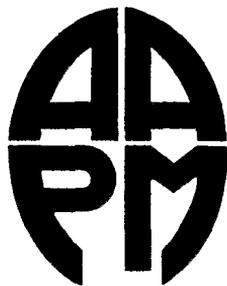


**STAFFING LEVELS AND RESPONSIBILITIES
OF PHYSICISTS IN DIAGNOSTIC RADIOLOGY**



AAPM REPORT NO. 33

**STAFFING LEVELS AND RESPONSIBILITIES
OF PHYSICISTS IN DIAGNOSTIC RADIOLOGY**

REPORT OF TASK GROUP 5
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REPORT SUMMARY

This report reviews the need for diagnostic radiological physics services in any facility that provides diagnostic imaging or related diagnostic techniques. Based on these needs, the American Association of Physicists in Medicine (AAPM) has developed guidelines for the physics staff and support personnel required to manage the diagnostic image quality, radiation safety, and associated patient care responsibilities of a facility. Such staffing levels can assure the regulatory and accreditation requirements are satisfactorily met.

The AAPM recommendations for physics staffing are based upon the type and amount of equipment in the radiology facility. However, the physics services extend far beyond the support of the listed equipment. The equipment merely serves as an index value for assessment of the needed physics staff. The AAPM recommendations are given in Table #1.

Table 1

AAPM Physics Staffing Recommendations

Amount of Equipment	Staff Recommendations* For Physicists
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I. Diagnostic X-ray

For each mobile radiography unit	0.015 FTE
For each general x-ray room	0.015 FTE
For each mobile fluoroscope	0.03 FTE
For each R/F room	0.05 FTE
For each Special Procedures Room	0.08 FTE
For each digital system**	0.04 FTE
For each CT scanner	0.08 FTE

II. In Nuclear Medicine

For each scintillation camera	0.10 FTE
For each image processing computer	0.25 FTE
For each SPECT	0.25 FTE
For each PET	TBD***

III. Ultrasound

For each ultrasound scanner	0.015 FTE
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IV. MRI

For each MRI	<u>0.1 - 0.25 FTE</u>
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* These FTE numbers given above pertain only to the physics staff. Additional staff must be provided to support the physics operations. The ratio of support staff to physicists should be about 1.5:1. The support staff should consist of QC technologists, and radiation safety personnel. See text for specific recommendations on support staff. These recommendations do not include needs generated for engineering services, research projects, special teaching needs for residents and medical students, or needs associated with PET scanners.

** This refers to digital radiography or to the digital component of a fluoroscopy system.

*** To be determined in accordance with need.

I. INTRODUCTION

Diagnostic radiology includes x-ray imaging (roentgenography, computed tomography and fluoroscopy), nuclear medicine imaging, some non-imaging studies with radionuclides, and diagnosis by ultrasound and magnetic resonance (MR). Traditionally, radiology departments provide both the technological services and equipment for various forms of medical imaging and some non-imaging diagnostic evaluations. These departments typically represent the largest financial investment in high technology equipment in the medical facility and require highly educated professionals to provide satisfactory patient care. The significant investment in and the complexity of medical imaging equipment has increased the demand for skilled diagnostic medical physics support. Individuals who provide such support are referred to as diagnostic radiological physicists.

Diagnostic radiological physicists provide professional services for selecting, evaluating, monitoring and optimizing imaging devices. They are also directly involved in patient care, radiation safety, teaching, and administrative functions. They play an essential role in developing policies and procedures for diagnostic radiological departments.

The American Association of Physicists in Medicine (AAPM) recommends that physicists qualified to practice diagnostic radiological physics be certified in diagnostic radiological physics by an appropriate certifying board. At the time of this publication the appropriate boards are the American Board of Radiology and the American Board of Medical Physics, and that of the Canadian College of Physicists. Throughout the rest of this document, qualified radiological physicists may be referred to as diagnostic physicists or simply as physicists.

In this document, the AAPM Task Group on "Physics Manpower Needs in Diagnostic Radiology" summarizes the requisite physics support for diagnostic imaging departments. Staff size recommendations are based on the equipment inventory of the diagnostic imaging department with emphasis placed on the primary physics needs generated by each piece of equipment. Among these needs are radiation safety, quality control, and acceptance testing. Time devoted to these concerns can vary considerably depending on the specific needs and priorities of individual institutions as well as on the regulatory compliance requirements of different states in which the institutions reside. The variations in needs between types of institutions have not been addressed in the staffing recommendations of this report. It is important to note that physics staffing must also address

the educational services physicists provide to individuals who work with or around the equipment, as well as responsibilities for administrative and accreditation requirements associated with the equipment.

These needs ultimately depend on the equipment inventory of the department. Basing recommendations on equipment inventory provides a firm foundation for which there can be no confusion or misinterpretation. However, it is important to note that the number of physicists required for each piece of equipment must reflect not only the needs directly associated with that piece of equipment but also many other duties and responsibilities which may not be directly related the equipment. It also must reflect administrative, regulatory, and accreditation work associated with the equipment.

The recommendation in this document in this document are based upon the effort required to perform the various duties typically requested of physicists in diagnostic radiology facilities. The information provided in this report should be beneficial to administrators, departmental directors, radiologists, physicists, and other health care professionals when assessing their diagnostic physics staffing needs.

II. THE NEED FOR DIAGNOSTIC PHYSICISTS

The increasing sophistication, complexity, high cost, and high technology of medical imaging equipment has created an increasing demand for experts who can ensure that the financial investment in these technologies is fully realized in daily performance. Physicists are experts in the scientific and mathematical principles of imaging as well as in the technology behind the performance evaluation of medical imaging and non-imaging diagnostic devices. They are trained in the safe uses of all forms of radiations employed in a diagnostic department. Their goal is to help establish a cost-effective and consistent high standard of diagnostic image quality, radiation safety, and patient care. Their scientific expertise spans the spectrum of the imaging technologies from conventional x-ray to ultrasound and nuclear medicine, from CT and digital angiography to magnetic resonance (MR). In meeting the above goals a physicist can help ensure that federal, state and local regulatory requirements for radiation safety are met. Current JCAHO accreditation standards require, in addition to quality image performance and radiation safety, that each institution evaluate radiation exposures to patients (See Appendix I, Item 1, Section DR.2.2.10.2). Several documents that discuss regulatory and accreditation requirements and other needs addressed by physicists are cited in Appendix I.

III. PROFESSIONAL RESPONSIBILITIES AND SERVICES

The professional activities and services provided by diagnostic physicists can be divided into three categories. These are:

A. Essential functions to:

1. Meet the clinical demand for excellence in imaging and patient care while providing a safe radiation environment, and
 2. To ensure compliance with various regulatory requirements, and
 3. To help promote cost effective operations through improved equipment selection, utilization and to ensure consistency through routine quality control evaluations.
- B. Optional research and developmental activities for those facilities involved in the advancement of new technologies and procedures.

These responsibilities are discussed below.

A. Essential Functions

1. Policies and Procedures

As defined by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO), policies and procedures in departments of diagnostic radiology and nuclear medicine are designed to "assure effective management, safety, proper performance of equipment, effective communication and quality control..." Because these departments are heavily invested in a variety of radiation producing equipment that requires continual monitoring for safety and quality, the radiological physicists play an essential role in developing the policies and procedures in the respective departments. This essential role is recognized in the JCAHO requirement that the policies and procedures be reviewed periodically by a medical radiation physicist in order to meet this need. (See Appendix I, Item 1, Section DR.2.1.1.).

2. Quality Control Program

As defined by the American College of Radiology (ACR), Quality Assurance is the overall program required to assure proper medical care is provided to patients. The Quality Assurance program includes the monitoring of medical records, patient handling, medical procedures and safety practices. Quality Control (Q.C.) is a portion of the overall Quality Assurance program. Quality Control is a

periodic monitoring of aspects of precision or accuracy as they relate to the equipment, techniques, or testing of equipment performance rather than clinical decision-making (ACR Q.A. Guide, 1983). JCAHO and regulatory agencies require that QC programs under the direction of a qualified expert be established at all radiology facilities (See Appendix I, Item 1, Sections DR.2.2.7, DR.2.2.10, NM.2.2.8 and NM.2.2.14).

Physicists should direct and be responsible for the Quality Control programs. The foremost goal of these programs is to obtain and maintain optimal image quality and reliability while minimizing radiation exposure and ensuring compliance with radiation safety requirements. QC programs include diagnostic systems that produce or utilize ionizing radiation and other systems such as MR and ultrasound that utilize non-ionizing radiations. A cost-effective practice is to designate a QC technologist to perform some of the measurements under the supervision of a physicist. QC technologists are individuals who are familiar with both the radiology equipment and the test instrumentation. They are specifically trained to make some of the measurements required to assess imaging equipment performance. QC technologists are usually ARRT (American Registry of Radiological Technologists) certified x-ray or nuclear medicine technologists who have at least several years experience working with radiology equipment and ionizing radiation.

QC programs include daily, weekly, monthly and semi-annual surveys and spot checks of all imaging equipment and relevant non-imaging instrumentation. For instance, daily checks may be performed for film processors; weekly checks might include certain functional and image quality measurements to detect more gradual changes in image performance; and semi-annual evaluations may include complete assessments of the image quality, generator calibrations and safety checks to assure long-term stability of the entire system. This testing is designed to detect problems before serious malfunctions in the equipment occur. Thus, the tests result in improved equipment "up-time" and performance. Moreover, patient radiation exposures are optimal for properly functioning equipment. Such QC testing requires about 2-4 person-days per year for each radiographic tube (x-ray tube or image intensifier).

The tests will also result in cost savings. Repeat rates of films are reduced. Studies have shown that QC programs typically reduce rates from 10-14% to 5-7% which represents a significant saving in film cost, personnel time and increased patient throughput (see for instance: Quality Assurance Programs for Diagnostic Facilities, HEW Publication (FDA) 80-8110, 1980; and Barnes et al, SPIE Vol. 96, 1976, p. 19).

A number of different publications have listed QC procedures that should be performed on diagnostic radiology equipment. A brief section with references discussing QC test procedures is included in the Appendix II of this report.

3. New Equipment Specification and Evaluation

Physicists provide recommendations and technical information regarding new equipment selection, layout and installation. The physics services for new equipment installations include: gathering information on clinical requirements and the products to meet such requirements, information analysis, equipment comparison surveys, site visits to inspect installations at other hospitals, preparation of technical bid specifications for the equipment performance and optional accessories, evaluation of the manufacturer's bids, room design in conjunction with the physicians, administrators, architects, and others; and radiation shielding specifications.

For installations of complex and expensive radiology equipment, these services can result in a considerable cost savings. The amount of time spent performing such services depends on the sophistication of the equipment and the status of the room in which it will reside. For example, the effort for a simple conventional x-ray room may require one week's work but for an angiographic suite, up to six weeks may be required to complete all the above mentioned services. Since the average life of x-ray equipment is typically 7-10 years (AHA, Estimated Useful Lives of Depreciable Hospital Assets, 1983), a replacement schedule can involve 10-15% of the existing equipment each year.

4. Acceptance Testing

After new rooms are installed, physicists test the performance of the equipment to ensure that the quality of performance is commensurate with the investment, and that performance complies with the technical specifications itemized in the purchase contract. This testing should be the most thorough evaluation that the equipment will undergo. It involves mechanical checks, electronic evaluation of generator calibrations, radiation safety evaluations, image quality assessments and overall system performance measurements. These tests provide the baseline data for future quality control checks. The time allotted to complete these tests inevitably depends on the complexity of the equipment and the degree to which performance specifications are met following installation by the manufacturer.

The time necessary for acceptance testing can range from one day up to perhaps four to six weeks. Because of the variability in systems, it is impossible to give a firm cost figure for the services discussed under sections 3 and 4. A general figure of one percent of the capital equipment costs provides a guideline value. This is returned on improved equipment performance.

5. Interface with Maintenance Operations

Effective maintenance is a necessary part of a QC program. Physicists cooperate with maintenance and in some cases direct maintenance personnel to ensure appropriate repair, calibration and preventative maintenance of radiology equipment. Following major repairs, replacement or preventative maintenance of radiology equipment, the physicist checks the equipment for function, image quality, and safety. The physics services also include the evaluation of new x-ray tubes for specified focal spot sizes, filtration, output, leakage radiation, and calibration. Replacement image intensifiers are checked for conversion efficiency, spatial resolution, contrast ratio, uniformity, linearity, and input dose rates. Similar measurements are performed following major repairs or parts replacements.

Physicists help "trouble shoot" equipment problems and are frequently mediators who resolve whether malfunctions are due to operator error, ancillary equipment malfunction (film or processor problems) or electronic problems. With good maintenance records, the physicist's input can be used to effectively budget for equipment replacement needs as well as reduce cost by eliminating unnecessary or inappropriate purchases of x-ray tubes, image intensifiers and other equipment. In addition, safety problems may be uncovered and corrected under the physicist's directions before serious hazards occur.

6. Implementation of New Clinical Instrumentation or Procedures

Physicists often assist in the initial implementation of new high technology equipment or new clinical procedures not previously provided at an institution. Examples of high technology equipment with which physicists provide assistance include: Picture Archiving and Communications Systems (PACS), teleradiology, digital radiology systems, new CT scanner procedures, MR units, computer software, computer reporting systems, personal computers and similar items.

7. Radiation Safety Operations

A separate radiation safety office may or may not exist in a given hospital. Even when a separate radiation safety office does exist, many primary radiation safety duties are still the responsibility of a diagnostic radiological physicist. A diagnostic physicist has special training in radiological safety which prepares him for these functions. The safe use of ionizing radiation is of concern to not only the personnel working at the hospital but also to the patients and general public. Personnel dosimeters must be issued to radiation workers. The physicists must make certain that the dosimeters are worn and the reports are reviewed. Safe use of equipment and sources producing ionizing radiation must be established and instituted. Records and inventories of radioactive sources must be meticulously maintained. Procedures manuals must be developed. Wipe tests for radioactive contamination must be taken at regular intervals. Lead aprons must be inspected at least annually. Radiation room shielding design must be performed for new installations to determine adequate shielding thickness. Radiation surveys of the shielded rooms such as fluoroscopic areas and isotope areas must be performed regularly. Training sessions are used to instruct radiology personnel about the proper use of radiation producing equipment and shielding devices. All of the above should be written in as part of -the departmental policy and procedures.

As the size of a facility increases, radiation safety needs inevitably become more complex because of increased traffic in and out of radiation producing areas and because of increased mobility of radiation sources used throughout the facility for patient care. In order to assure adequate protection to the public and personnel, the number of radiation safety personnel required to support larger facilities may be greater in proportion to their size than the number required to support small facilities. Larger facilities should carefully assess any extra radiation safety personnel, beyond those recommended in this report, who may be required to provide adequate control of radiation. At a minimum, a 400 bed hospital requires 0.4 FTE physicist to handle radiation safety.

8. Radiation Dosimetry

Physicists are frequently requested to provide information on radiation dose or exposure to patients or staff. Measurement of radiation dose is referred to as dosimetry. Patient dosimetry is also performed to ensure the safety of patients, to comply with JCAHO requirements, and to compare doses and exposures with regulatory guidelines or national averages. Dosimetry may be performed

to determine why a high radiation badge reading occurred, to estimate fetal dose for patients or staff, or to evaluate existing shielding devices. The estimates may involve measurement with phantoms or direct measurements. Physicists also handle inquiries from patients and the general public about radiation levels and effects.

9. Preparation for JCAHO and Regulatory Inspections

JCAHO inspections are frequently limited to audits of the records to ensure appropriate physics services are provided. Nevertheless, JCAHO requires that an ongoing Quality Control (QC) program to "maximize the quality of diagnostic information for diagnostic radiology." All radiation producing equipment must be checked by the physicist at least once per year. Moreover, patient radiation exposure calculations for typical procedures performed in each room must be determined from measurements made on each x-ray tube. The physicist should audit the exposures to ensure the requirements for JCAHO have been adequately addressed.

State or local regulatory agencies usually conduct inspections that involve testing of the equipment and radiation surveys of the facilities. Deficiencies uncovered during inspections by State or local regulatory agencies can result in significant fines or restrictions placed upon the radiological facility. Regulatory requirements of various radiation control agencies typically include annual calibration reports on each piece of x-ray and nuclear medicine equipment that produces or measures ionizing radiation. Complete records must be kept on all radioactive sources. Area surveys of radiation levels around these radiation producing devices must be obtained and documented.

To meet these requirements, physicists must make numerous measurements and maintain detailed and complete records. Prior to an inspection, equipment is usually rechecked and repaired. The physicists frequently meet with the inspectors, schedule the inspection of the equipment, review the inspection procedures, review the findings and arrange for corrective actions as required.

Between 0.2 to 1.0 days may be required per room to adequately prepare for the above inspections. The actual time depends on the equipment and the size of the facility. In some states, regulations are stricter than in other states and this adds to the effort.

10. Teaching

Physicists are responsible for teaching health and imaging aspects of radiological physics to radiology residents. Additionally, the physicist frequently teaches radiation safety and radiation effects to medical students, technologists, residents, radiology staff, nurses, security personnel and housekeeping staff. Diagnostic radiology residents must be prepared to pass written board examinations containing a significant number of physics questions. Considering the large number of topics which must be taught, the resident courses should have a significant number of in-class hours and laboratory sessions. The Nuclear Regulatory Commission (NRC) requires the nuclear medicine residents to have a minimum of 200 classroom hours in order to become licensed (See Appendix I, Item 13). Residents should have a minimum of 50 classroom hours of instruction per year.

For institutions with residency programs and/or student technology programs in radiology, lectures are intended to provide fundamental knowledge about scientific principles, an understanding about imaging equipment, to enhance their ability to properly utilize clinical devices, and to provide an understanding about the hazards and safe usage of ionizing radiation. The usual criteria for estimating teaching loads is one to three hours of preparation for every hour in the classroom.

11. Administrative Duties

A certain percentage of every diagnostic radiological physicist's time is devoted to administrative duties. These items include writing reports, preparing operating budgets, maintaining equipment files, attending committee meetings, communicating with administrators, requesting the purchase, repair and calibration of physics equipment and other similar functions. In large institutions, the chief physicist inevitably incurs increased administrative duties above those of the average physicist.

12. Continuing Education

It is essential that the need for continuing education of medical physicists be recognized and that appropriate time be allotted. Physicists should attend professional meetings, refresher courses, scientific sessions and technical exhibits to remain abreast of innovative developments in new equipment, techniques, and other medical imaging issues. Physicists should also keep abreast of information in technical and clinical publications. About 5%-10% of a physicist's time should be dedicated to continuing education.

B. DEVELOPMENT OF NEW DIAGNOSTIC TECHNIQUES

1. Computer Support

Physicists' knowledge of computer systems enables them to assist the physician to develop or modify clinical studies which utilize this equipment. Examples of these services include but are not limited to: Quantitative analysis of nuclear medicine images; display, reformatting and analysis of CT images; processing of digital radiology data; and analysis of cardiac images for ventricular performance indices.

2. Mathematical Analysis of Data

Many clinical studies require someone to analyze the clinical data in some mathematical fashion. These types of analyses may include: statistical analyses such as linear regression and correlation studies, mean and standard deviation, T-tests, sensitivity-specificity studies, receiver operating characteristic (ROC) curves, and many other types of calculations. Clinical examples include establishing the evaluation of ventilation-perfusion and renal flow studies in nuclear medicine as well as cardiac function and bone mineral determinations in diagnostic radiology. A physicist's strong training in mathematics enables him to provide technical advice and assistance in the appropriate analysis of clinical data. Once the analyses are established, a trained technologist performs these functions, but a physicist should periodically monitor the adequacy of these evaluations.

3. Research and Publications

At most large medical facilities, physicists are expected to assist the radiologists with both basic and clinical research. A diagnostic physicist's training in mechanics, electronics, mathematics, chemistry, physiology and clinical exposure permits him to bring a strong scientific background to many research projects. If this function is appropriate for the institutional position, then extra time should be allocated for physicists to perform the library research and to do pilot studies necessary to develop research proposals that are submitted for funding consideration. Efforts to write articles intended for publication in journals and for presentation at professional meetings must also be considered.

4. Consultation Services

Physicists are often requested to provide advice and technical assistance to other departments in the medical institutions; these include dentistry, cardiology, urology,

surgery and orthopedics. The physicist's broad area of expertise for medical imaging can be applied across departmental lines in medical institutions.

5. Other Training Programs

Physicists are involved in training programs for technologists, other radiological physicists, and physicians. Often facilities have special short courses to provide training for physicians and technologists so that they understand radiation safety principles in the utilization of high technology equipment. This training may be on an individual basis or at local and national meetings.

IV. Recommendations for Physics Staffing

The recommendations in this document for physics staffing utilize an itemization of equipment within the facility. These recommendations are summarized in Table 1. The recommendations address the primary needs generated by each piece of equipment at the institution as well as other indirectly related requirements for radiological physics services. These needs include quality control, radiation safety, replacement of aging equipment, regulatory requirements, educational activities for the staff, clinically related needs and administrative functions.

These recommendations do not include needs generated for research projects, special teaching needs for residents and medical students, or needs associated with PET scanners. The needs required by each institution to fulfill these specialized function vary greatly. Therefore, each institution should allocate positions for physicists on the basis of their teaching demands, services provided at the PET facilities, and the emphasis they place upon research.

In addition to the required physics staff, there must be some provision to provide support personnel to assist the physicists. Physicists are often assisted in the performance of their various services in a diagnostic facility by QC technologists, processor monitoring Radiation Safety technicians and other support staff. QC technologists are utilized to assist the physicists with various routine QC measurements in order to make a more effective use of the physicist's time. The QC technologists may directly perform the more routine measurements on the less sophisticated radiology equipment which they review with the physicists.

For example, the monitoring of automated film processors is an essential function that must be performed on a daily basis. Some regulatory codes mandate the daily monitoring of film processors with sensitometry films. The sensitometry films are usually exposed, processed in each film processor, measured and plotted by a designated processor QC technician. For a facility with many film processors, the monitoring operations can require a significant expenditure of effort. Similarly, the Radiation Safety technicians may be involved with many assorted services from the distribution of radiation badge monitors to the disposal of radioactive waste from nuclear medicine and research laboratories. Other Radiation Safety operations involve monitoring of the proper use of radioactive materials and radiation producing facilities, licensure and various recordkeeping functions.

The number of physics support staff can be directly related to the number of FTE physicists. In this document, the recommendations for physics support staff are 1.5 FTE support staff per physicist. The physics support staff would be comprised of QC technologists, processor monitoring personnel, Radiation Safety technicians and other associated personnel.

In order to illustrate the application of the staffing recommendations given in Table 1 of this report, an example of a medium size diagnostic radiology facility is used. The equipment in this facility may be similar to that found in a 400-600 bed hospital. The facility in this example has 22 x-ray rooms, 1 CT scanner, 7 mobile x-ray units, 2 nuclear medicine imagers, 1 SPECT device and 4 ultrasound units. The equipment is categorized according to type in Table #2.

The recommended physics support for this facility is calculated based upon the number and type of radiology equipment contained in the facility. Based upon the recommendations, in this report, the facility* should employ 1.72 FTE physicists and 2.58 FTE support staff. The x-ray operations would require a full-time-physicist; and the nuclear medicine, ultrasound and radiation safety operations would require the services of a part-time physicist expending approximately 50%-70% effort.

In order to perform the various physics service for the facility in the example, the recommended staffing seems to be reasonable. The number is also consistent with a 1973 USHEW (FDA) recommendation that each hospital with more than 300 beds have a least one full-time professional medical physicist. (Appendix I, reference 11) The USHEW (FDA) recommendations were written before the implementation of considerable high technology equipment in diagnostic radiology facilities; and therefore, it represents a lower limit to estimating necessary physics support.

Table 2. The equipment of a facility and FTE physicists and support staff are summarized as follows:

<u>Equipment</u>	<u>FTE's per Equipment</u>	<u>Recommended FTE Physicists</u>
15 general x-ray rooms	0.015/room	0.225
4 RF rooms	0.05/room	0.20
3 special procedures rooms	0.08/room	0.24
2 digital systems	0.04/system	0.08
1 CT scanner	0.08/room	0.08
5 radiographic portable units	0.015/unit	0.075
2 portable fluoro-scopic units	0.03/unit	0.06
2 nuclear medicine imagers	0.10/unit	0.20
1 image processing computer	0.25/unit	0.25
1 SPECT unit	0.25/unit	0.25
4 ultrasound units	0.015/unit	0.06
Total.....		1.72

Practical Staffing: 2.0 FTE Physicists and 2.6 (1.5 x 1.75) FTE Support Staff

The facility could hire 1 full-time physicist in x-ray with an additional 72% part-time physicist in Nuclear Medicine, Ultrasound and Radiation Safety operations. In practical terms, 2 physicists are appropriate. The appropriate physics support staff is 2.6 FTE's.

V. Conclusions

Guidelines have been set for estimating the number of appropriate physics staff and their support personnel for a given facility. These recommendations use the type and amount of radiology equipment as an index to estimate the amount of physics support required. Even though some physics services are not directly related to the equipment, this method serves as a mechanism that can be unambiguously utilized to obtain a value for the amount of physics staff that should be provided in a given radiology facility.

This document recommends that the total number of full time equivalent physicists be determined separately from the support staff. In this way, both the values for the physicists and the support personnel can be appropriately determined.

In many instances, the numbers for staff size generated by use of Table 1 will contain fraction of personnel. The needs of the department can be fulfilled by hiring part-time equivalent individuals or consultant physics services to provide the necessary physics support. However, all radiologic facilities should have some support from a diagnostic radiological physicist to handle their diagnostic radiological physics needs. For small diagnostic radiology facilities in which less than one physicist is required, a physicist should be employed as a consultant or on a part-time basis in order to supervise the physics operations.

The data given in this report should enable administrators, departmental directors, radiologists, physicists, and other health care professionals to assess properly the diagnostic physics staffing requirements for their particular medical facility. The information should aid in the evaluation of the need for increased staff members required as new equipment is purchased or as the department expands. Following these guidelines will provide an institution with a competitively consistent high standard of diagnostic image quality, radiation safety and patient care necessary to meet the requirements of today's increasingly technologically complex radiology facilities.

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References on Physics Support in Diagnostic Radiology

1. Joint Commission on Accreditation of Healthcare Organizations
"Standard"
 - DR.2 There are policies and procedures to assure effective management, safety, proper performance of equipment, effective communications, and quality control in the diagnostic radiology department/service.*

Required Characteristics

- DR.2.1 Policies and procedures are developed in cooperation with the medical staff, administration, nursing services, and, as necessary, other clinical departments/ services, and are implemented.*
 - DR.2.1.1 The policies and procedures are reviewed periodically by a medical radiation physicist.
 - DR.2.1.2 The policies and procedures are revised when necessary.
 - DR.2.1.2.1 Each revision is documented.
- DR.2.2. The written policies and procedures include, but need not be limited to, the following:*
 - DR.2.2.7 A quality control program designed to minimize patient, personnel, and public risks and maximize the quality of diagnostic information;*
 - DR.2.2.9 Compliance with applicable law and regulation
 - DR.2.2.10 Provisions that a qualified physician, qualified medical radiation physicist, or other qualified individual*
 - DR.2.2.10.1 Monitors performance evaluations of diagnostic and treatment equipment at least annually;* and
 - DR.2.2.10.2 Monitors doses from diagnostic radiology procedures.*

DR.2.2.11 With respect to radiation hazards from equipment, adherence to the recommendations of any currently recognized and reliable authority on radiation hazards, such as the National Council on Radiation Protection and Measurements, and any requirements of appropriate licensing agencies or other government bodies:

DR.2.2.12 Guidelines for protecting personnel and patients from radiation.

DR.2.2.13 The monitoring of staff and personnel for exposure to radiation.

DR.2.2.14 Guidelines developed in consultation with infection control committee for the protection of staff, patients, and equipment;

DR.2.2.15 Orientation and a safety education program for all personnel.

* Indicates key factors in the accreditation decision process. From: Accreditation Manual for Hospital, Joint Commission on Accreditation of Healthcare Organizations, 1988.

2. Joint Commission on Accreditation of Healthcare Organizations
"Standard"

NM.2 There are policies and procedures to assure effective management, safety, proper performance of equipment, effective communication, and quality control in the nuclear medicine department/service.*

Required Characteristics

NM.2.1 Policies and procedures are developed in cooperation with the medical staff, administration, nursing services, and, as necessary, other clinical departments/ services, and are implemented.*

NM.2.1.1. The policies and procedures are reviewed periodically by a medical radiation physicist

NM.2.1.2 The policies and procedures are revised when necessary.

- NM.2.1.2.1 Each revision is documented.
- NM.2.2 The written policies and procedures include, but need not be limited to, the following:
 - NM.2.2.8 A quality control program designed to minimize patient, personnel, and public risk and maximize the quality of diagnostic information.*
 - NM.2.2.10 The maintenance of records on radionuclides and radiopharmaceuticals from the point of administration and final disposal;
 - NM.2.2.10.1 Information in the records includes, at least,
 - NM.2.2.10.1.1 The date, method of receipt, identity of radionuclide, activity, and disposal;
 - NM.2.2.10.1.2 Supplier and lot number
 - NM.2.2.10.1.3 Identity of recipient, identity of radionuclide, activity of radionuclide administered, and date
 - NM.2.2.11 Safety policies, including
 - NM.2.2.11.1 The receipt, storage, transport, preparation, handling, use, and disposal of radionuclides;* and
 - NM.2.2.11.2 Implementation of standard PL.6 through required characteristic PL.6.10 in the "Plant, Technology, and Safety Management" chapter of this Manual (for the management of hazardous materials).*
 - NM.2.2.12 Compliance with applicable law and regulation.
 - NM.2.2.13 For purposes of standardizing equipment performance, radiation standards having energies equivalent to those radionuclides used in patient studies.
 - NM.2.2.14 Provisions that a qualified physician, qualified medical radiation physicist, or other qualified individual*

NM.2.2.14.1 Monitors performance evaluations of diagnostic equipment on a quarterly basis;*

NM.2.2.14.2 Monitors doses administered to patients for acceptable agreement with prescribed doses;*

NM.2.2.14.3 Monitors, for validity, quantitative results obtained from procedures; and*

NM.2.2.14.4 Monitors absorbed doses of radiation in individual patients as requested by the director.*

NM.2.2.15 Guidelines for protecting personnel and patients from radiation.*

NM.2.2.16 The monitoring of staff and personnel for exposure to radiation.*

NM.2.2.17 The monitoring of receipt, storage, preparation, and use areas for radionuclide contamination.*

NM.2.2.18 Guidelines to be followed in the event of radionuclide contamination of the environment, patients, personnel, or equipment.

NM.2.2.19 Guidelines developed in consultation with the infection control committee for the protection of staff, patients, and equipment.

NM.2.2.20 Orientation and a safety education program for all personnel.*

* Indicates key factors in the accreditation decision process. From: Accreditation Manual for Hospitals, Joint Commission on Accreditation of Healthcare Organizations, 1988.

3. "Medical physicists should be responsible for the practical aspects of diagnostic radiology, including quality control. The medical physicist's teaching obligations should reflect this practical involvement. From Quality Assurance for Diagnostic Imaging Equipment, NCRP Report No. 99, 1988.
4. "Before x-ray equipment is put into regular use, complete radiation safety surveys shall be carried

out." From Radiation Protection for Medical and Allied Health Personnel, NCRP Report No. 48, 1976.

5. "All new installations and existing installations not previously surveyed shall have a Radiation Protection Survey performed by or under the direction of a qualified expert. From Structural Shielding Design and Evaluation for Medical Use of X-rays and Gamma Rays of Energies Up to 10 meV, NCRP Report No. 49, 1976.
6. "In larger radiation utilization programs, a qualified individual should be designated as the Radiation Safety Officer. ... Specialized education in health physics at the undergraduate or college level, combined with practical experience, is preferable." From Operational Radiation Safety Program, NCRP Report No. 59, 1978.
7. "An adequate diagnostic quality assurance (QA) program involves periodic checks of components in a diagnostic x-ray imaging system. The optimum QA program for any individual facility will depend on a number of factors which include, but may not necessarily be limited to, items such as the type of procedures performed, type of equipment utilized and patient workload. The program should be developed under the guidance and supervision of a medical physicist qualified in this area of expertise by education, training and experience." from Basic Quality Control in Diagnostic Radiology, American Association of Physicists in Medicine (AAPM) Report No. 4, 1978.
8. "Who needs a Radiological Physicist? Every facility with any of the following: x-ray generating equipment, nuclear medicine imaging equipment, ultrasound or MRI equipment, radioisotope laboratory, research utilizing radioactive materials, radiation therapy equipment, plans to acquire any of the above mentioned equipment, and/or education programs for radiology residents, medical students or radiological technologists." from The Radiological Physicist, American College of Radiology (ACR), 1985.
9. "... in the radiological field (diagnostic imaging, radiation oncology, nuclear medicine and radiation protection) there is an obvious need for a clinical medical physics service... Again, it is the position of the AAPM that it is high unlikely that optimal imaging (and therefore the best available medical care) can be provided by those imaging departments that do not provide for and use medical imaging services." from The Roles, Responsibilities and Status of the Clinical Medical Physicist, American Association of Physicists in Medicine (AAPM), 1985.

10. QA programs are recommended for all diagnostic radiology facilities and physicists (where available) should play a major role." from Burkhardt RL, Quality Assurance Programs for Diagnostic Radiology Facilities, HEW Publications (FDA) 80-8110, February 1980.
11. "Periodic measurements using appropriate, calibrated instruments should be conducted to determine facilities (radiation) exposure levels for the "standard patients." from Evaluation of Radiation Exposure from Diagnostic Radiology Examination - General Recommendations, USHHS Publications (FDA) 85-8246, August 1985.
12. "Recommendation: At least one full-time professional medical physicist is needed in each medical institution with more than 300 hospital beds." from Status and Future Manpower Needs of Physicists in Medicine in the United States, USHEW Publication (FDA) 74-8014, November 1973.
13. "Sixty hours of documented instruction in Magnetic resonance imaging physics, instrumentation and clinical apparatus are recommended." from MRI Guidelines, ACR Bulletin, Vol. 41, No. 10, October 1985.
14. "Suggested minimal acceptable training of Diagnostic Radiology Physicians with special competence in Nuclear Medicine:
 - a. Radiation Physics and Instrumentation-----100 hours
 - b. Radiation Protection ----- 30 hours
 - c. Mathematics pertaining to the use and ----- 20 hours
measurement of radioactivity
 - d. Radiation Biology ----- 20 hours
 - e. Radiopharmaceutical Chemistry ----- 30 hours

TOTAL 200 hours

For Diagnostic Radiology:

- a. Radiation Physics and Instrumentation-----110 hours
- b. Radiation Protection ----- 40 hours
- c. Mathematics pertaining to the use and ---- 25 hours
measurement of radioactivity
- d. Radiation Biology _____ 25 hours

from Federal Register, Vol. 47, No. 232, December 2, 1982.
(With a 3:1 ratio of preparation time to classroom hours,
the 200 hours of training would amount to 0.40 FTE
physicist.)

- 15. "Each facility shall establish a committee of individuals to be responsible for Radiation Safety and Quality Assurance for those departments within the facility which utilize x-rays for diagnostic purposes. ... the committee should be composed of a minimum of one Radiologist, the Chief Technologist, the QC technologist(s) and a Diagnostic Radiological Physicist and a member of the in-house x-ray service." The document then details the QC testing which is deemed necessary.
from Guide for Radiation Safety/Quality Assurance Programs, New York State Department of Health, Bureau of Environmental Radiation Protection, April 1985.
- 16. "A large facility (with 15 to 20 rooms) should have a full-time QC technologist and two or more full-time service engineers. A facility of this size should have a physicist working at least half-time and available at the facility 20 hours per week on a fixed schedule. In addition, the physicist should be available for consultation by telephone at all times.
from Gray JE, Winkler NT, Stears J and Frank ED:
Quality Control in Diagnostic Imaging, Aspen Publishers, Inc., Rockville, MD, 1983.
- 17. "The physicist, who is a member of the team responsible for choosing new equipment, provides advice on the performance characteristics of imaging systems and comments on the suitability of the equipment for proposed usage. ... Performance assessment deals with the relationship between dose and image quality for any particular imaging system and clinical application.
...Regular monitoring of equipment, including retake

and reject analysis, is necessary to ensure effective operation and image quality."

from The Role of the Medical Physicist in the Scientific and Technical Support of Diagnostic X-ray Services, Hospital Physicists' Association, London 1985.

18. "... The physicist should be responsible for evaluating performance characteristics of new diagnostic equipment... Physics instruction of diagnostic residents should be given by a physicist..."
from Nice CM and Bushon SC, The Diagnostic Radiologic Physicist, Radiology 109:225-226, October 1973.
19. "It is the position of the College that ABR Certified radiological physicists (or equivalent) be required (to provide Quality Control services to the hospital radiology departments) and that State safety inspections are conducted to indentify equipment deficiencies rather than to assist in improving health care quality."
from ACR Physics Report, American College of Radiology August 1, 1983.
20. "The new (JCAHO 1987) standards enhance the role of radiological physicists. The policies and procedures of the three radiology services must be reviewed periodically by a medical radiation physicist. The standards will also require periodic monitoring of performance evaluations of radiologic equipment. This will be done on an annual, quarterly and monthly basis, respectively for diagnostic, nuclear medicine and radiation oncology services: The monitoring will be handled by a qualified physician, medical radiation physicist or other qualified individual."
from ACR Bulletin, American College of Radiology, May 1986.

Appendix II

Quality Control Test Procedures

In this appendix, the Task Group lists a number of Quality Control tests which should be routinely conducted in Diagnostic Imaging Departments. The manner in which the QC tests are performed are not described since several publications (1-7) are devoted to this topic. Furthermore, a more comprehensive QC program may include a number of additional procedures which provide a more detailed assessment of the equipment. The QC procedures enumerated below are the basic tests that are essential to ensure proper and consistent operation of the diagnostic imaging equipment. Associated with QC tests is the necessity to document results so that trends may be traced and performance more closely evaluated. Since the many tests are very specific to certain types of equipment such as ultrasound units or MR scanners, the items discussed are limited to the certain x-ray equipment. The test procedures and an estimation of the frequency for the testing are given. Testing frequencies, however, are heavily dependent upon the type of equipment and its clinical usage; certain critical units may require checks on a monthly or quarterly basis. The goal of this section is to provide the reader of this document with an understanding of the extensive nature of typical QC programs which are normally performed under the supervision of a diagnostic radiological physicist.

A. Film Processor Monitoring

1. Essential test - Processor speed, contrast, base plus fog and developer temperature should be monitored on a daily basis for each processor. These tests could be conducted by a designated quality control technologist. In addition, artifacts on clinical films should be routinely noted and diagnosed by individual technologists or the technologist assigned to quality control films as they emerge from the processor.

B. Darkroom Fog

1. Essential tests - each darkroom should be checked for (sources of unsafe light) at least annually or anytime darkroom fog is suspected. This test could be conducted by a quality control technologist (or possibly a darkroom technologist).

C. Screen-Film Contact

1. Essential tests - new cassettes and/or screens should be checked for screen-film contact prior to acceptance. Cassettes already in use should be checked on an annual basis or whenever damaged screens or cassettes are suspected.

D. X-Ray Tube Checks

1. Essential tests - half-value layer and consistency checks should be conducted annually or after a new x-ray tube is installed. Focal spots should be measured periodically. In addition, the half-value layer should be checked after any service that requires that the collimator be removed from the x-ray tube.
2. Additional tests - checks of the x-ray tube protective circuitry should be thoroughly checked prior to acceptance of a new room and subsequently on an annual basis.

E. Collimator Checks

1. Essential tests - x-ray field/light field congruence, collimator accuracy, Bucky tray alignment and automatic collimator field size should be checked every 6 months, after collimator light changes and after any service that requires that the collimator be removed by the x-ray tube.
2. Additional tests - Bucky grid motions and alignment tests should be conducted on an annual basis.

F. Radiographic Generator Checks

1. Essential tests - exposure reproducibility, mA linearity, timer reproducibility and accuracy and kVp reproducibility and accuracy should be checked every 6 months or following any service to the x-ray generator.

G. Automatic Exposure Control (AEC) Checks

1. Essential tests - reproducibility, backup time, minimum exposure time, thickness compensation and kVp compensation should be evaluated following changes in intensifying screens and every 6 months.

H. Fluoroscopic Checks

1. Essential tests - fluoroscopic image size and beam limitation should be checked every 3 months. Maximum tabletop exposure rates (or maximum entrance exposure

rates for above table tubes) should be checked every 6 months. At the same time, "standard" entrance exposure rates should be checked using an appropriate phantom. High and low contrast resolution checks of the TV monitor, screen-film spots, photospots and cine should be conducted every 6 months. Other checks such as HVL, focal spot and AEC performance should be checked as outlined above.

2. Additional tests - grid alignment checks and qualitative tests of the automatic brightness control can be checked on an annual basis

I. Tomographic Checks

1. Essential tests - tomographic cut level, cut thickness, motion completeness and resolution, should be checked every 6 months. Other tests for radiographic generator, tubes and collimators should be conducted as specified above.
2. Additional tests - exposure angle accuracy and tomographic plane flatness can also be checked every 6 months.

J. Patient Entrance Skin Exposure

1. Essential tests - entrance skin exposures for several representative projections of a standard patient should be measured on each radiographic (and tomographic system) on an annual basis.

K. Computed Tomography

1. Essential test - CT number, noise and field uniformity should be checked via a water phantom daily. Patient dose levels should be measured annually.
2. Additional tests - contrast scale, high and low contrast resolutions and slice thickness accuracy and alignment should be checked on a weekly basis.

Many of the aforementioned tests should be conducted by QC technologists under the direction of a diagnostic radiological physicist. However, a diagnostic physicist should more actively participate in those tests which involve patient dosimetry, image quality evaluations, complex measurements and radiation safety issues.

References

1. Basic Quality Control in Diagnostic Radiology. AAPM Report, No. 4, New York, NY, November, 1977.
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4. Gray, JE: Photographic Quality Assurance in Diagnostic Radiology, Nuclear Medicine and Radiation Therapy, Vol. I and II. HEW Publications (FDA) 76-8043, June, 1976 and 77-8028, July, 1977.
5. Hendee, WR, and Rossi, RP: Quality Assurance for Radiographic X-ray Units and Associated Equipment. HEW Publications (FDA) 80-8094, October, 1979.
6. Hendee, WR and Rossi, RP: Quality Assurance for Fluoroscopic X-ray Units and Associated Equipment. HEW Publications (FDA) 80-8095, October, 1979.
7. Hendee, WR and Rossi, RP: Quality Assurance for Conventional Tomographic X-ray Units. HEW Publication (FDA) 80-8096, October, 1979.
8. McCrohan, JL, Showalts, CK, Burkhart, RL and Schuniam, FGD: The Status of Quality Assurance for Computed Tomography Systems. SPIE 419:145-156, 1983.
9. National Council on Radiation Protection and Measurements: Quality Assurance for Diagnostic Imaging Equipment. NCRP, Bethesda, MD, 1988.
10. Nickoloff, EL: X-ray Quality Control Programs in Encyclopedia of Medical Devices and Instrumentation. Webster, JG (ed): John Wiley and Sons, Inc. 1988, Vol. 4, pp. 2912-2929.