0.034*2] + [0.003 + (0.016*60/100)] + [0.006 + (0.032*60/50)] = 0.690 extrapolated to 1 FTE because there is a targeted internal radiotherapy activity.

Radiology
Example 1 - One remotely controlled table with ceiling suspension mounting (factor A of 1.3) used for emergency procedures 24h/24 (factor A of 1.5) with 15,000 patients/year
FTE = 0.033*1.5 + 0.011*1*(15000/7500)=0.071
Example 2 - One single X-ray tube room with a standard activity of 6000 patients/year on a remote site (factor of 1.2)
FTE=(0.033*1+0.011*1*(6000/7500))*1.2=0.050
Example 3 - A single-tube scanner used in the scheduled activity without innovative protocols with 11,000 patients/year and a team of 20 medical and paramedical staff
FTE=0.084*1+0.05*1*(11000/10000)=0.139
Example 4 - A biplanar interventional neuroradiology room (factor A of 1.5) from manufacturer X (adjacent room from manufacturer Y, therefore factor D of 1.2) with rotational angiography (factor B of 1.5) with 750 patients/year in a university centre with high rate of personnel renewal (factor B of 1.5)
FTE = 0.075*1.5*1.2+0.059*1.5*(750/1000)=0.201

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[13] At the start of 2013, DQPRM students must spend 10 weeks in nuclear medicine and 6 weeks in radiodiagnostics.

VI. CONCLUSION

For all the medical imaging disciplines, controlling the doses received by patients and ensuring the quality and safety of practices represent major public health issues today.

The aim of this report was to identify the needs in medical physics to tackle these issues and to quantify the human resource requirements.

The work presented in this report is naturally based on the European regulations in effect at the beginning of 2013. Several learned societies or international federations of societies have issued recommendations with varying degrees of detail. Among the situations of several countries, 3 of them – namely Belgium, Spain and Germany – have attracted particular attention because they tend to be in advance and they have strong points in terms of medical physics training and organisation, particularly in imaging. The situation in France has also been assessed.
Making a synthesis of these recommendations could have been a work focus, but they are highly diverse and probably insufficiently detailed to allow an in-depth comparison. Furthermore, it would have been extremely difficult to correlate the situation of each of the countries (for which we have recommendations) with that of France. The reason for this is that the situation depends among other things on the tasks attributed to the medical physicists.

The innovative work set out in this report to our knowledge has never before been carried out in other countries with such a degree of exhaustiveness and precision.
All the tasks relating to medical physics in radiology and nuclear medicine have been listed and the time required to perform each task has been evaluated. The new hybrid radiological imaging systems and the acquisition systems allowing 3D reconstruction have not been detailed in this report. The personal investment of the medical physicist in these new technologies will nevertheless be crucial, be it from the aspect of user training or the optimising and monitoring of performance in the years to come.
The imaging systems used in radiotherapy rooms have not been considered in this report.

The delegation of certain tasks, the organisation of the medical physics team and the equipment requirements do not fall within the scope of this report. It is the responsibility of the medical facilities to define the organisation that enables them to successfully fulfil the medical physics tasks. It is nevertheless vital to underline that some of the tasks mentioned herein cannot be entrusted to professionals other than the medical physicists working in the establishments concerned, therefore they cannot be delegated.

This report provides an aid so that each medical centre or department can determine its own needs in terms of medical physics.
These needs are defined according to the technical platform, the procedures and techniques practised on it, the number of patients treated and the number of persons in the medical and paramedical teams requiring periodic training. Making a «calculation aid» available on the SFPM website in the months following the publication of this report will simplify the calculation of the medical physics personnel requirements, which remains a complex exercise, even if all the necessary data figure in this report.
Furthermore, some establishments may perform tasks that are not identified in this report. In such cases they will have to study their own specific additional staffing needs.
Likewise, some centres may entrust certain tasks to the manufacturers or service providers, in which case they must adjust the required staffing assessment accordingly.

It should be noted that a portion of the needs, which are now quantifiable, is already provided for (by incumbent medical physicists who may or may not delegate certain tasks, or by outsourcing to medical physics service providers or equipment manufacturers), but a large proportion nevertheless remains to be provided for.

It is also important to underline that over and beyond having adequate staff numbers, the level of expertise must also be appropriate (combining qualification, competence and experience), otherwise control of the potential risks in the treatment of patients cannot be achieved.

It is recommended that medical establishments periodically review - at a frequency consistent with the revising of the medical physics organisation plans - the estimation of medical physics staff numbers and the team's required level of expertise according to the way equipment and practices develop.

This work, which has endeavoured to be as complete as possible, has not indicated any priorities in resource allocation among the various medical imaging sectors. It is up to the medical establishments to define their priorities, which should be based on a risk analysis of their activities. This being said, nuclear medicine and targeted internal radiotherapy in particular, interventional radiology and computed tomography are 3 areas which, because of their radiation protection implications for the patients, stand out with regard to short-term needs in medical physics.

In April 2013, nuclear medicine is the area in which the medical physics staff numbers currently in place are the closest to the recommendations made in this report. Nevertheless, the efforts to recruit medical physicists in this area must continue given the deployment in the short term of highly complex treatment and imaging techniques (particularly the new PET markers and new therapeutic targets).

Staffing levels in radiology are the lowest of all the areas of medical physics and are far below the recommendations expressed in this report. They will therefore have to increase substantially to meet the challenges in the face of diagnostic and therapeutic imaging techniques which are increasingly complex and potentially risky, particularly in interventional radiology and computed tomography.

APPENDICES

APPENDIX 1. Composition of the working group and consultations

APPENDIX 2. Areas of work of the imaging medical physicist and the associated tasks and corresponding annual number of hours in medical physics

APPENDIX 3. Results of responses to the questionnaire relating to nuclear medicine

APPENDIX 4. Results of responses to the questionnaire relating to radiology

APPENDIX 5. References

APPENDIX 6. List of acronyms

APPENDIX 1. Composition of the working group and consultations

Representatives of the SFPM

- Cécile Salvat (coordinator of the SFPM representatives)
- Arnaud Dieudonné
- Marie-Thérèse Guilhem
- Dominique Le Du
- Noëlle Pierrat

Representatives of ASN

Ionising radiation and health department:
- Aurélie Isambert
- Marc Valéro

Strasbourg Division:
- Vincent Blanchard

12 meetings were held between December 2010 and December 2012

In March 2012, the French professional council for radiology (G4) and the French professional council for nuclear medicine were consulted about the guide undergoing preparation.

APPENDIX 2. Areas of activity of imaging medical physicists and the associated tasks and corresponding annual number of hours in medical physics

Each column in the tables in appendix 2 indicates the estimated times (in hours) required to accomplish the task corresponding to a single machine or to the reference number of patients.

Reminder: The term «medical physics» as used herein designates all the human resources assigned to this discipline, including the medical physicists and the supporting staff. The FTEs proposed in the table concern all the medical physics personnel.

Equation 1. Calculation of the medical physics FTE per machine

For each machine in the imaging equipment pool (radiology and nuclear medicine), the following formula is to be applied:

$$\mathrm{FTE}_{\text{Physics/machine}} = \mathrm{FTE}_{\text{equipment}} \times A \times D + \mathrm{FTE}_{\text{clinical}} \times B \times (\text{number of patients}/C)$$

The $\mathrm{FTE}_{\text{medical physics}}$ is the sum of the $\mathrm{FTEs}_{\text{physics/machine}}$

The complexity factors A, B, C and D are detailed in chapter V.

Appendix 2.1. When purchasing an equipment item (in annual number of hours)

		Areas of intervention														
		Nuclear medicine					Therapeutic nuclear medicine (targeted internal radiotherapy)			Radiology						
	Role of medical physics	Gamma-cameras and dedicated cameras	Hybrid cameras	PET-CT	Dose Calibrators	Peroperative and thyroid probes	Non-cancer treatments*	Systemic treatments**	Selective treatments (in situ)***	Mobile X-ray units	C-arm unit	Conventional radiology room	Interventional radiology room	CT scanner	Mammography	MRI
	Organisation of dose calibrator calibration and purchase/ management of sealed sources for quality control	1	1	1	1	1	N/A	N/A	N/A	0	0	0	0	0	0	0
	Evaluation of image processing tools provided with the system in collaboration with the medical practitioners	4	5	5	0	0	N/A	N/A	N/A	0	0	2	2	4	2	4
	Evaluation of the different tomographic reconstruction and/ or image enhancement methods and tools provided with the system															
	Evaluation of patient dosimetry	0	1	1	0	0	N/A	N/A	N/A	1	1	2	6	6	2	0
In collaboration with the biomedical team	Participation in the drafting of the ARS and/or ASN authorisation application or declaration to ASN	7	16	16	2	2	N/A	N/A	N/A	1	2	3	12	16	3	8
	Participation in describing the allotment of the call for proposals															
	Participation in drafting the specifications															
	Participation in the preparation of the proposals assessment grid															
	Implementation of performance evaluation test procedures															
	Participation in the expert appraisal and evaluation of the technical proposals															
	Participation in the analysis of the suppliers' files															
	Participation in choosing equipment and options (for reducing doses and enhancing image quality in particular).															
With the PCR	Collaboration with the PCR in the design and fitting out of the premises and/or equipment in compliance with the regulations	16	20	30	0	0	N/A	N/A	N/A	0	1	1	1	1	1	0

* Example: hyperthyroid treatment by I-131, synoviorthesis, etc.

** Example: treatment of thyroid cancers, treatment of lymphomas by Zevalin®, treatment of endocrine tumours by Octreoscan®.

*** Example: treatment of hepatocarcinomas by resin or glass microspheres marked with yttrium 90.

Appendix 2.2. When installing an equipment item (in annual number of hours)

		Areas of intervention														
		Nuclear medicine					Therapeutic nuclear medicine (targeted internal radiotherapy)			Radiology						
	Role of medical physics	Gamma-cameras and dedicated cameras	Hybrid cameras	PET-CT	Dose Calibrators	Peroperative and thyroid probes	Non-cancer treatments*	Systemic treatments**	Selective treatments (in situ)***	Mobile X-ray units	C-arm unit	Conventional radiology room	Interventional radiology room	CT scanner	Mammography	MRI
	Scheduling and management of EQC, performance of the initial IQC	16	32	32	2	1	N/A	N/A	N/A	1	1	1	1	1	2	0
	Participation with the medical teams in the development of acquisition, reconstruction and/or image processing protocols in application of the optimisation principle	16	32	32	3	1	N/A	N/A	N/A	2	5	6	10	14	3	16
	Participation in the development of the patient radiological monitoring methodology (for dose reconstruction, etc.)															
	Implementation of internal image quality and dosimetry protocols for checking performance stability over time															
	Calibration verification and complement															
With the biomedical team	Performance and validation of acceptance tests	16	24	24	8	2	N/A	N/A	N/A	1	2	3	8	10	5	5
	Implementation of the register of maintenance and quality control operations															
	Implementation of deviation management															
With the PCR	Participation in the optimisation of worker radiation protection (devices, methods, etc.)	2	3	9	2	1	N/A	N/A	N/A	0	2	2	2	2	2	0

* Example: hyperthyroid treatment by I-131, synoviorthesis, etc.

** Example: treatment of thyroid cancers, treatment of lymphomas by Zevalin®, treatment of endocrine tumours by Octreoscan®.

*** Example: treatment of hepatocarcinomas by resin or glass microspheres marked with yttrium 90.

Annexe 2.3. After putting equipment into service, as part of its routine clinical utilisation (in annual number of hours)

		Areas of intervention														
		Nuclear medicine					Therapeutic nuclear medicine (targeted internal radiotherapy)			Radiology						
	Role of medical physics	Gamma-cameras and dedicated cameras	Hybrid cameras	PET-CT	Dose Calibrators	Peroperative and thyroid probes	Non-cancer treatments*	Systemic treatments**	Selective treatments (in situ)***	Mobile X-ray units	C-arm unit	Conventional radiology room	Interventional radiology room	CT scanner	Mammography	MRI
	Scheduling and management of EQC	70	90	90	16	2	N/A	N/A	N/A	2	4	6	8	6	10	6
	Performance or delegation of the periodic IQC and other stability tests - Traceability and analysis of results															
	Regulations watch	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1
	Ionising radiation metrology that is vital for any process to optimise doses delivered to patients	26	30	30	2	1	N/A	N/A	N/A	3	6	10	18	20	8	30
	Participation in the studies to optimise equipment operation, between medical practitioners and manufacturers															
	Participation in the development of new acquisition or processing protocols for new examinations, in application of the principle of optimisation															
	Interfacing with the manufacturer as an expert in medical physics, image processing and metrology	10	10	10	4	2	N/A	N/A	N/A	1	2	3	10	10	4	0
	Scientific, technological, documentation watch	1	1	1	1	1	1	6	12	0	1	1	1	1	1	0
With the biomedical team	Management and tracking of deviations	10	10	10	2	1	N/A	N/A	N/A	1	2	3	5	5	6	5
	Verification and analysis of maintenance and software updating operations performed by the maintenance technicians, and ensuring that all work is communicated to the medical physicist.															

* Example: hyperthyroid treatment by I-131, synoviorthesis, etc.

** Example: treatment of thyroid cancers, treatment of lymphomas by Zevalin®, treatment of endocrine tumours by Octreoscan®.

*** Example: treatment of hepatocarcinomas by resin or glass microspheres marked with yttrium 90.

Annexe 2.4. In the care and treatment of patients (in annual number of hours)

		Areas of intervention														
		Nuclear medicine					Therapeutic nuclear medicine (targeted internal radiotherapy)			Radiology						
	Role of medical physics	Gamma-cameras and dedicated cameras	Hybrid cameras	PET-CT	Dose Calibrators	Peroperative and thyroid probes	Non-cancer treatments*	Systemic treatments**	Selective treatments (in situ)***	Mobile X-ray units	C-arm unit	Conventional radiology room	Interventional radiology room	CT scanner	Mammography	MRI
	Participation in determining diagnostic reference levels (DRL), analysing the dosimetric indicators and the corrective actions to be implemented.	1	1	1	0	0	N/A	N/A	N/A	1	1	4	8	12	2	0
	Organising the "patient dosimetry" studies, calculating the doses received in the event of an incident or an unknown pregnancy, monitoring cumulative doses (dose reconstruction, etc.)	2	3	3	0	0	N/A	N/A	N/A	2	10	14	60	50	3	0
	Evaluation of the foetal dose in the case of pregnancy															
	Setting up the statistical analysis of doses received by patients (per protocol, practitioner, etc.)	2	3	3	0	0	N/A	N/A	N/A	0	0	0	24	20	4	0
	Implementation of alert thresholds per protocol and defining the steps to consider taking if the thresholds are exceeded.	1	1	1	1	0	N/A	N/A	N/A	0	0	0	10	5	0	0
	Participation in the development of "information for patients" or "information for patients' family circle" sheets	16	16	16	0	0	1	1	1	0	0	1	1	1	0	0
	Participation in the management of adverse events and quality management	2	2	2	0	0	1	1	2	0	0	3	10	10	3	5
With the radiopharmacist	Defining the optimum conditions for measuring activity	0	0	0	8	0	N/A	N/A	N/A	0	0	0	0	0	0	0

* Example: hyperthyroid treatment by I-131, synoviorthesis, etc.

** Example: treatment of thyroid cancers, treatment of lymphomas by Zevalin®, treatment of endocrine tumours by Octreoscan®.

*** Example: treatment of hepatocarcinomas by resin or glass microspheres marked with yttrium 90.

Annexe 2.5. Therapeutic nuclear medicine (targeted internal radiotherapy) (in annual number of hours)

	Areas of intervention														
	Nuclear medicine					Therapeutic nuclear medicine (targeted internal radiotherapy)			Radiology						
Role of medical physics	Gamma-cameras and dedicated cameras	Hybrid cameras	PET-CT	Dose Calibrators	Peroperative and thyroid probes	Non-cancer treatments*	Systemic treatments**	Selective treatments (in situ)***	Mobile X-ray units	C-arm unit	Conventional radiology room	Interventional radiology room	CT scanner	Mammography	MRI
Validation of treatment preparation (conformity with medical prescription)	N/A					25	50	250	N/A						
Calculation of the activity to administer															
Choice of method of calculating the activity to administer that allows optimum adherence to the medical prescription															
Participation in defining the conditions of use of multimodality image merging tools to help implement the treatment															
Implementation of the available tools allowing personalised dosimetric calculations															
Calculation of the dose to the organs at risk															

Annexe 2.6. Training of all the personnel concerned (in annual number of hours)

	Areas of intervention														
	Nuclear medicine					Therapeutic nuclear medicine (targeted internal radiotherapy)			Radiology						
Role of medical physics	Gamma-cameras and dedicated cameras	Hybrid cameras	PET-CT	Dose Calibrators	Peroperative and thyroid probes	Non-cancer treatments*	Systemic treatments**	Selective treatments (in situ)***	Mobile X-ray units	C-arm unit	Conventional radiology room	Interventional radiology room	CT scanner	Mammography	MRI
For optimised use of radiological equipment, participation in the implementation of new protocols or major change of version	10	10	10	2	1	1	1	1	2	2	4	16	20	4	10
Training in the procedures associated with exceeding of the dosimetric alert threshold															0

Annexe 2.7. Recommended sizing

	Nuclear medicine					Therapeutic nuclear medicine (targeted internal radiotherapy)			Radiology						
	Gamma-cameras and dedicated cameras	Hybrid cameras	PET-CT	Dose Calibrators	Peroperative and thyroid probes	Non-cancer treatment*	Systemic treatments**	Selective treatments (in situ)***	Mobile X-ray unit	C-arm units	Conventional radiology room	Interventional radiology room	Computed tomography (CT) scanner	Mammography	MRI
Reference activity (in number of patients per year)	1 000	1 000	1 000	N/A		100	50	50	N/A		7 500	1 000	10000	1 500	N/A
Number of "clinical" hours/reference activity	6	8	8	0	0	26	51	252	2	10	17	94	80	10	5
"Clinical FTE[1]" / reference activity	0.004	0.005	0.005	0	0	0.016	0.032	0.158	0.001	0.006	0.011	0.059	0.050	0.006	0.003
Number of "equipment" hours	224	304	320	55	17	4	9	15	16	32	53	120	135	56	85
"Equipment FTE[1]"	0.140	0.190	0.200	0.034	0.011	0.003	0.006	0.009	0.010	0.020	0.033	0.075	0.084	0.035	0.053
FTE training supervising students	Master's degree students				One FTE of 0.2 over the months of supervision per student										
	DQPRM students				0.07 FTE/student in nuclear medicine and 0.05 FTE/student in radiology (according to DGOS/INCa recommendations)										
Research activities	Depends on the research role of the medical facility and on its projects														

[1] **The times expressed in hours were converted into FTE on the basis of 1600 hours of work per year.**

* Example: hyperthyroid treatment by I-131, synoviorthesis, etc.
** Example: treatment of thyroid cancers, treatment of lymphomas by Zevalin®, treatment of endocrine tumours by Octreoscan®.
*** Example: treatment of hepatocarcinomas by resin or glass microspheres marked with yttrium 90.

APPENDIX 3. Results of responses to the questionnaire relating to nuclear medicine

Annexe 3.1. Number of replies received: 26 (6 from cancer centres, 19 from public hospitals and 1 from a private centre)

Number of centres having replied	26
Number of medical physicists assigned to nuclear medicine for the centres having replied	30

Contractual FTE[1]	Effective FTE [1]	FTE not provided for (hiring in progress)
20.95 (0.8 per centre on average)	18.7 (0.7 per centre on average)	1

1. Contractual FTE means the theoretical number of FTE medical physicists assigned to nuclear medicine with respect to the effectively assigned number of FTEs.

Appendix 3.2 Equipment

Equipment	Total number for 26 centres	Number of centres concerned	Number of centres in which the physicist is involved in the following tasks:						FTE medical physicist / machine [min; max]
			Administrative management (ARS, ASN, CCTP files, maintenance management, etc.)	Performance and management of IQC - Management of EQC	Performance evaluation, appraisals, complex techniques, new protocols, etc.	Optimisation / radiation protection of patient and family/image quality/ DRL	Interface with manufacturer	Others(2)	
Number of centres concerned		26	22	26	21	24	21	10	
Single-detector gamma camera	7	6	6	6	4	6	5		[0.025 ; 0.10]
SPECT	44	25	19	25	20	23	19		[0.05 ; 0.25]
SPECT-CT	23	19	16	19	15	17	15		[0.07 ; 0.20]
Dedicated gamma camera or SPECT (heart, brain, breast)	5	4	3	4	3	3	2		[0.05 ; 0.12]
PET-CT	22	19	16	19	17	16	14		[0.06 ; 0.40]
Dose calibrators	77	26	14	22	15	11	17		[0 ; 0.05]
Peroperative probe	48	22	9	19	9	6	10		[0.001 ; 0.05]
Thyroid gamma-ray counter	11	9	3	8	5	3	3		[0.005 ; 0.01]
									Average FTE per centre = 0.49 [0.1 ; 0.95]

(2). Other tasks mentioned at least once : research, regulations watch, drafting of procedures, first-line repair, image reconstruction and processing optimisation protocols, calibration.

Average medical physicist FTE per machine

SPECT or dedicated cameras (heart, brain, etc.)	0.116
SPECT-CT	0.14
PET-CT	0.217
Dose calibrators	0.035
Probes and counters	0.013

Appendix 3.3. Therapy

Therapeutic activity	Number of centres concerned	Number of centres in which the physicist is involved in the following tasks:			
		Calculation and validation of the activity to administer	Optimisation, calculation of dose to the target and organs at risk	Complex techniques, new techniques	Others(3)
Number of centres concerned	22 (85% of the respondent centres have at least one therapy activity)	17	10	9	10
Hyperthyroidism treatment by Iodine 131	17	10	1	1	4
Synoviorthesis	11	4	0	1	0
Thyroid cancer treatment by Iodine 131	15	9	1	0	2
Pain-relief treatment of bone metastasis	16	8	1	1	3
Treatment of non-Hodgkin lymphomas by Zevalin® marked with Yttrium 90	17	8	1	1	5
Treatment of liver cancers by microspheres marked with Yttrium 90	6	6	6	6	2
Others Lipiodol, octreoscan®, etc.	4	3	2	3	1

(3). Other tasks mentioned: research, radiation protection recommendations for patients, family circle, environment, and personnel.

The medical physicist FTEs devoted to therapy vary from 0.02 to 0.5 for an average FTE per centre of 0.2.

The answers to the questionnaire indicate that certain tasks are sometimes delegated, such as giving radiation protection recommendations to patients, their relatives, concerning the environment and the personnel.

Appendix 3.4 Teaching

Type of teaching	Number of centres where the medical physicists have a training activity /26 replies
Initial and continuous training of medical and paramedical personnel	18
Supervision of Master's degree 1st year students	10
Supervision of Master's degree 2nd year students	8
Supervision of DQPRM students	14
Others (specify) Thesis supervision, faculty of medicine, etc.	9

It can be noted that 88% of the respondent centres have at least one teaching activity (23/26). The medical physicist FTEs devoted to teaching activities vary from 0.01 to 0.45 with an average of 0.16.

Appendix 3.5. Miscellaneous questions

Hierarchical attachment of medical physicists

Number of replies	To an administrative department: Quality and Risk Management Department (QRMD), General Management (GM), Human Resources Department(HRD), Purchasing and Logistics Department (PLD)	To the head of the nuclear medicine department or head of a unit (imaging)	To a functional unit (FU) of medical physics and radiation protection
15	4	5	6 (FU attached to PLD, GM, biomedical department, head of radiotherapy, radiology or nuclear medicine department)

Research in medical physics

Number of replies	Number of physicists involved	Role	FTE
19	10	Small animal platforms: 4 Project managers: 4 Supervision of theses: 1	0.06 to 0.5

Clinical studies protocols

Number of replies	Number of physicists involved	Number of protocols per year per department
19	9	1 to 2

Radiation protection of nuclear medicine personnel

Number of replies	Number of physicists involved	Role	FTEs per physicist devoted to RP of nuclear medicine personnel
20	16	PCR - appraisal	0.02 to 0.25

Radiation protection of personnel in the medical centre

Number of replies	Number of physicists involved	Role	FTEs per physicist devoted to RP of medical centre personnel
5	4	PCR	0.4 to 0.5

Waste management

Number of replies	Number of physicists involved	Role	FTEs per physicist devoted to waste management
19	15	PCR - appraisal	0.05 to 0.1

APPENDIX 4. Results of responses to the questionnaire relating to radiology

Appendix 4.1. Number of replies received: 19 (6 from cancer centres, 12 from public hospitals and 1 from a private centre).

Number of centres having replied	19
Number of medical physicists assigned to radiology in the centres having replied	18
Effective FTE for the 19 centres	5.4 medical physics FTEs

➜ General remarks on the replies received:

- Only one reply received from a private radiology practice with a medical physicist FTE of 0.
- One reply reported a physicist (1 FTE) working in 4 sites of a university research hospital, 3 hospital centres and 10 radiology practices (representing 110 X-ray generators).

➜ Replies concerning the medical physicist FTEs:

- Average medical physicist FTE = 0.24 ± 0.24 out of 19 replies.
- Average medical physicist FTE for centres taking on DQPRM students = 0.25 of which 0.11 FTEs devoted to the supervision of DQPRM students.
- Certain centres have reported that the total FTEs devoted to radiology is equal to the FTEs supervising the DQPRM students in radiology.
- The medical physicist FTEs desired by the questioned physicists are generally 3 times greater than the current FTEs.

Appendix 4.2 Equipment

Equipment	Number of equipment items	Number of centres (out of 19 replies) in which the physicist is involved in the following tasks:							
		Participation in the ARS and ASN authorisation files if necessary	Participation in drafting the CCTP, choice of equipment and options	Appraisal of equipment proposed in tender	Application of new protocols	Performance of IQC, management of EQCs	Optimisation and DRL	Individual dosimetry (child, pregnant woman, total, etc.)	Performance stability after manufacturers' interventions
Mammography	20	6	8	3	6	9	8	7	5
Conventional radiology room	89	7	10	7	7	14	13	10	8
Dedicated interventional radiology room	36	3	4	2	4	8	6	8	6
Operating room interventional radiology facility	79	3	2	1	3	9	4	5	3
Mobile X-ray unit	133	6	7	3	3	13	9	9	7
CT scanner	37	10	11	6	12	15	15	14	11
MRI	24	4	4	1	4	2	1	1	2

The majority of the radiological medical physicist's activity is devoted firstly to computed tomography, and then to strictly regulatory duties in conventional radiology (IQC, EQC, DRL) and the supervision of DQPRM students.

Interventional radiology is revealed to be a relatively minor activity in cancer centres, unlike mammography which is more prevalent than in other structures.

Appendix 4.3. Therapy

Therapeutic activity in interventional radiology	Number of centres / 19 replies
Cardiology	5
Neuroradiology	3
Osteo-articular	3
Visceral and vascular	6

9 of the 19 centres have therapeutic activities in radiology:
- the 9 centres have an average medical physicist FTE of 0.34 (i.e. higher than the average of 0.24),
- 4 of the 9 sites practising interventional radiology have medical physicist FTE ≥0.4.

The 5 other sites practising interventional radiology have FTEs of between 0 and 0.2.

Appendix 4.4 Teaching

Type of teaching	Number of centres where the medical physicists have a teaching or training activity (out of 19 replies)
Initial and continuous training of medical and paramedical personnel	11
Supervision of Master's degree 1st year students	2
Supervision of Master's degree 2nd year students	1
Supervision of DQPRM students	7
Other (Thesis supervision, faculty of medicine, etc.)	5

58% of the respondent centres have at least one teaching activity.
11 out of 19 centres participate in the training of medical and paramedical personnel.

Appendix 4.5. Miscellaneous questions

Research in medical physics

Number of replies	Number of physicists involved	Role
1/19	1	Project managers: 1 Supervision of theses: 1

Clinical studies protocols

Number of replies	Number of physicists involved
1/19	1

Hierarchical attachment

Number of replies	To an administrative department: Quality and Risk Management Department (QRMD), General Management (GM), Human Resources Department (HRD), Purchasing and Logistics Department (PLD)	To the head of a radiology department or head of a unit (imaging)	To another medical physicist head of a medical physics unit
18/19	6	6	6

Concerning the hierarchical attachment with respect to the average FTE of medical physicists, the study reveals that:

- If the medical physicist is attached to a radiotherapy supervisor (physicist or head of department), the average FTE is 0.16;
- If the medical physicist is attached to an imaging supervisor (physicist or head of department), the average FTE is 0.21;
- If the medical physicist is attached to an administrative department, the average FTE is 0.35.

Attachment of the medical physicist to an administrative department therefore seems to favour the time devoted to radiology assignments.

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APPENDIX 6. List of acronyms

AAPM: American Association of Physicists in Medicine

AFSSAPS: French national agency for drug and health product safety

ANSM: French national agency for drug and health product safety (formerly AFSSAPS)

APHP: Public Assistance – Paris Hospitals

ARS: Regional health agency

ASN: French Nuclear Safety Authority

CCTP: Particular technical specifications

CH/CHR/CHRU: Hospital Centre, Regional Hospital Centre, Regional University Hospital Centre

CLCC: Cancer Centre. There are 20 cancer centres located in 16 regions in France, established further to an edict by General de Gaulle dated 1st October 1945 (article L.312 & following of the Public Health Code). The cancer centres are private non-profit health facilities that play a university hospital role.
(http://www.fnclcc.fr/fr/institutionnel/fnclcc/mission.php)

CSN: Spanish nuclear safety council

CT: Computed Tomography

DGOS: General directorate for healthcare provision

DQPRM: Qualifying diploma in radiological and medical physics

DRL: Diagnostic Reference Level

EFOMP: European Federation Of Medical Physics

EQC: External Quality Control

FANC: Federal Agency for Nuclear Control (Belgium)

FOPH: Federal Office of Public Health (Switzerland)

GPMED: The Advisory Group of Experts in radiation protection for medical applications is called upon by ASN to give its opinions and, where applicable, recommendations in the field of radiation protection of professionals and the public for medical and forensic applications of ionising radiation.

InVS: French health monitoring institute

IQC: Internal Quality Control

MRI: Magnetic Resonance Imaging

PACS: Picture Archiving and Communication System

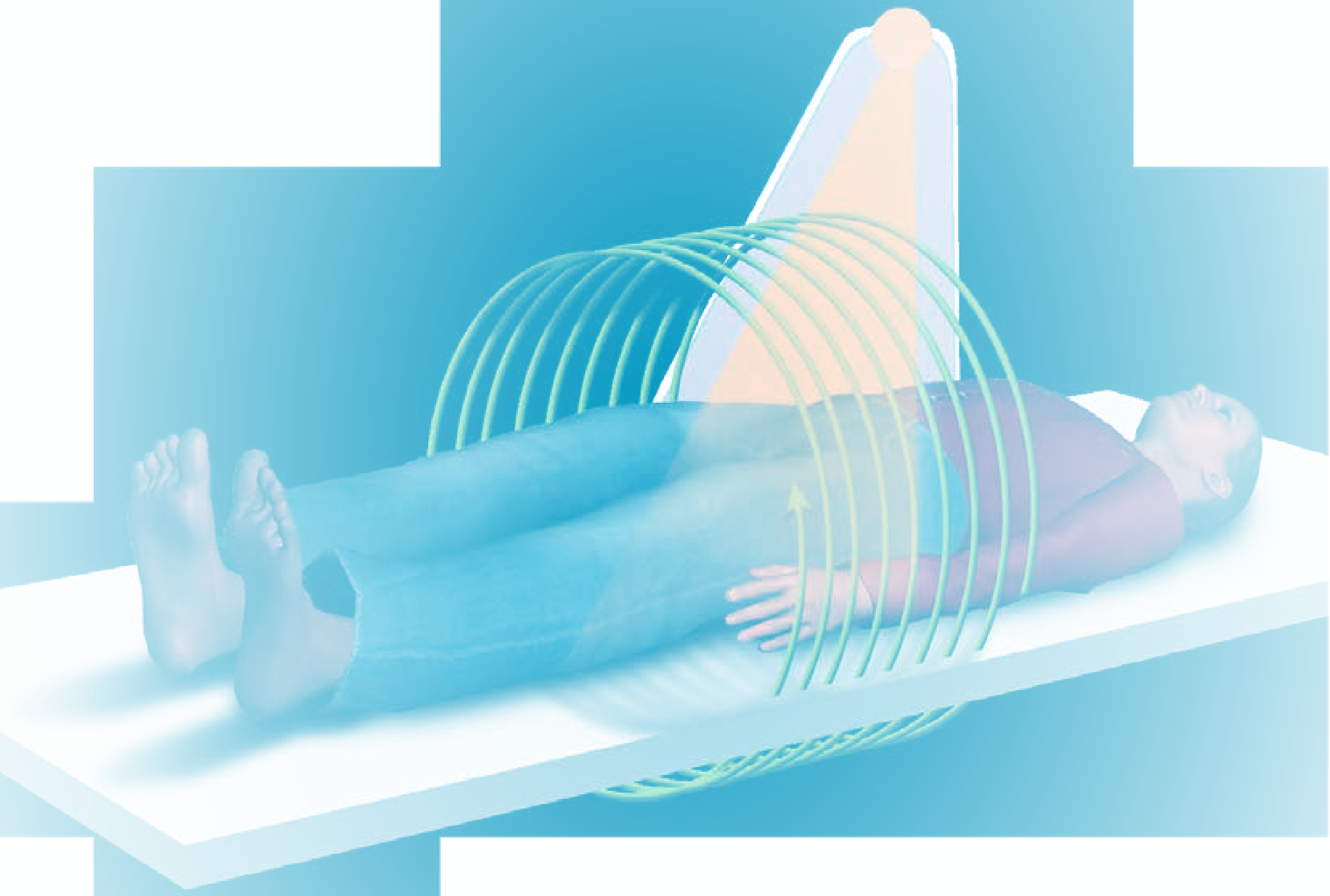
PCR: Person Competent in Radiation protection (Radiation protection officer)

PET: Positron Emission Tomography

PSRPM: French acronym for «Person Specialised in Medical Radiation Physics», referred to in English as «medical physicist»

SFPM: French Society of Medical Physics

SPECT: Single-Photon Emission Computed Tomography



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