AAPM REPORT NO. 36

ESSENTIALS AND GUIDELINES FOR HOSPITAL BASED MEDICAL PHYSICS RESIDENCY TRAINING PROGRAMS

Published for the
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Essentials and Guidelines For Hospital Based Medical Physics Residency Training Programs

A Report of the
AAPM Presidential Ad Hoc Committee
on
The Clinical Training of Radiological Physicists

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Section I

INTRODUCTION

INTRODUCTION

In the fall of 1988, Faiz M. Khan, Ph.D., then President-Elect of the American Association of Physicists in Medicine, established the Presidential Ad Hoc Committee on the Clinical Training of Radiological Physicists for the following purposes:

1. To gather, summarize, and analyze data concerning professional issues which relate to the education and training of medical radiological physicists such as job responsibilities, manpower, and financial support.

and

2. To develop a detailed description of a hospital-based education and training program for medical radiological physicists which would include basic education requirements, course work, clinical training, and the necessary prerequisites for certification.

The Committee met formally three times: in New Orleans (October, 1988), in St. Louis (February, 1989), and in San Diego (June, 1989). Working groups developed the format and content of the material presented in this report, and draft copies were also sent to the Committee consultants for further review and comment. The resulting document thus represents the broad collective opinion of a group of experienced clinical medical physicists and physicians who are both practitioners and educators.

Several recent surveys and projections indicate that U.S. clinical medical physicists currently number about 1500, with two-thirds working exclusively or primarily in radiation oncology, and the remainder in diagnostic imaging and nuclear medicine. Although it is impossible to predict with any certainty the future impact of Federal, State, and local cost containment programs on health-care manpower expenditures, the employment picture for medical physicists has remained strong for many years. The demand for clinical medical physicists rose steadily during the past decade and seems to be accelerating. Whereas four years ago the AAPM Placement Service advertised fewer than 200 positions annually, nearly 300 positions were listed last year.

To meet this demand, 34 training programs throughout the country each year graduate approximately 100 medical physicists at the Masters, Doctorate, and Post-Doctorate level.[1] Most of these graduates enter immediately into medical physics employment but some delay entry for additional training or for other reasons.

Although every graduate medical education program for training physicians must meet certain standards as established by the Accreditation Council for Graduate Medical Education and the Residency Review Committee, the situation is dramatically different in medical physics. Of the 34 U.S. medical physics training programs, only five have been accredited by the AAPM Commission on Accreditation of Educational Programs. For the most part, training programs in medical physics are defined locally with no particular requirement to demonstrate to an independent accrediting organization adequacy of facilities, curriculum, or faculty.

Furthermore, many of the medical physics training programs, particularly those which are university-affiliated, concentrate on providing academic rather than clinical training. Only 69% of the Master's programs, 30% of the Doctora programs, and 37% of the Post-Doctoral programs surveyed in 1989 emphasize clinical training as contrasted with academic and research training.

The proposed residency programs are aimed at both educating and providing practical experience so that an individual would be ready to be examined for certification and practice in a hospital setting. They are conceptually different than the academic programs and post-doctoral fellowships where the aim is primarily research.

In regard to the entry educational requirements, a case can be made to exclusively require an M.S. or Ph.D. degree in Medical Physics. However, if this were to become a requirement at present, the number of available candidates would be much more limited. The requirement is therefore extended to all physical sciences, including medical physics. It must be realized that this report represents merely a first step; in the future, more stringent entry requirements could be stipulated if there are sufficient candidates for the residency programs.

Medical physicists act as consultants to radiologists who practice in various aspects of diagnosis, therapy, and nuclear medicine, and they also work directly with other physicians and health care professionals in developing and providing safe and accurate clinical care. Because of these patient-oriented responsibilities, the Ad-Hoc Committee strongly endorses the mandatory completion of an accredited two-year hospital-based residency for all medical physicists before they enter clinical practice.

The guidelines and essentials described in the following sections are intended to be used by Medical Physics Program Directors to create and maintain hospital-based clinical medical physics residency programs which conform to the model standards proposed by the Ad-Hoc Committee.

AAPM Placement Service data suggest that the demand for qualified medical physicists may far exceed the current rate of production. A significant contributing factor to this imbalance has been a chronic deficiency of financial resources specifically earmarked to support clinical medical physics training programs. The Ad-Hoc Committee urges the AAPM to assertively investigate mechanisms that will secure appropriate funding for the clinical training of medical physicists just as such support is now provided for radiation oncologists, diagnostic radiologists, and nuclear medicine physicians.

We anticipate that enactment of the recommendations made by the Ad Hoc Committee will encourage the development of a high quality clinical medical physics instructional environment on an nationwide basis and make an important contribution to the protection of the public health, safety, and welfare.

Reference

(1) Orton, C. “Medical Physics Training in the U.S.” Presented at the Sixth Annual Meeting of the American College of Medical Physics. June, 1989.

Section II

ESSENTIALS AND GUIDELINES FOR RADIATION ONCOLOGY PHYSICS RESIDENCY TRAINING PROGRAMS

ESSENTIALS AND GUIDELINES FOR RADIATION ONCOLOGY PHYSICS RESIDENCY TRAINING PROGRAMS

INTRODUCTION

Radiation Oncology Physics is that branch of medical physics related to the management of patients with cancer and related diseases with special emphasis on:

1. calibration of therapy equipment
2. calculation and measurement of dose
3. computer dose planning
4. physical treatment planning
5. design and fabrication of treatment aids
6. quality assurance
7. training of physicists, clinical radiation oncology residents, dosimetrists, therapy technologists, and other allied health professionals in radiation oncology
8. education of health professionals and the public in radiation oncology physics and radiation effects
9. clinical and laboratory research in radiation oncology physics
10. additional duties as listed in Appendix IA

OBJECT OF A PHYSICS RESIDENCY TRAINING PROGRAM

The object of the residency training program is to educate and train physicists in the practice of radiation oncology physics. To accomplish this goal, adequate structure, facilities, staff, patient resources and educational environment must be provided.

STRUCTURE AND CONDUCT OF PHYSICS RESIDENCY PROGRAM

Length of training

A minimum post-graduate (M.S. or Ph.D.) education of 2 years is required. The first year must provide a broad experience in clinical radiation oncology physics. The purpose of the first year is to provide the physicist with the capability of managing, either alone or with others, the broad range of clinical physics problems of patients under a radiation oncologist's care.

This experience must be obtained in clinical service for a period of not less than 11 months in the first year. A minimum of one additional year shall b spent in the radiation oncology physics program. At least six months dedicated to “practicals" designed to develop competency in those areas listed in Appendix IA is required.

During these 2 years, not less than 22 months must be spent in clinical radiation oncology. No more than 3 months may occur in rotations to affiliated institutions outside the single institution in which the program resides, or outside of those participating institutions united to form an integrated program.

Program director

The program director (1) must be certified in Radiation Oncology Physics by an appropriate certifying board; (2) must be a full-time staff member, qualified in and practicing radiation oncology physics; (3) must contribute sufficient time to the program to insure adequate direction; (4) is responsible for the total training in radiation oncology physics, which includes the instruction and supervision of physics residents; (5) must arrange for the provision of adequate facilities, teaching staff, clinical resources and educational resources; and (6) is responsible for the selection of physics residents and must insure that the appointed residents meet the eligibility requirements listed in Appendix IIA.

Staff

The program must provide adequate staff for the teaching of clinical radiation oncology physics, clinical radiation oncology and radiation biology. The teaching staff must be qualified in those areas in which they are assigned to instruct and supervise physics residents, and staff members must have a real interest in teaching and devote the necessary time and effort to the educational program. The staff should be engaged in scholarly activities such as (1) participation in regional and national scientific societies; (2) participation in their own continuing education; (3) scientific publication and presentation; and (4) active involvement in radiation oncology physics research. Clear documentation of an adequate faculty commitment to the physics residency training program is essential.

An adequate staff must include at least the following:

1. Two full time radiation oncology physicists, both certified by an appropriate certifying board.
2. A full time radiation oncologist certified by the American Board of Radiology or its equivalent.
3. Accessibility to a full time radiation biologist .

Training content

The clinical physics training staff must provide for progressive supervised resident responsibility for patient care and must insure that the physics resident personally performs those clinical physics procedures commonly accepted in all aspects of radiation oncology. Training must encompass the sciences essential to radiation oncology physics including radiation physics, clinical radiation oncology with special emphasis on anatomy, neoplasia, and radiation effects, and radiation biology (See Appendices IIIA-VA). The training curriculum will identify the manner in which those basic sciences will be taught. The content must include those topics outlined in the appendices. The training must include a systematic course of instruction with demonstrations on clinical and technical subjects pertinent to the various phases of radiation oncology physics including interstitial and intracavitary radiation, unsealed radioactive sources, superficial irradiation and/or orthovoltage irradiation, megavoltage irradiation (both with low energy and high energy ($\geq$10 MV)), electron beam therapy, simulation, computerized dose planning, physical and treatment planning, construction of treatment aids, the calibration and monitoring of radiation therapy equipment, and radiation safety procedures. Trainees must obtain an in depth knowledge in the clinical physics areas listed in Appendix IA.

A detailed list of clinical physics procedures performed by the resident must be kept by the resident. This will be periodically reviewed by the program director, and submitted as required to the certifying board.

Training complement

The complement of residents in the training program must be commensurate with the total capacity of the program to offer an adequate educational experience in radiation oncology physics. There should be a minimum of two positions. The maximum number of residents in the 24 months of clinical radiation oncology must not exceed the number of full-time equivalent staff radiation oncology physicists by more than a ratio of 1.5 to 1, excluding those residents and staff who are off service.

Training evaluation

The program director is responsible for the continuing evaluation of the program and documentation of the educational progress and performance of each physics resident. Resident performance and progress must be documented at least twice yearly using appropriate techniques such as written staff appraisal, oral or written tests, or practical demonstrations. The results of these evaluations must be discussed with the resident.

It is the program director's responsibility to document adequately any prior training from another institution that is to be used to meet any future training criteria of the appropriate certifying board.

It is the program director's responsibility to counsel, censure, and after due process to dismiss residents who fail to demonstrate appropriate industry, competence, responsibility, learning abilities, and ethics.

Facilities

Space adequate for the conduct of a good clinical physics practice and training program must be available.

There must be: (1) two or more megavoltage machines. It is desirable to have superficial, orthovoltage x-ray and multiple energy electron beam machines. If not, the program must provide clinical training on such equipment at another approved institution; (2) a dedicated therapy simulator; (3) required equipment to do interstitial and intracavitary brachytherapy procedures; (4) equipment for computer treatment planning and construction of special treatment aids; and (5) a physics laboratory and (6) availability of electronics and machine shops.

Clinical resources

The training program in radiation oncology physics must provide a sufficient volume and variety of cancer patients for adequate resident experience. The number of new patients treated per year should be at least 500.

Institutional support

The institution sponsoring the program of clinical training in radiation oncology physics should provide administrative support in terms of budget, space, clinical and educational resources.

Educational environment

The clinical training in radiation oncology physics must occur in an environment that encourages exchange of knowledge and experience among physics residents in the program and with clinical residents located in the same institution participating in the program.

Conferences

Conferences and teaching rounds must provide for progressive resident participation. Adequate frequency of conferences and attendance by physics residents, radiation oncology physicists, radiation oncologists and other staff should be documented. Adequate conference room and audio-visual facilities must be provided.
There must be intra-departmental clinical oncology conferences including new patient conferences, weekly chart reviews and problem case conferences, and physics/dosimetry conferences; other conferences should include morbidity and mortality; radiation biology; and journal review.

Library resources

A sufficient variety of journals, reference books, and resource materials pertinent to radiation oncology physics and associated fields in oncology and basic sciences should be provided and must be immediately accessible for resident study. In addition, physics residents must have access to a general medical library.

ESSENTIALS AND GUIDELINES FOR DIAGNOSTIC IMAGING PHYSICS RESIDENCY TRAINING PROGRAMS

INTRODUCTION

Diagnostic Imaging Physics is that branch of medical physics related to the medical diagnosis of patients with special emphasis on:

1. calibration of imaging equipment
2. calculation and measurement of exposure and dose
3. improving and maintaining medical image quality
4. training of physicists, clinical diagnostic imaging residents, radiologic and ultrasound technologists, and other allied health professionals in diagnostic radiology
5. education of health professionals and the public in diagnostic imaging physics and radiation effects
6. clinical and laboratory research in diagnostic imaging physics
7. additional duties as listed in Appendix IB

OBJECT OF A PHYSICS RESIDENCY TRAINING PROGRAM

The object of the residency training program is to educate and train physicists in the practice of diagnostic imaging physics. To accomplish this goal, adequate structure, facilities, staff, patient resources and educational environment must be provided.

STRUCTURE AND CONDUCT OF PHYSICS RESIDENCY PROGRAM

Length of training.

A minimum post-graduate (M.S. or Ph.D.) education of 2 years is required. The first year must provide a broad experience in clinical diagnostic imaging physics. The purpose of the first year is to provide the physicist with the capability of managing, either alone or with others, the broad range of imaging physics problems of patients referred to a diagnostic radiologist. This experience must be obtained in clinical service for a period of not less than 11 months in the first year. A minimum of one additional year shall be spent in the diagnostic imaging physics program. At least six months dedicated to “practicals” designed to develop competency in those areas listed in Appendix IB is required.

During these 2 years, not less than 22 months must be spent in clinical diagnostic imaging. No more than 3 months may occur in rotations to affiliated institutions outside the single institution in which the program resides, or outside of those participating institutions united to form an integrated program.

Program director

The program director (1) must be certified in Diagnostic Imaging Physics by an appropriate certifying board; (2) must be a full-time staff member qualified in and practicing diagnostic imaging physics; (3) must contribute sufficient time to the program to insure adequate direction; (4) is responsible for the total training in diagnostic imaging physics, which includes the instruction and supervision of physics residents; (5) must arrange for the provision of adequate facilities, teaching staff, clinical resources and educational resources; and (6) is responsible for the selection of physics residents and must insure that the appointed residents meet the eligibility requirements listed in Appendix IIB.

Staff

The program must provide adequate staff for the teaching of diagnostic imaging physics, clinical diagnostic imaging and radiation biology. The teaching staff must be qualified in those areas in which they are assigned to instruct and supervise physics residents, and staff members must have a real interest in teaching and devote the necessary time and effort to the educational program. The staff must be engaged in scholarly activities such as (1) participation in regional and national scientific societies; (2) participation in their own continuing education; (3) scientific publication and presentation; and (4) active involvement in diagnostic imaging physics research. Clear documentation of an adequate faculty commitment to the physics residency training program is essential.

An adequate staff must include at least the following:

1. Two full time diagnostic imaging physicists, both certified by an appropriate certifying board.
2. A full time diagnostic radiologist certified by the American Board of Radiology or its equivalent.
3. Accessibility to a full time radiation biologist.

Training content

The clinical physics training staff must provide for progressive supervised resident responsibility for patient care and must insure that the physics resident personally performs those clinical physics procedures commonly accepted in all aspects of diagnostic imaging. Training must encompass the sciences essential to diagnostic imaging physics including radiation physics, clinical diagnostic imaging with special emphasis on anatomy, and radiation effects, and radiation biology. (See Appendices IIIB-VB.) The training curriculum will identify the manner in which those basic sciences will be taught. The content must include those topics outlined in the appendices. The training must include a systematic course of instruction with demonstrations on clinical and technical subjects pertinent to the various phases of diagnostic imaging physics including the principles and procedures involved in the production of clinical diagnostic images, methods of image evaluation, techniques for optimization of radiation exposure for diagnostic examination, methods of calculating specific organ doses and risk estimations, the calibration and monitoring of diagnostic imaging equipment, and radiation safety procedures. Trainees must obtain an in depth knowledge in the clinical physics areas listed in Appendix IB.

A detailed list of clinical physics procedures performed by the resident must be kept by the resident. This will be periodically reviewed by the program director, and submitted as required to the certifying board.

Training complement

The complement of residents in the training program must be commensurate with the total capacity of the program to offer an adequate educational experience in diagnostic imaging physics. There should be a minimum of two positions. The maximum number of residents in the 24 months of clinical diagnostic imaging must not exceed the number of full-time equivalent staff diagnostic imaging physicists by a ratio of 1.5 to 1, excluding those residents and staff who are off service.

Training evaluation

The program director is responsible for the continuing evaluation of the program and documentation of the educational progress and performance of each physics resident. Resident performance and progress must be documented at least twice yearly using appropriate techniques such as written staff appraisal, oral or written tests, or practical demonstrations. The results of these evaluations must be discussed with the resident.

It is the program director's responsibility to document adequately any prior training from another institution that is to be used to meet any future training criteria of the appropriate certifying board.

It is the program director's responsibility to counsel, censure, and after due process to dismiss residents who fail to demonstrate appropriate industry, competence, responsibility, learning abilities, and ethics.

Facilities

Space adequate for the conduct of a good clinical physics practice and training program must be available.

There must be: (1) radiographic/fluoroscopic systems for general radiography, mammography, cardiac catheterization, and special procedures: (2) a computed tomography scanner; (3) a magnetic resonance imaging scanner; (4) an ultrasound imager; (5) a digital imaging system; (6) a physics laboratory; and (7) availability of electronics and machine shops. If not, the program must provide clinical training on such equipment at another approved institution.

Clinical resources

The training program in diagnostic imaging physics must provide a sufficient volume and variety of patients for adequate resident experience. The number of diagnostic imaging examinations per year must be at least 100,000.

institutional support

The institution sponsoring the program of clinical training in diagnostic imaging physics should provide administrative support in terms of budget, space, clinical and educational resources.

Educational environment

The clinical training in diagnostic imaging physics must occur in an environment that encourages exchange of knowledge and experience among physics residents in the program and with clinical residents located in the same institution participating in the program.

Conferences

Conferences and teaching rounds must provide for progressive resident participation. Adequate frequency of conferences and attendance by physics residents, diagnostic imaging physicists, diagnostic radiologists and other staff should be documented. Adequate conference room and audio-visual facilities must be provided.

There must be intra-departmental clinical conferences including staff radiology conferences, and interesting case conferences, and physics conferences; other conferences should include radiation safety, radiation biology, and journal review.

Library Resources

A sufficient variety of journals, reference books, and resource materials pertinent to diagnostic imaging physics and associated fields in diagnostic radiology and basic sciences should be provided and must be immediately accessible for resident study. In addition, physics residents must have access to a general medical library.

ESSENTIALS AND GUIDELINES FOR NUCLEAR MEDICINE PHYSICS RESIDENCY TRAINING PROGRAMS

INTRODUCTION

Nuclear Medicine Physics is that branch of medical physics related to the diagnostic, therapeutic and investigational use of radionuclides with special emphasis on:

1. specification, acceptance testing and calibration of nuclear medicine equipment
2. calculation and measurement of dose
3. quality assurance and radiation safety
4. training of physicists, clinical nuclear medicine residents, nuclear medicine technologists, and other allied health professionals in nuclear medicine
5. education of health professionals and the public in nuclear medicine physics and radiation effects
6. clinical and laboratory research in nuclear medicine physics
7. additional duties as listed in Appendix IC, Section VII

OBJECT OF A PHYSICS RESIDENCY TRAINING PROGRAM

The object of the residency training program is to educate and train physicists in the practice of nuclear medicine physics. To accomplish this goal, adequate structure, facilities, staff, patient resources and educational environment must be provided.

STRUCTURE AND CONDUCT OF PHYSICS RESIDENCY PROGRAM

Length of training.

A minimum post-graduate (M.S. or Ph.D.) education of 2 years is required. The first year must provide a broad experience in clinical nuclear medicine physics. The purpose of the first year is to provide the physicist with the capability of managing, either alone or with others, the broad range of clinical physics problems of patients under a nuclear medicine physician's care. This experience must be obtained in clinical service for a period of not less than 11 months in the first year. A minimum of one additional year shall be spent in the nuclear medicine physics program. At least six months

dedicated to “practicals" designed to develop competency in those areas listed in Appendix IC is required.

During these 2 years, not less than 22 months must be spent in clinical nuclear medicine. No more than 3 months may occur in rotations to affiliated institutions outside the single institution in which the program resides, or outside of those participating institutions united to form an integrated program.

Program director

The program director (1) must be certified in Nuclear Medicine Physics by an appropriate certifying board; (2) must be a full-time staff member qualified in and practicing nuclear medicine physics; (3) must contribute sufficient time to the program to insure adequate direction; (4) is responsible for the total training in nuclear medicine physics, which includes the instruction and supervision of physics residents; (5) must arrange for the provision of adequate facilities, teaching staff, clinical resources and educational resources; and (6) is responsible for the selection of physics residents and must insure that the appointed residents meet the eligibility requirements listed in Appendix IIC.

Staff

The program must provide adequate staff for the teaching of clinical nuclear medicine physics, clinical nuclear medicine and radiation biology. The teaching staff must be qualified in those areas in which they are assigned to instruct and supervise physics residents, and staff members must have a real interest in teaching and devote the necessary time and effort to the educational program. The staff must be engaged in scholarly activities such as 1) participation in regional and national scientific societies; 2) participation in their own continuing education; 3) scientific publication and presentation; and 4) active involvement in nuclear medicine physics research. Clear documentation of an adequate faculty commitment to the physics residency training program is essential. A staff that does not exhibit such characteristics will cause grave concern to the accretiting authorities as to its adequacy and suitability for conducting a program of graduate education in nuclear medicine physics.

An adequate staff must include at least the following:

1. One full time nuclear medicine physicist, certified by an appropriate certifying board.
2. A full time nuclear medicine physician certified by the appropriate certifying board.
3. Accessibility to a radiation pharmacist.
4. Accessibility to a full time radiation biologist.

Training content

The clinical physics training staff must provide for progressive supervised resident responsibility for patient care and must insure that the physics resident personally performs those clinical physics procedures commonly accepted in all aspects of nuclear medicine. Training must encompass the sciences essential to nuclear medicine physics including radiation physics, clinical nuclear medicine with special emphasis on anatomy and radiation effects, and radiation biology. (See Appendices IIIC-VC.) The training curriculum will identify the manner in which those basic sciences will be taught. The content must include those topics outlined in the appendices. The training must include a systematic course of instruction with demonstrations on clinical and technical subjects pertinent to the various phases of nuclear medicine physics including the calibration and monitoring of nuclear medicine equipment, assay of radiopharmaceuticals, computer applications and radiation safety procedures. Trainees must obtain an in depth knowledge in the clinical physics areas listed in Appendix IC.

A detailed list of clinical physics procedures performed by the resident must be kept by the resident. This will be periodically reviewed by the program director, and submitted as required to the certifying board.

Training complement

The complement of residents in the training program must be commensurate with the total capacity of the program to offer an adequate educational experience in nuclear medicine physics. There should be a minimum of two positions. The maximum number of residents in the 24 months of clinical nuclear medicine must not exceed the number of full-time equivalent staff nuclear medicine physicists by more than a ratio of 2 to 1, excluding those residents and staff who are off service.

Training evaluation

The program director is responsible for the continuing evaluation of the program and documentation of the educational progress and performance of each physics resident. Resident performance and progress must be documented at least twice yearly using appropriate techniques such as written staff appraisal, oral or written tests, or practical demonstrations. The results of these evaluations must be discussed with the resident.

It is the program director's responsibility to document adequately any prior training from another institution that is to be used to meet any future training criteria of the appropriate certifying board.

It is the program director's responsibility to counsel, censure, and after due process to dismiss residents who fail to demonstrate appropriate industry, competence, responsibility, learning abilities, and ethics.

Facilities

Space adequate for the conduct of a good clinical physics practice and training program must be available.

There must be: (1) two or more gamma cameras: (2) a SPECT unit; (3) computer for image analysis; (4) nuclear medicine dose calibration instrumentation; (5) a physics laboratory; and (6) availability of electronics and machine shops. If not, the program must provide clinical training on such equipment at another approved institution.

Clinical resources

The training program in nuclear medicine physics must provide a sufficient volume and variety of patients for adequate resident experience. The number of nuclear medicine procedures administered per year must be at least 3000 procedures.

Institutional support

The institution sponsoring the program of clinical training in nuclear medicine physics should provide administrative support in terms of budget, space, clinical, and educational resources.

Educational environment

The clinical training in nuclear medicine physics must occur in an environment that encourages exchange of knowledge and experience among physics residents in the program and with clinical residents located in the same institution participating in the program.

Conferences

Conferences and teaching rounds must provide for progressive resident participation. Adequate frequency of conferences and attendance by physics residents, nuclear medicine physicists, nuclear medicine physicians and other staff should be documented. Adequate conference room and audio-visual facilities must be provided.

There must be intra-departmental clinical conferences including new patient conferences, problem case conferences, and physics conferences; other conferences should include radiation safety, radiation biology, and journal review.

Library resources

A sufficient variety of journals, reference books, and resource materials pertinent to nuclear medicine physics and associated fields in medicine, oncology, and basic sciences should be provided and must be immediately accessible for resident study. In addition, physics residents must have access to a general medical library.

Section III

STIPENDS AND BENEFITS FOR MEDICAL PHYSICS RESIDENTS

STIPENDS AND BENEFITS FOR MEDICAL PHYSICS RESIDENTS

STIPENDS

Stipends and benefits provided to Medical Physics Residents and their dependents should be comparable to those provided to medical house staff. A profile summary of nationwide medical house staff stipends for 1988-89 is presented in Table 1.[1] These data can be used as a guideline for establishing stipend ranges for Medical Physics Residency programs, but should be updated annually and adjusted appropriately to reflect local situations.

Table

U.S. Hospital Residency Stipends
(1988-89)

Year of Training	25th Percentile	Mean	75th Percentile
1st Year	$21,960	$23,607	$24,800
2nd Year	$23,147	$25,126	$26,405

FRINGE BENEFITS

In addition to the base salary stipend, fringe benefits provided might include health benefits, housing, meals, leave time for vacation and educational seminars, and other benefits. It should be expected that the cost of fringe benefits will equal about 20-35 percent of basic stipend costs.

Section IV

APPENDICES

SOURCES OF FUNDING

Possible sources of funding for the Medical Physics Residency Program include:

1) Patient revenues and general operating appropriations
2) State appropriations earmarked for residency expenses
3) Municipal appropriations earmarked for residency expenses
4) Veterans Administration appropriations
5) Physician fee revenue
6) Medical School/University funds
7) NIH
8) Other Federal agencies
9) Endowment income
10) Industry/commercial grants
11) Foundation grants, voluntary agencies

Reference

1. Zimmerman, SC. and Bigelow, J.S. COTH Survey of Housestaff Stipends, Benefits and Funding. Association of American Medical Colleges, Washington, D.C., 1988.

Appendix I

Expected Areas of Competence for a Clinical Medical Physicist

Appendix IA - Radiation Oncology

Appendix IB - Diagnostic Imaging

Appendix IC - Nuclear Medicine

Note: The areas of competence outlined in Appendix I indite those activities and areas of expertise which would generally be expected of a practicing clinical medical physicist. It is not required that the physics residency program offer formal training in all of the competencies listed under Additional Duties, but Program Directors should ensure that their residents have some exposure to these topics during the training period.

APPENDIX IA

Expected Areas of Competence for a Clinical Medical Physicist in Radiation Oncology

APPENDIX IA: Expected Areas of Competence for a Clinical Physicist in Radiation Oncology

I. TREATMENT EQUIPMENT - Megavoltage photons (linear accelerators and cobalt-60 units) and electrons, orthovoltage, and/or superficial x-rays.

A. Selection

1. Performance specification
2. Feature comparison
3. Mechanical/architectural considerations
4. Performance test design

B. Protection

1. Room Design
2. Licensing (NRC and/or state)
3. Construction supervision
4. Survey (> 10MV desirable)

C. Acceptance/Commissioning

1. Mechanical, safety, and radiation
2. Treatment planning data

D. Calibration

1. Instrumentation
2. Photons
3. Electrons

E. Quality Assurance

1. Daily and/or weekly
2. Biweekly to monthly
3. Semi-annual to annual

II. SIMULATOR

A. Selection

B. Protection/Design/Architectural

1. Walls/Ceiling/Floor
2. Control area
3. Darkroom

C. Acceptance Testing

D. Quality Assurance

1. Mechanical/radiation
2. X-ray/fluoroscopic
3. Processor

E. Radiographic Techniques

III. RADIATION PROTECTION (GENERAL)

A. Regulations/Recommendations/Licensing

1. National/State/Local
2. NRC
3. ALARA
4. JCAHO
5. Radiation safety committee

B. Survey meter

1. Calibration
2. Quality assurance (constancy)

C. Monitoring

1. TLD
2. Film badges
3. Pen dosimeters

D. Guidelines/Instructions for Personnel

1. Residents
2. Medical students
3. Technology students
4. Hospital, medical and nursing staff
5. Maintenance, custodial staff

E. Hazards of Low Levels of Radiation

IV. PATIENT TREATMENTS

A. Clinical Support

1. Site specific information
2. Tumor localization/contours
3. Immobilization
4. Custom blocking
5. Port film techniques
6. Bolus
7. Fetal dose

B. Quality Assurance

1. Chart checks
2. Monitor unit calculation rechecks
3. Patient positioning
4. Portal imaging
5. Tissue compensators
6. Monitor unit calculators

C. Monitor Unit Calculations

1. SSD (%DD)
2. SAD (TPR/TMR/TAR)
3. Extended SSD
4. Off-axis points
5. Inhomogeneities
6. Tissue compensation
7. Asymmetric collimation

D. Special Techniques

1. Total body photon irradiation (TBI)
2. Total skin electrons (TSE)
3. Intraoperative (electrons)
4. Small field (radiosurgery)
5. Electron arc
6. Tissue compensation
7. Bolus

E. Computerized Isodose Generation

1. Data acquisition
2. Acceptance testing
3. Quality assurance
4. Computer algorithms (models)
5. Treatment techniques
6. Normalization
7. Inhomogeneity corrections

F. In-vivo Dosimetry

1. TLD
2. Diodes

V. BRACHYTHERAPY

A. Radionuclides

1. Sealed sources
2. Unsealed sources

B. Sealed sources

1. Form/construction
2. Activities
3. Protection/storage/handling
4, Standardization/calibration
5. Activity check
6. Leak checks
7. Licensing
8. Most appropriate survey instrument

C. Radiation Protection

1. Shielding design
2. Surveys
3. Badging hospital personnel
4. Shipping
5. Radioactive patients

D. Clinical Applications

1. Radionuclide selection
2. Applicator choice
3. Activity considerations
4. Protection
5. Procedure requirements

E. Treatment Planning

1. Spacings
2. Activities
3. Dose rates
4. Source localization
5. Computerized planning

F. Quality Assurance

VI. ADDITIONAL DUTIES

A. Educational

1. Teaching
2. Extramural lectures

B. Developmental Studies

1. Treatment techniques
2. Treatment aids
3. Computational techniques
4. Dosimetric techniques
5. Equipment performance evaluation

C. Administrative

1. Personnel management
2. Budgeting
3. Continuing education
4. Department/institutional service
5. National obligations
6. Planning
7. Coordination of programs

D. Research

1. Define needs/interests/programs
2. Formulate/prioritize efforts
3. Formulate programs
4. Obtain support
5. Organize/supervise programs/target points
6. Seek continuance/terminate when appropriate

APPENDIX IB

Expected Areas of Competence for a Clinical Medical Physicist in Diagnostic Imaging

Appendix IB: Expected Areas of Competence for a Clinical Medical Physicist In Diagnostic Imaging

I. IMAGING SYSTEMS - Radiographic, fluoroscopic, special procedures, conventionaltomographic mammographic, CT, ultrasound, and MRI.

A. Design and Fundamentals

B. Selection

1. Performance specification
2. Feature comparison
3. Siting issues
4. Performance test design

C. Acceptance Testing/Calibration

1. Mechanical
2. Radiation output
3. Shielding adequacy
4. Baseline performance measurements
5. Imaging techniques
6. Quantitative evaluation

D. Quality Control

1. Imaging equipment
2. Film processors
3. Video/laser multi-image format cameras
4. Film densitometer
5. Computer equipment
6. Image transmission devices
7. Quantitative procedures

II. COMPUTER SYSTEMS

A. Hardware and operation

B. Software

C. Acceptance testing

D. Interfacing/Peripherals

E. Image transmission devices

F. Clinical applications

III. RADIATION PROTECTION

A. Shielding Design

B. Survey

1. X-ray
2. Radiofrequency

C. Regulations/Recommendations

1. National/State/Local
2. ALARA
3. JCAHO
4. Radiation Safety Committee

D. Monitoring

1. TLD
2. Film badges
3. Pen dosimeters

E. Guidelines/Instructions for Personnel

1. Residents
2. Medical students
3. Technology students
4. Hospital, medical and nursing staff
5. Maintenance, custodial staff

F. Hazards of Low Levels of Radiation

G. Anatomical Awareness (e.g. gonadal shielding)

IV. DOSIMETRY

A. Techniques (Design/Calibration/Uses)

1. Ion chamber
2. TLD
3. Film

B. Patient Dose Values

1. Sensitive tissues
2. Assessment of doses (risk analysis)

V. ADDITIONAL DUTIES

A. Educational

1. Teaching
2. Extramural lectures

B. Developmental Studies

1. Imaging techniques
2. Dose reduction
3. Computational techniques
4. Dosimetric techniques
5. Equipment performance evaluation
6. Evaluation of system upgrades

C. Administrative

1. Personnel management
2. Budgeting
3. Continuing education
4. Departmental/institutional service
5. National obligations
6. Planning
7. Coordination of programs

D. Research

1. **Define needs/interests/programs**
2. **Formulate/prioritize efforts**
3. **Formulate programs**
4. **Obtain support**
5. **Organize/supervise programs/target points**
6. **Seek continuance/terminate when appropriate**

APPENDIX IC

Expected Areas of Competence for a Clinical Medical Physicist in Nuclear Medicine

Appendix IC: Expected Areas of Competence for a Clinical Medical Physicist In Nuclear Medicine

I. EQUIPMENT - Rectilinear scanners, gamma cameras, uptake study equipment, well-type gamma scintillation counters, liquid scintillation counter, tomographic cameras, SPECT and PET systems (optional), computer analysis systems, multi-image format cameras and film processors.

A. Selection

1. Performance specification
2. Feature comparison
3. Mechanical/architectural considerations
4. Performance test design

B. Acceptance Testing

1. Mechanical/safety
2. Baseline performance measurements
3. Imaging techniques
4. Quantitative evaluations

C. Quality Assurance

1. Daily
2. Weekly to monthly
3. Semi- to annually

D. Calibration

1. Scintillation counters
2. Multichannel analyzers
3. Survey meters
4. Gamma cameras (SPECT, PET)
5. Sealed sources
6. Dose calibrators

E. Computer Systems

1. Hardware operations
2. Software
3. Quality assurance
4. Peripheral connections/operations
5. Image transmission devices
6. Clinical applications

II. Radiation Safety

A. Radiation Control

1. Area surveys
2. Surface wipes
3. Receipt
4. Disposal

B. Protection

1. Patient
2. Personnel
3. Darkrooms

C. Radiation Incidents

1. Decontamination
2. Misadministrations

D. Therapeutic Procedures

E. Regulations/Recommendations

1. National/State/Local
2. ALARA
3. JCAHO
4. Radiation Safety Off ice
5. Radioactive Materials License

F. Monitoring

1. TLD
2. Film badges
3. Pen dosimeters

G. Guidelines/instructions for Personnel

1. Residents
2. Medical students
3. Technology students
4. Hospital, medical and nursing staff
5. Maintenance, custodial staff

H. Hazards of Low Levels of Radiation

III. ROOM DESIGN

A. Air exhaust

B. Hot laboratory

C. materials storage

D. Darkroom

E. Safety features

IV. PATIENT DOSIMETRY

A. Internal organ dose calculations

B. Therapeutic procedures

V. RADIOPHARMACY

A. Kit preparation

B. Quality control

C. Activity assay

VI. CLINICAL STUDIES

A. Anatomy/Function

B. Isotope/Activity

C. Organ Dosages

D. Computer Analysis/Techniques

E. Improvements

1. Existing studies
2. New studies

VII. ADDITIONAL DUTIES

A. Educational

I. Teaching
2. Extramural lectures

B. Developmental Studies

1. Treatment techniques
2. Treatment aids
3. Computational techniques
4. Dosimetric techniques
5. Equipment performance evaluation

C. Administrative

1. Personnel management
2. Budgeting
3. Continuing education
4. Departmental/institutional service
5. National obligations
6. Planning
7. Coordination of programs

D. Research

1. Define needs/interests/programs
2. Fomulate/prioritize efforts
3. Formulate programs
4. Obtain support
5. Organize/supervise programs/target points
6. Seek continuance/terminate when appropriate

Appendix II

Education Requirements for Medical Physics Residents

Note: The education requirements outlined in Appendix II should be considered a minimum prerequisite for acceptance into a Medical Physics residency program. Candidates who have not had formal coursework in these areas should take appropriate courses during the residency training period to correct any deficiencies

Appendix II: Education requirements for medical physics residents

I. DEGREE

A. M.S. or Ph.D. in

1. Medical Physics from an approved institution, preferably from an AAPM accredited program, or

2. Physics, or a closely related discipline.

II. Curriculum

The applicant's undergraduate and graduate education should demonstrate knowledge acquired in the following areas:

A. Fundamental Physics
B. Advanced Mathematics
C. Advanced Atomic and Nuclear Physics
D. Electronics
E. Computers
F. Physical Chemistry

III. Background Knowledge

Graduates of programs in Medical Physics should have demonstrated knowledge in topics considered to be minimal by AAPM guidelines for M.S. in Medical Physics Academic Programs, which includes knowledge in the following areas:

A. Radiation Physics
B. Radiation Dosimetry
C. Radiation Measurement Techniques and Instrumentation
D. Radiation Protection
E. Principles of Imaging
F. Radiation Biology
G. Human Anatomy and Physiology
H. Introduction to Clinical Radiology and Radiation Oncology

Appendix III

Radiation Physics Topic Outlines for Medical Physics Residents

Appendix IIIA - Radiation Physics Topic Outline forRadiation Oncology Physics Residents

Appendix IIIB - Radiation Physics Topic Outline forDiagnostic Imaging Physics Residents

Appendix IIIC - Radiation Physics Topic Outline forNuclear Medicine Physics Residents

Note: The topic outlines presented in these appendices are not to be considered as course work requirements for an academic degree (M.S. or Ph.D) program in Medical Physics. For courses and other requirements of degree programs, please refer to the AAPM document on academic programs in medical physics (in preparation). A medical physics residency program should either include instruction in these topics during the residency period or accept trainees only if they have already acquired requisite knowledge in these areas through their prior academic programs.

Appendix IIIA

Radiation Physics Topic Outline for Radiation Oncology Physics Residents

APPENDIX IIIA: Radiation physics topic outline for radiation oncology physics residents

I. Atomic and nuclear structure

A. Atomic structure

1. Energy levels, binding energy
2. Transitions, characteristic radiations

B. Nuclear structure

1. Mass, atomic, and neutron numbers
2. Nuclear binding energy
3. Fission, fusion
4. Nuclear reactors

II. Radioactive decay

A. Modes of decay

1. N/P ratio, even-odd relationship
2. Beta (negatron) decay
3. Positron decay and electron capture
4. Alpha decay
5. Isometric transitions, gamma emission, internal conversion

B. Mathematics of radioactive decay

1. Units, half-life, graphing
2. Transient and secular equilibrium
3. Radionuclide generators

C. Natural radioactivity

1. Naturally occurring isotopes
2. Decay series

D. Artificial radioactivity

1. Production by neutron bombardment
2. Fission products
3. Production by charged particle bombardment

III. Interactions of particulate radiations

A. Type of interactions

1. Elastic, inelastic
2. Excitation, ionization

B. Properties of particulate radiations

1. Specific ionization
2. W quantity
3. LET

C. Interactions of heavy charged particles and pions

1. Bragg peak
2. Possibilities for radiation therapy

D. Interactions of electrons

1. Interactions with electrons
2. Interactions with nuclei
3. Applications to radiation therapy

E. Neutron interactions

1. Slow neutron interactions
2. Fast neutron interactions
3. Applications to radiation therapy

IV. Production of x-rays

A. X-ray tubes

1. Requirements for x-ray production
2. Historical development
3. Focal spot size
4. Reflection and transmission targets
5. X-ray production efficiency

B. X-ray circuits

1. Primary circuit
2. Secondary circuit
3. Filament circuit
4. Modes of rectification
5. Single phase and three phase operation

V. High energy treatment machines

A. Cobalt units

B. Van de Graaff generators

C. Linear accelerators

D. Betatrons

E. Resonance transformers

F. Cyclotrons for neutron therapy

VI. Interactions of x- and gamma-rays

A. Attenuation of a beam of x- or gamma-rays

1. Attenuation and absorption coefficients
2. Attenuation in the body

B. Modes of interaction

1. **Photoelectric absorption**
2. **Compton scattering**
3. **Pair production**
4. **Photodisintegration**

VII. Measurement of radiation exposure

A. Photon and energy flux density and fluence

B. The roentgen

C. Electronic equilibrium

D. Ionization chambers

1. **Free-air chambers**
2. **Thimble chambers**
3. **Condenser chambers**
4. **Electrometers**
5. **Extrapolation chambers**

E. Exposure calibration of an x- or gamma-ray beam

1. **Selection of calibration** variables
2. **Selection of chamber**
3. **Positioning of chamber**
4. **Corrections to readings**

F. Quality assurance checks on radiation therapy units

VIII. Radiation quality

A. Measures of quality

1. **HVL and effective energy**
2. **Measurement of HVL**

B. Factors influencing quality

1. **Variations in quality across a beam**
2. **Filtration and accelerating potential**

IX. Measurement of absorbed dose

A. Units of radiation dose, dose equivalent, RBE-dose

B. Calculation of dose **from exposure**

C. Measurement of absorbed dose **with an ionization chamber**

1. **Bragg-Gray cavity theory**

D. Direct measurement of absorbed dose

1. **Film**
2. **TLD**
3. **Calorimetry**
4. **Chemical dosimetry**

X. Calibration of high energy photon and electron beams

A. Photons

1. **Stopping power ratios and energy absorption coefficients**
2. A_{eq}
3. C_t
4. **TG 21**

B. Electrons

1. C_E
2. **TG 21**

XI. Dose distributions, external beam therapy (computer treatment planning)

A. Dosimetric variables

1. Backscatter factor
2. Percent depth dose
3. Tissue-air ratio
4. Scatter-air ratio
5. Tissue-maximum and tissue-phantom ratios
6. Isodose distributions
7. Treatment time calculations
8. Fixed SSD and isocentric treatment techniques

B. Single and multiple field dose distributions

1. Corrections for wedges
2. Design for compensating filters
3. Corrections for surface obliquities
4, Corrections for heterogeneities
5. Dose perturbations at interfaces
6. Adjoining fields
7. Integral dose

C. Dose distributions for rotational therapy

D. Calculation of dose in large, irregular fields

E. Electron Beam Planning

XII. Dose distributions, sealed source therapy

A. Handling of sealed radioactive sources

B. Dose distributions for sealed implant sources

C. Design of sealed source implants

D. Radium and its substitutes

E. Special techniques for ^{192}Ir and ^{125}I

F. Other sealed sources in therapy

G. Implant systems Interstitial/Intracavitary

XIII. Computerized treatment planning

A. External X and gamma-ray beams

1. Rectangular fields
2. Irregular fields

B. Electron beams

C. Implanted sources

1. Intracavitary implants
2. Interstitial implants

XIV. Radiation protection from external sources

A. Concepts and units

1. Quality factors
2. Dose equivalent
3. Protection regulations

B. Treatment room design

1. Primary radiation
2. Scatter
3. Leakage
4. Special problems with high energy photon and electron beams

C. Sealed source storage

D. Protection surveys

E. Personnel monitoring

XV. Radiation protection from internal sources

A. Body burdens and critical organs

1. MPBB and MPG
2. Effective half lives for uptake and elimination

B. Internal dose computations

1. Locally absorbed radiation
2. Penetrating radiation

C. Handling radionuclide therapy patients

D. Licensing procedures for using radionuclides

Appendix MB

Radiation Physics Topic Outline for Diagnostic Imaging Physics Residents

APPENDIX IIIB: Radiation physics topic outline for diagnostic imaging physics residents

I. Atomic and nuclear structure

A. Atomic structure

1. Energy levels, binding energy
2. Transitions, characteristic radiations

B. Nuclear structure

1. Mass, atomic, and neutron numbers
2. Nuclear binding energy
3. Fission, fusion
4. Nuclear reactors

II. Radioactive decay

A. Modes of decay

1. N/P ratio, even-odd relationship
2. Beta (negatron) decay
3. Positron decay and electron capture
4. Alpha decay
5. Isometric transitions, gamma emission, internal conversion

B. Mathematics of radioactive decay

1. Units, half-life, graphing
2. Transient and secular equilibrium
3. Radionuclide generators

C. Natural radioactivity

1. Naturally occurring isotopes
2. Decay series

D. Artificial radioactivity

1. Production by neutron bombardment
2. Fission products
3. Production by charged particle bombardment

III. Interactions of particulate radiations

A. Type of interactions

1. Elastic, inelastic
2. Excitation, ionization

B. Properties of particulate radiations

1. Specific ionization
2. W quantity
3. LET

C. Interactions of heavy charged panicles and pions

D. Interactions of electrons

E. Neutron interactions

IV. Production of x-rays

A. X-ray tubes

1. Requirements for x-ray production
2. Historical development
3. Focal spot size
4. X-ray targets
5. X-ray production efficiency
6. Characteristic and Bremsstrahlung spectra
7. mA and kVp effects
8. Heat production and dissipation (rating charts)
9. Line-focus principle
10. Special tubes
    a. Grid controlled
    b. Field emission
    c. Mammography

B. X-ray generators

1. Primary circuit
2. Secondary circuit
3. Filament circuit
4. Modes of rectification
5. Single phase and three phase operation
6. Others
   a. Falling load
   b. Capacitor discharge
   c. Constant potential
   d. Battery operated

V. Interactions of x- and gamma-rays

A. Attenuation of a beam of x- or gamma-rays

1. Attenuation and absorption coefficients
2. Attenuation in the body

B. Modes of interaction

1. Photoelectric absorption
2. Compton scattering
3. Pair production
4. Photodisintegration

VI. Measurement of radiation exposure

A. Photon and energy flux density and fluence

B. The roentgen

C. Electronic equilibrium

D. Ionization chambers

1. Free-air chambers
2. Thimble chambers
3. Condenser chambers

4. 5. Electrometers chambers

E. Exposure calibration of an x- or gamma-ray beam

1. Selection of calibration variables
2. Selection of chamber
3. Positioning of chamber
4. Corrections to readings

F. Quality assurance checks on diagnostic imaging units

VII. Radiation quality

A. Measures of quality

1. HVL and effective energy
2. Measurement of HVL

B. Factors influencing quality

1. Variations in quality across a beam
2. Filtration and accelerating potential

VIII. Measurement of absorbed dose

A. Units of radiation dose, dose equivalent, RBE-dose

B. Calculation of dose from exposure

C. Measurement of absorbed dose with an ionization chamber

1. Bragg-Gray cavity theory

D. Direct measurement of absorbed dose

1. Film
2. TLD
3. Calorimetry
4. Chemical dosimetry

IX. Imaging concepts

A. Mode

1. Transmission
2. Emission
3. Reflection
4. Reconstruction

B. Image characteristics

1. Density, contrast, latitude
2. Detail, resolution, MTF
3. Noise
4. Speed
5. Dose
6. Inter-relationships

C. Viewing conditions

1. Visual receptors
2. Film vs. video
3. Variables

D. Analog vs. digital considerations

X. Filters and beam-limiting devices

A. Filtration

1. Inherent
2. Added
3. Special purpose
4. Effect upon image quality and radiation dose

B. Scattered radiation

1. Image quality and dose effects

C. Heel effect

D. Beam-limiting devices

1. Aperature
2. Cones
3. Collimators
4. Positive beam limitation
5. Performance measurements

Xi. imaging geometry

A. Magnification

B. Distortion (unequal magnification)

C. Geometric unsharpness

D. Motion unsharpness

XII. Scattered radiation

A. Grids

1. Construction
2. Nomenclature
3. Types
4. Performance parameters
5. Practical considerations

B. Air gap

C. Slot radiography

D. Equilization radiography

XIII.Intensifying screens

A. Uses

B. Construction

C. Principles of operation

D. Conversion efficiency

E. Speed

F. Resolution

G. Inter-relationships

XIV. Film

A. Uses

B. Construction

C. Processing

D. Photographic properties

E. Characteristic curve

XV.FLUOROSCOPY

A. System design

B. Image intensifiers

C. Image quality measures

D. Automatic brightness control

E. Television

F. Spot films

G. Photospots

H. Video recording

XVI. SPECIAL TECHNIQUES

A. Stereoradiography

B. Xeroradiography

C. Subtraction techniques

D. 3-dimensional imaging

E. Duplication

F. Film changers

XVII. COMPUTED TOMOGRAPHY

A. Basic principles

B. Data acquisition

C. Image reconstruction

D. Image display

E. Image analysis

F. Artifacts

G. Quantitative CT

H. Dual energy CT

I. Fast CT

XVIII. ULTRASOUND

A. Basic principles

B. Physical characteristics

C. Transducers

D. Modes

E. Real time

F. Doppler

G. Duplex systems

H. Image quality measurements

I. Scan converter

IX. MAGNETIC RESONANCE

A. Basic principles

B. Nature of NMR signal

C. Pulse sequences

D. Spin system encoding

E. Image reconstruction

F. Image contrast

G. Equipment

1. Magnets
2. RF systems
3. Gradient systems

H. Bioeffects

I. Fast scan techniques

J. Flow imaging

K. Chemical shift imaging

L. Spectroscopy

M. Image quality measurements

N. Artifacts

O. Site planning

P. Patient and personnel protection issues

Appendix IIIC

Radiation Physics Topic Outline for Nuclear Medicine Physics Residents

APPENDIX IIIC: Radiation physics topic outline for Nuclear Medicine residents

I. Atomic and nuclear structure

A. Atomic structure

1. Energy levels, binding energy
2. Transitions, characteristic radiations

B. Nuclear structure

1. Mass, atomic, and neutron numbers
2. Nuclear binding energy
3. Mass defect
4. Fission, fusion
5. Nuclear reactors
6. Particle accelerators
7. Cyclotrons
8. Nuclear nomenclature
   a. Isotopes
   b. Isotones
   c. Isomers
   d. Isobars

II. Radioactive decay

A. Modes of decay

1. N/P ratio, even-odd relationship
2. Beta (negatron) decay
3. Positron decay and electron capture
4. Alpha decay
5. Isometric transitions, gamma emission, internal conversion, metastable states

B. Mathematics of radioactive decay

1. Units, half-life, graphing
2. Sources of nuclear data

C. Natural radioactivity

1. Naturally occurring isotopes
2. Decay series

D. Artificial radioactivity

1. Production and decay rates
2. Transient and secular equilibria
3. Production by neutron bombardment
4. Fission products
5. Production by charged particle bombardment
6. Radionuclide generators

III. Interactions of particulate radiations

A. Type of interactions

1. Elastic, inelastic
2. Excitation, ionization

B. Properties of particulate radiations

1. Specific ionization
2. W quantity
3. LET
4. Bremsstrahlung production
5. Scatter radiation, characteristic radiation, Auger electrons

C. Interactions of heavy charged particles and pions

1. Bragg peak
2. Possibilities for nuclear medicine

D. Interactions of electrons

1. Interactions with electrons
2. Interactions with nuclei
3. Applications to nuclear medicine

E. Neutron interactions

1. Slow neutron interactions
2. Fast neutron interactions
3. Applications to nuclear medicine

IV Interactions of x- and gamma-rays

A. Attenuation of a beam of x- or gamma-rays

1. Attenuation and absorption coefficients
2. Attenuation in the body

B. Modes of interaction

1. Photoelectric absorption
2. Compton scattering
3. Pair production
4. Photodisintegration

V. Production of x-rays

A. X-ray tubes

1. Requirements for x-ray production
2. Historical development
3. Focal spot size
4. Reflection and transmission targets
5. X-ray production efficiency

B. X-ray circuits

1. Primary circuit
2. Secondary circuit
3. Filament circuit
4. Single phase and three phase operation

VI. Measurement of radiation exposure

A. Photon and energy flux density and fluence

B. The roentgen

C. Electronic equilibrium

D. Ionization chambers

1. Free-air chambers
2. Thimble chambers
3. Condenser chambers
4. Electrometers
5. Extrapolation chambers

E. Exposure calibration of an x- or gamma-ray beam

1. Selection of calibration variables
2. Selection of chamber
3. Positioning of chamber
4. Corrections to readings

F. Quality assurance checks on nuclear medicine units

VII. Radiation Detectors

A. Gas-filled detectors

1. Ion chambers
2. Proportional counters
3. Geiger-Muller tubes

B. Scintillation crystals

1. Fluorescence and phosphorescence
2. Types of crystals
3. Conversion efficiency
4. Light output
5. Decay time
6. Photomultiplier tubes

C. Scintillation fluids

D. Semiconductor detectors

1. Solid-state physics

E. Thermoluminescent detectors

VIII. Counting statistics

A. Error

1. Determinate
2. Indeterminate

B. Precision and accuracy

C. Frequency distributions

D. Standard deviation and confidence limits

E. Precision of measurement data

1. Total counts and time
2. t-test
3. Chi square

A. Isotope calibrators

B. Common components

1. Pre-amplifiers and amplifiers
2. Discriminators and scalers
3. Rate meters
4. Pulse-height analyzers

C. Well counters

D. Probe systems

E. Pulse height analysis

1. Photopeak
2. Compton plateau
3. Compton edge
4. Secondary peaks
5. Calibration
6. Comparison among detectors
7. FWHM

F. Scintillation Camera

1. History
2. Collimation
3. Crystals and photomultiplier tubes
4. Electronic components, corrections, and display
5. Camera-computer interface
6. Performance characteristics
   a. Spatial, energy, and temporal resolution
   b. Sensitivity
   c. Uniformity
7. Static versus dynamic acquisition
8. Artifacts and methods for correction
   a. Uniformity correction
   b. Energy correction
   c. Dual-isotope correction
9. Multi-crystal devices

G. Rectilinear scanners

H. Tomographic Imaging

1. Pinhole and slant-hole tomography
2. Single photon emission computed tomograpy
   a. Calibrations
   b. Reconstruction techniques
   c. Display
   d. Reformation

3. Positron emission tomograpy
    a. History and biological importance of positron emitting radionuclides
    b. Acquisition principles
    c. Radiopharmaceuticals
    d. Scanner designs
    i. Time of flight systems
    e. Matching of performance characteristics with clinical examination

I. Survey Instruments

1. Area monitoring
2. Personnel monitoring

X. Radiopharmaceuticals

A. Biologically important radionuclides

B. Physico-chemical properties and biodistributionpatterns

C. Purities

D. Assays for radioactivity

E. Mechanisms for localization and release

F. Uptake and elimination

1. Physics, biological, and effective half-life

G. Monoclonal antibodies

XI. RADIOPHARMACEUTICAL DOSIMETRY

A. Sources of internal radionuclides

B. Standard man model

C. Critical organ

D. Body burden

E. MIRD method

1. Cumulated activity
2. Equilibrium dose constant
3. S-factor
4. Absorbed fraction

F. Factors affecting internal dose

G. Bioassays

XII. Radiation safety

A. Regulatory agencies

B. Licensing procedures

C. Maximum permissible doses

1. MPBB and MPC
2. Effective half lives for uptake and elimination

D. ALARA

1. de minimus
2. Action levels

E. Protection principles

1. Time
2. Distance
3. Shielding

F. Laboratory procedures

1. Handling
2. Patient administration
3. Decontamination
4. Procedures for radionuclide therapy

G. License requirements

1. Labeling of areas
2. Surveys and wipe test
3. Waste disposal
4. Personnel monitoring
5. Records and reports
6. Personnel instruction
7. Emergency procedures
   a. Spill protocol
8. Shielding requirements
9. Misadministration definitions and procedures
10. Radiation safety officer
11. Radiation safety committee

XIII. Radiation quality for x-ray sources

A. Measures of quality

1. HVL and effective energy
2. Measurement of HVL

B. Factors influencing quality

1. Variations in quality across a beam
2. Filtration and accelerating potential

XIV. Measurement of absorbed dose for external sources

A. Units of radiation dose, dose equivalent, a RBE-dose

B. Calculation of dose from exposure

C. Measurement of absorbed dose with an ionization chamber

1. Bragg-Gray cavity theory

D. Direct measurement of absorbed dose

1. Film
2. TLD
3. Calorimetry
4. Chemical dosimetry

Appendix IV

Clinical Topic Outlines for Medical Physics Residents

Appendix IVA - Clinical Topic Outline for Radiation Oncology Physics Residents

Appendix IVB - Clinical Topic Outline for Diagnostic Imaging Physics Residents

Appendix IVC - Clinical Topic Outline for Nuclear Medicine Physics Residents

Appendix IVA

Clinical Topic Outline for Radiation Oncology Physics Residents

APPENDIX IVA: Clinical topic outline for radiation oncology physics residents

Topics listed should be covered pertaining to primary malignancies of anatomical sites:

I. Epidemiology

A. Influence of sex, age, occupation, geography, etc.

II. Pathologic classification

A. Relative incidence of each type

B. Radiation response relative to histology

III. Site(s) of primary occurrence

A. Anatomy of region

B. Relative incidence of such occurrence

C. Physical findings

D. Diagnostic procedures to evaluate primary disease

IV. Modes of metastases

A. Anatomical considerations

B. Incidence of types of metastases

V. Sites of metastases

A. Anatomy of spread

B. Incidence of spread to various sites

C. Diagnostic studies to evaluate metastases

VI. Extent of Disease

A. Clinical staging

B. Systems of clinical staging

C. Pathologic staging when applicable

D. Studies available to aid in clinical staging

E. Physical findings in the different clinical staging

VII. Complications of primary and/or secondary disease

A. Anatomical considerations

B. Pathologic considerations

C. Physiologic considerations

D. Methods of evaluating complications

VIII. Discussions of indicated treatment-primary disease

A. Surgery

B. Radiation therapy

C. Chemotherapy

D. Combinations of above

E. Immunology

F. Hyperthermia

G. Other dose modifiers

IX. Indicated treatment-metastatic disease

X. Radiation dosimetry and treatment planning

A. Systems available for dosimetry

B. Methods of use of dosimetry

C. Techniques of treatment planning

D. Optimal beams and/or radionuclides

XI. CPR

Appendix IVB

Clinical Topic Outline for Diagnostic Imaging Physics Residents

Appendix IVB: Clinical topic outline for diagnostic Imaging physics residents

I. Medical terminology

II. Anatomy

A. Normal structures and appearance

B. Normal variants

C. Radiographic appearance

1. Image quality and artifacts
   a. Radiographic
   b. Fluoroscopic
   c. CT
   d. US
   e. MRI

III. Physiology

A. Normal organ function

B. Normal organ variation

C. Pathophysiology of disease

D. Metabolic cycles and interactions

E. Laboratory tests

IV. Patient Procedures

A. Radiographic

1. Neuro
2. Chest

3. Musculoskeletal
4. Mammography
5. Gastrointestinal
6. Genitourinary
7. Pediatric
8. Obstetric
9. Vascular

B. Fluoroscopic

1. Gastrointestinal
2. Chest
3. Interventional

C. Special Imaging

1. CT
2. Ultrasound
3. Nuclear Medicine
4. MRI

V. Contrast media

A. Functions

1. Modality difference

B. Biochemistry

C. Physiology reactions

VI. CPR

Appendix IVC

Clinical Topic Outline for Nuclear Medicine Physics Residents

APPENDIX IVC: Clinical topic outllne for nuclear medicine physics residents

I. Considerations for the clinical use of radiopharmaceuticals

- A. Normal biodistribution of diagnostic radiopharmaceuticals
- B. Radiopharmacokinetics in nuclear medicine
- C. Biodistribution in radiodiagnostics
- D. Matabolic fate of radiopharmaceuticals
- E. Considerations in the selection of radiopharmaceuticals
- F. Radiopharmaceutical kits and quality control
- G. Adverse reactions associated with radiopharmaceutlcals

II. Instrumentation and procedural problems in nuclear medicine

III. Patient preparation for nuclear medicine studies

IV. Nuclear medicine procedures

- A. Central nervous system
- B. Lung
- C. Reticuloendothelial system
- D. Bone
- E. Renal
- F. Cardiovascular
- G. Thyroid
- H. Tumor

V. Therapy

A. Therapeutic applications of radiopharmaceuticals

B. Nuclear medicine procedures for monitoring patient therapy

VI. Role of the Federal Drug Administration and the Nuclear Regulatory Commission in Nuclear Pharmacy and Medicine

VII. CPR

Appendix V

Radiation Biology Topic Outlines for Medical Physics Residents

Appendix VA - Radiation Biology Topic Outline for Radiation Oncology Physics Residents

Appendix VB - Radiation Biology Topic Outline for Diagnostic Imaging Physics Residents

Appendix VC - Radiation Biology Topic Outline for Nuclear Medicine Physics Residents

Appendix VA

Radiation Biology Topic Outline for Radiation Oncology Physics Residents

APPENDIX VA: Radiation biology topic outline for radiation oncology physics residents

1. Interaction of radiation with matter

   A. Types of ionizing radiations

   B. Excitation and ionization

   C. Absorption of x-rays

   D. Absorption of neutrons

   E. Absorption of pions

   F. Free radical production

   G. Free radical scavengers and antioxidants

   H. Direct and indirect effects

   I. Chain of events between absorption of energy and expression of biological consequences

II. MammaLian cell radiosensitivity

   A. Interphase and reproductive death

   B. Cell survival curves in vitro

   C. Characterization of cell survival curves

   D. Critical sites and target theory

      1. DNA
      2. Membranes

   E. Dose response curves in vivo

      1. Skin clones
      2. Surviving crypts
      3. Bone marrow colonies growing in spleen

F. Quantitative normal tissue systems that are not cell survival curves

1. Pig skin
2. Rodent skin
3. Lung
4. Esophagus
5. Kidney

III. Factors that modify radiation response

A. The oxygen effect

1. Effect of oxygen concentration
2. Time of action of oxygen
3. Mechanism of the oxygen effect
4. Implications for radiotherapy
5. Methods to overcome problems of hypoxic cells

B. The age response function

1. The cell cycle
2. Age response for cells cultured in vitro
3. Age response for tissues in vivo
4. Age response for neutrons
5. The oxygen effect through the cell cycle
6. Implications for radiotherapy

C. Potentially lethal damage

1. Repair in vitro
2. Repair in vivo
3. PLD and high LET radiations
4. Implications in radiotherapy

D. Sublethal damage

1. Split-dose experiments with cells in vitro
2. Sublethal damage repair in normal tissues
3. Sublethal damage repair in tumors
4. Sublethal damage and hypoxia
5. Sublethal damage and high LET radiations
6. DQ as a measure of repair

E. Dose-rate

1. Dose-rate effect in cells in vitro
2. Dose-rate effect in normal tissues
3. Dose-rate effect in tumors
4. Interstitial therapy
5. Beam therapy at low dose rate

F. Radiosensitizers

1. The halogenated pyrimidines
2. Hypoxic cell radiosensitizers
   a. Structure and mode of action
   b. Enhancement ratio
   c. Metronidazole/misonidazole
   d. Pharmacokinetics in the human
   e. Clinical limitations
3. Antibiotics

G. Radioprotectors

1. Free radical scavenger

IV. Solid tumor systems

A. Experiment models

1. Tumor regrowth measurements
2. Tumor cure--LD_{50} assay
3. Dilution assay technique
4. Lung colony assay system
5. In situ treatment/in vitro assay
6. Spheroids

B. Demonstration of hypoxic cells in tumors

C. Proportion of hypoxic cells in tumors

D. Reoxygenation

E. Implications for radiotherapy

V. Linear energy transfer

- A. Definition
- B. Track and energy average
- C. LET for different types of radiation
- D. OER as a function of LET

VI. Relative biological effectiveness

- A. Definition
- B. RBE for different cells and tissues
- C. RBE as a function of dose
- D. RBE and fractionation
- E. RBE as a function of LET
- F. Q factor

VII. Cell and tissue kinetics

- A. The cell cycle
- B. Autoradiography
- C. Constituent parts of the cell cycle
- D. Percent labelled mitoses technique
- E. Growth fraction
- F. Cell loss factor
- G. Growth kinetics of human tumors

VIII. Tissue radiosensitivity

A. Classification based on radiation pathology

B. Types of cell populations

1. Self renewal
2. Conditional renewal
3. Stem cell
4. Differentiated

1X. Time-dose and fractionation

A. The 4 R's of radiobiology

B. The basis of fractionation

C. The Strandquist plot

D. Nominal standard dose

X. New radiation modalities

A. Protons

1. Production
2. Processes of absorption
3. Depth dose patterns
4. Advantages compared with x-rays
5. Facilities available

B. Neutrons

1. Production
2. Processes of absorption
3. Depth dose patterns
4. Advantages compared with x-rays
5. Facilities available

C. Pions

1. Production
2. Processes of absorption
3. Depth dose patterns
4. Advantages compared with x-rays
5. Facilities available

D. High energy heavy ions

1. Production
2. Processes of absorption
3. Depth dose patterns
4. Advantages compared with x-rays
5. Facilities available

XI. Chemotherapeutic agents used as adjuvants with radiation

A. Antibiotics

B. Alkylating agents

C. Antimetabolites

D. Plant alkaloids

E. Other synthetic agents

XII. Hyperthermia

A. Methods of heating

1. RF microwaves
2. Ultrasound
3. Water baths

B. Systemic hyperthermia

C. Localized heating

D. Cellular response to heat

E. Repair of thermal damage

F. Thermotolerance

G. Hyperthermia combined with irradiation (x-rays)

H. Time sequence of heat and irradiation

I. Hypoxic cells and heat

J. Effect of pH on the response to hyperthermia

K. Response of transplanted tumors to heat

L. Response of spontaneous tumors to heat

M. Response of normal tissues to heat

N. Heat and the therapeutic gain factor

O. Hyperthermia and chemotherapy

XIII. Total body irradiation-acute effects

A. Prodromal radiation syndrome

B. Central nervous system/cerebrovascular syndrome

C. Gastrointestinal syndrome

D. Hematopoietic syndrome

E. Mean lethal dose (LD_{50})

F. Treatment of radiation accidents

XIV. Late effects

A. Non specific life shortening

1. **Definition**
2. **In animals**
3. **In man**

B. Carcinogenesis

1. **The latent period**
2. **Dose response curve in animals**
3. **Leukemia**
4. **Breast cancer**
5. **Thyroid cancer**
6. **Bone cancer**
7. **Skin cancer**
8. **Lung cancer**
9. **Other tumors**
10. **Malignancies in prenatally exposed children**
11. **Mechanisms for radiation carcinogenesis**

C. Genetics of irradiation

1. **Point mutations**
2. **Relationship to dose**
3. **Chromosome aberrations**
4. **Relationship to dose**
5. **Doubling dose**
6. **Genetically significant dose (GSD)**
7. **Genetic effect in humans**
8. **Background radiation in relation to GSD**

XV. Radiation effects in the developing embryo and fetus

A. Intrauterine death

B. Congenital abnormalities including neonatal death

C. Growth retardation

D. Dependence of the above effects on dose, dose-rate and stage in gestation

E. Carcinogenesis following in utero exposure

F. Human experience of pregnant women exposed to therapeutic doses

G. Occupational exposure of potentially pregnant women

H. Elective booking or "10 day rule"

I. The "practical threshold" for therapeutic abortion

XVI. Radiophysiology of human tissues

A. Effects of irradiation of the skin

1. Clinical manifestations
2. Histological substratum of effects
3. Repair
4. Degrees of sequelae
5. Injurious-effects

B. Effects of irradiation of bone and cartilage

1. Effects of growing bones and cartilage
2. Effects on adult bones and cartilage
3. Clinical manifestations
4. Histological substratum of effects
5. Functional consequences and sequelae

C. Effects of irradiation of the kidney

1. Clinical manifestations
2. Histological substratum of effects
3. Acute and chronic functional repercussions
4. Permanent sequelae

D. Effects of irradiation of the lung

1. Acute clinical effects
2. Ultimate effects
3. Histologic substratum of effects
4. Measures to reduce final effects
5. Sequelae

E. Effects of irradiation of nervous tissues

1. Effects on the brain
2. Effects on spinal cord
3. Effects on peripheral nerves
4. Clinical manifestations
5. Histological substratum
6. Sequelae

F. Effects of irradiation of the ovary

1. Clinical manifestations
2. Histological substratum
3. Reversibility of effects
4. Therapeutic implications

G. Effects of irradiation

1. Clinical consequences
2. Histological substratum
3. Reversibility
4. Protective measures

H. Effects of irradiation of the eye

1. Clinical consequences
2. Histological substratum
3. Protective measures
4. Time-dose connotations
5. Sequelae-therapy

I. Effects of irradiation of lymphoid tissues

1. Clinical manifestations
2. Histological substratum
3. Reversibility

J. Effects of irradiation of the bone marrow

1. Clinical and laboratory manifestations
2. Chronology of effects
3. Histologic substratum
4. Recovery
5. Therapeutic applications

K. Effects of irradiation of the oral, pharyngolaryngeal and esophageal mucous membrane

1. Clinical manifestations
2. Histological substratum
3. Repair
4. Sequelae

L. Effects of irradiation of the salivary glands

1. Acute manifestations
2. Histological substratum
3. Dental consequences
4. Prophylaxis

M. Untoward effects observable in clinical radiotherapy

1. Technological protection
2. Role of total dose
3. Rote of fractionation
4. Measures of prevention
5. Therapeutic measures

N. Effects of irradiation of human embryo

1. Role of age
2. Role of dose
3. Teratogenic effects
4. Measures of prevention

Appendix VB

Radiation Biology Topic Outline for Diagnostic Imaging Physics Residents

APPENDIX VB: Radiation Biology topic outline for diagnostic imaging physics biology

I. Interaction of radiation with matter

A. Types of ionizing radiations

B. Excitation and ionization

C. Absorption of x-rays

D. Absorption of neutrons

E. Absorption of pions

F. Free radical production

G. Free radical scavengers and antioxidants

H. Direct and indirect effects

I. Chain of events between absorption of energy and expression of biological consequences

II. Mammalian cell radiosensitivity

A. Interphase and reproductive death

B. Cell survival curves in vitro

C. Characterization of cell survival curves

D. Critical sites and target theory

1. DNA
2. Membranes

E. Dose response curves in vivo

1. Skin clones
2. Surviving crypts
3. Bone marrow colonies growing in spleen

F. Quantitative normal tissue systems that are not cell survival curves

1. Pig skin
2. Rodent skin
3. Lung
4. Esophagus
5. Kidney

III. Factors that modify radiation response

A. The oxygen effect

1. Effect of oxygen concentration
2. Time of action of oxygen
3. Mechanism of the oxygen effect
4. Implications for radiotherapy
5. Methods to overcome problems of hypoxic cells

B. The age response function

1. The cell cycle
2. Age response for cells cultured in vitro
3. Age response for tissues in vivo
4. Age response for neutrons
5. The oxygen effect through the cell cycle
6. Implications for radiotherapy

C. Potentially lethal damage

1. Repair in vitro
2. Repair in vivo
3. PLD and high LET radiations
4. Implications in radiotherapy

D. Sublethal damage

1. Split-dose experiments with cell in vitro
2. Sublethal damage repair in normal tissues
3. Sublethal damage repair in tumors
4. Sublethal damage and hypoxia
5. Sublethal damage and high LET radiations
6. DQ as a measure of repair

E. Dose-rate

1. Dose-rate effect in ceils in vitro
2. Dose-rate effect in normal tissues
3. Dose-rate effect in tumors

F. Radiosensitizers

1. The halogenated pyrimidins
2. Hypoxic cell radiosensitizers
3. Antibiotics

G. Radioprotectors

1. Free radical scavenger

IV. Solid tumor systems

A. Experiment models

1. Tumor regrowth measurements
2. Tumor cure--LD_{50} assay
3. Dilution assay technique
4. Lung colony assay system
5. In situ treatment/in vitro assay
6. Spheroids

B. Demonstration of hypoxic cells in tumors

C. Proportion of hypoxic cells in tumors

D. Reoxygenation

E. Implications for radiotherapy

V. Linear energy transfer

A. Definition

B. Track and energy average

C. LET for different types of radiation

D. OER as a function of LET

VI. Relative biological effectiveness

A. Definition

B. RBE for different cells and tissues

C. RBE as a function of dose

D. RBE and fractionation

E. RBE as a function of LET

F. Qfactor

VII. Cell and tissue kinetics

A. The cell cycle

B. Autoradiography

C. Constituent parts of the cell cycle

D. Percent labelled mitoses technique

E. Growth fraction

F. Cell low factor

G. Growth kinetics of human tumors

VIII. Tissue radiosensitivity

A. Classification based on radiation pathology

B. Types of cell populations

1. Self renewal
2. Conditional renewal
3. Stem cell
4. Differentiated

IX. Time-dose and fractionation

A. The 4 R's of radiobiology

B. The basis of fractionation

C. The Strandquist plot

D. Nominal standard dose

X. Total body irradiation-acute effects

A. Prodromal radiation syndrome

B. Central nervous system/cerebrovascular syndrome

C. Gastrointestinal syndrome

D. Hemotopoietic syndrome

E. Mean lethal dose (LD_{50})

F. Treatment of radiation accidents

XI. Late effects

A. Non specific life shortening

1. Definition
2. In animals
3. In man

6. Carcinogenesis

1. The latent period
2. Dose response curve in animals
3. Leukemia
4. Breast cancer
5. Thyroid cancer
6. Bone cancer
7. Skin cancer
8. Lung cancer
9. Other tumors
10. Malignancies in prenatally exposed children
11. Mechanisms for radiation carcinogenesis

C. Genetics of irradiation

1. Point mutations
2. Relationship to dose
3. Chromosome aberrations
4. Relationship to dose
5. Doubling dose
6. Genetically significant dose (GSD)
7. Genetic effect in humans
8. Background radiation in relation to GSD

XII. Radiation effects in the developing embryo and fetus

A. Intrauterine death

B. Congenital abnormalities including neonatal death

C. Growth retardation

D. Dependence of the above effects on dose, dose-rate and stage in gestation

E. Carcinogenesis following in utero exposure

F. Human experience of pregnant women exposed to therapeutic doses

G. Occupational exposure of potentially pregnant women

H. Elective booking or “10 day rule”

I. The “practical threshold” for therapeutic abortion

XIII. RISK ANALYSIS FOR LOW-LEVEL RADIATION EXPOSURE

Appendix VC

Radiation Biology Topic Outline for Nuclear Medicine Physics Residents

APPENDIX VC: Radiation biology topic outline for nuclear medicine physics residents

I. Interactlon of radiation with matter

A. Types of ionizing radiations

B. Excitation and ionization

C. Absorption of x-rays

D. Absorption of neutrons

E. Absorption of pions

F. Free radical production

G. Free radical scavengers and antioxidants

H. Direct and indirect effects

I. Chain of events between absorption of energy and expression of biological consequences

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A. interphase and reproductive death

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C. Characterization of cell survival curves

D. Critical sites and target theory

1. DNA
2. Membranes

E. Dose response curves in vivo

1. Skin clones
2. Surviving crypts
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3. Mechanism of the oxygen effect
4. Implications for radiotherapy
5. Methods to overcome problems of hypoxic cells

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6. Implications for radiotherapy

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2. Repair in vivo
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3. Sublethal damage repair in tumors
4. Sublethal damage and hypoxia
5. Sublethal damage and high LET radiations
6. DQ as a measure of repair

E. Dose-rate

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2. Dose-rate effect in normal tissues
3. Dose-rate effect in tumors

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1. The halogenated pyrimidines
2. Hypoxic cell radiosensitizers
   a. Structure and mode of action
   b. Enhancement ratio
   c. Metronidazole/misonidazole
   d. Pharmacokinetics in the human
   e. Clinical limitations
3. Antibiotics

G. Radioprotectors

1. Free radical scavenger

IV. Solid tumor systems

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2. Tumor cure--LD_{50} assay
3. Dilution assay technique
4. Lung colony assay system
5. In situ treatment/in vitro assay
6. Spheroids

B. Demonstration of hypoxic cells in tumors

C. Proportion of hypoxic cells in tumors

D. Reoxygenation

E. Imiplications for radiotherapy

V. Linear energy transfer

A. Definition

B. Track and energy average

C. LET for different types of radiation

D. OER as a function of LET

VI. Relative biological effectiveness

A. Definition

B. RBE for different cells and tissues

C. RBE as a function of dose

D. RBE and fractionation

E. RBE as a function of LET

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D. Percent labelled mitoses technique

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A. The 4 R's of radiobiology

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F. Treatment of radiation accidents

XI. Late effects

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7. Skin cancer
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9. Other tumors
10. Malignancies in prenatally exposed children
11. Mechanisms fo radiation carcinogenesis

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3. Chromosome aberrations
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5. Doubling dose
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7. Genetic effect in humans
8. Background radiation in relation to GSD

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C. Growth retardation

D. Dependence of the above effects on dose, dose-rate and stage in gestation

E. Carcinogenesis following in utero exposure

F. Human experience of pregnant women exposed to therapeutic doses

G. Occupational exposure of potentially pregnant women

H. Elective booking or “10 day rule”

I. The “‘practical threshold” for therapeutic abortion

J. Effects of irradiation of human embryo

XIII. RISK ANALYSIS FOR LOW-LEVEL RADIATION EXPOSURE