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ASTRO REPORT

ASTRO'S CORE PHYSICS CURRICULUM FOR RADIATION ONCOLOGY RESIDENTS

AD-HOC COMMITTEE ON TEACHING PHYSICS TO RESIDENTS:
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In 2002, the Radiation Physics Committee of the American Society of Therapeutic Radiology and Oncology (ASTRO) appointed an Ad-hoc Committee on Physics Teaching to Medical Residents. The main initiative of the committee was to develop a core curriculum for physics education. Prior publications that have analyzed physics teaching have pointed to wide discrepancies among teaching programs. The committee was composed of physicists or physicians from various residency program based institutions. Simultaneously, members had associations with the American Association of Physicists in Medicine (AAPM), ASTRO, Association of Residents in Radiation Oncology (ARRO), American Board of Radiology (ABR), and the American College of Radiology (ACR). The latter two organizations' representatives were on the physics examination committees, as one of the main agendas was to provide a feedback loop between the examining organizations and ASTRO. The document resulted in a recommended 54-h course. Some of the subjects were based on American College of Graduate Medical Education (ACGME) requirements (particles, hyperthermia), whereas the majority of the subjects along with the appropriated hours per subject were devised and agreed upon by the committee. For each subject there are learning objectives and for each hour there is a detailed outline of material to be covered. Some of the required subjects/h are being taught in most institutions (i.e., Radiation Measurement and Calibration for 4 h), whereas some may be new subjects (4 h of Imaging for Radiation Oncology). The curriculum was completed and approved by the ASTRO Board in late 2003 and is slated for dissemination to the community in 2004. It is our hope that teaching physicists will adopt the recommended curriculum for their classes, and simultaneously that the ABR for its written physics examination and the ACR for its training examination will use the recommended curriculum as the basis for subject matter and depth of understanding. To ensure that the subject matter and emphasis remain current and relevant, the curriculum will be updated every 2 years.

ASTRO, Radiation oncology, Physics, Education.

INTRODUCTION

In 2002, the Radiation Physics Committee of the American Society of Therapeutic Radiology and Oncology (ASTRO) appropriated an Ad-hoc Committee on Physics Teaching to Medical Residents. The main initiative was to develop a core curriculum. Publications have pointed to a wide variation in teaching intensity and subject matter (1–6). Klein's publication (6) on physics teaching revealed consistencies and variation. For example, most taught exclusively to postgraduate year 2 residents, while a minority taught different subjects (or levels) to different year residents. Radiation dosimetry, treatment planning, and brachytherapy constituted approximately half of the teaching hours. Some programs taught basic radiation physics intensely with minimal treatment planning coursework, while others had the reverse prioritization. On the average total classroom time was 61.4 h/year with a startling range of 24–118 h. The survey revealed enormous differences in national teaching efforts. Another challenge facing teaching programs is how to assess the physics teaching success. The underlying goal for teaching is to prepare the resident for a successful career that must include a strong physics backbone. But the more relevant assessment comes from the pass rate for the American Board of Radiology (ABR) written examination and the American College of Radiology's (ACR) Inservice Examination scoring. Both of these organizations have physics examination committees that strive to update examination questions for relevance and accuracy. However, they are challenged with deciding what is relevant and to what level. For the reasons of resolving teaching disparity and provid-

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ing examination consistency with acceptable training expectations, a physics core curriculum was deemed necessary.

METHODS AND MATERIALS

The committee was composed of physicists or physicians from various teaching institutions with active residency programs. Simultaneously, members had associations with the American Association of Physicists in Medicine (AAPM), ASTRO, the Association of Residents in Radiation Oncology (ARRO), the ABR, or the ACR. The latter two organizations' representatives were on their respective physics examination committees, as one of the main agendas was to provide a feedback loop between the examining organizations and ASTRO.

One of the first initiatives was to obtain a consensus from recent graduates as to the success of physics teaching. A survey (2002) was sent to recent radiation oncology resident graduates. Questions pertaining to examination and practice preparation were asked. Before the curriculum was developed, the committee wanted to use this recent survey as an update to needs of graduates, as the Klein paper was based on a 1995 survey. When asked, "Did your physics curriculum prepare you properly for the ABR written examination?," most answered "very good." However, when the same question was asked of the ACR examination, the responses ranged from "fair" to "very good." When asked, "Did the ACR In-service examination correlate with the ABR written examination?," the responses again ranged from "fair" to "very good." When asked, "Now that you are in practice, did your physics curriculum prepare you for your initial career needs?," the responses ranged from "good" to "very good." Questions were also asked in regard to subject matter. The residents were asked to choose key topics they felt did prepare them for a career. Most agreed that treatment planning, radiologic physics, and therapy machines/simulators were key topics. However, when asked what topics should have been covered (or in more detail), intensity-modulated radiation therapy (IMRT), three-dimensional (3D) planning, and fundamental treatment planning stood out as needed topics. This survey confirmed the need to develop a curriculum.

As the members came from teaching facilities of varying sizes, the members pooled their own institutions' curricula, which were then averaged to develop a first draft. The committee members then reviewed and commented on the subjects and intensity. Special consideration was made to include subject matter that was relevant to fundamental understanding of physics (radiologic physics), practice needs (treatment planning, up-to-date IMRT, imaging), and also to meet requirements of ACGME (particles, hyperthermia).

Once the curriculum was completed according to subjects and hours per subject, learning objectives were added for each subject to provide the level of intensity recommended for the subjects. This was organized hour by hour for each subject.

Table I. Recommended subjects and teaching hours for teaching physics to radiation oncology residents

Subject matter	Teaching hours subject
Atomic and nuclear structure (including decay and radioactivity)	3
Production of X-rays, photons, and electrons	2
Radiation interactions	3
Treatment machines and generators; simulators (including computed tomography)	3
Radiation beam quality and dose	2
Radiation measurement and calibration	4*
Photons and X-rays (including concepts, isodoses, monitor unit, heterogeneities, field shaping, compensation, field matching, etc.)	7*
Electrons (including concepts, isodoses, monitor unit, heterogeneities, field shaping, field matching, etc.)	3*
External beam quality assurance	2*
Radiation protection and shielding	2
Imaging for radiation oncology	4
3D-CRT including ICRU concepts and beam-related biology	3*
Assessment of patient setup and treatment (including electronic portal imaging device, immobilization, etc.)	2*
IMRT	2*
Special procedures (including radiosurgery, TBI, etc.)	3*
Brachytherapy (including intracavitary, interstitial, HDR, etc.)	7*
Hyperthermia	1
Particle therapy	1
Total	54

Abbreviations: 3D-CRT = three-dimensional conformal radiation therapy; ICRU = International Commission on Radiation Units; IMRT = intensity-modulated radiation therapy; TBI = total body irradiation; HDR = high dose rate.

* Indicates subject matter that should be complemented during a physics rotation.

RESULTS

The document resulted in a recommended 54-h course curriculum. The committee also decided it was necessary to complement some particular subjects with hands-on experience obtained during a physics rotation. Table 1 summarizes the curriculum.

Some of the required subjects/h are being taught in most institutions (i.e., 4 h of Radiation Measurement and Calibration), while some may be new subjects (4 h of Imaging for Radiation Oncology). The details of the subjects are detailed below, including the learning objectives for each subject.

1. Atomic and Nuclear Structure (3 lectures)

Learning objectives

The resident should:

1. *learn the structure of the atom, including types of nucleons, relation between atomic number and atomic mass, and electron orbits and binding energy*.
2. *be able to relate energy to wavelength and rest mass, and understand and describe an energy spectrum*.
3. *learn about radioactivity, including decay processes, probability, half life, parent-daughter relationships, equilibrium, and nuclear activation*.

A. The atom
 Protons, neutrons, electrons (charge, rest mass)
 Atomic number and atomic mass
 Orbital electron shells (binding energy, transitions)

B. Wave and quantum models of radiation
 Energy and wavelength, energy spectrum

C. Radioactivity and decay
 Decay processes
 Probability and decay constant
 Activity, half life, mean life
 Radioactive series
 Parent-daughter relationships and equilibrium
 Nuclear reactions, bombardment, and reactors

2. Production of Photons and Electrons (2 lectures)

Learning objectives

The resident should learn:

1. *the concepts of beam production, including acceleration of electrons in diagnostic X-ray tubes, Bremsstrahlung, X-ray tube design, and characteristic radiation*.
2. *about the general design of a linear accelerator, including major components and their functions, steering, flattening filtration, and beam hardening*.

A. Physics concepts of beam production
 Concept of Bremsstrahlung
 X-ray tube design
 Energy spectrum
 Characteristic radiation

B. Generation of beams
 Filters
 Gamma-radiation teletherapy sources (Co-60, Cs-137)
 Linear accelerator production

3. Radiation Interactions (3 lectures)

Learning objectives

The resident should learn:

1. *the physical description, random nature, and energy dependence of the five scatter and absorption interactions that X-ray photons undergo with individual atoms (coherent scatter, photoelectric effect, compton effect, pair production, and photonuclear disintegration).*
2. *definitions of the key terms such as attenuation, scatter, beam geometry, linear and mass attenuation coefficients, energy transfer, energy absorption, half-value layer, and how these terms relate to radiation scatter and absorption through the exponential attenuation equation*.
3. *the physical description and energy dependence of the elastic and inelastic collision processes in matter for directly and indirectly ionizing particulate radiation*.
4. *definitions of key terms such as linear energy transfer, specific ionization, mass stopping power, range, and how these terms relate to energy deposition by particulate radiation*.

A. Interactions of X-rays and γ-rays with matter
 Scatter vs. absorption
 Coherent scatter
 Photoelectric effect
 Compton effect
 Pair production
 Photonuclear disintegration

B. Attenuation of photon beams
 Attenuation, energy transfer, and energy absorption
 Exponential attenuation equation
 Attenuation coefficients
 Half-value layer
 Beam geometry

C. Interactions of particulate radiation
 Directly and indirectly ionizing particles
 Elastic and inelastic collisions with orbital electrons and the nucleus
 Linear energy transfer, specific ionization, mass stopping power, range
 Interactions of electrons
 Interactions of heavy charged particles
 Interactions of neutrons

4. Treatment Machines and Generators; Simulators (3 lectures)

Learning objectives

The resident should learn about:

1. *the mechanics and delivery of radiation with respect to wave guides, magnetron vs. klystron for production.*
2. *the production and delivery of electrons by the electron gun, buncher, and scattering foil vs. scanning.*
3. *the production and delivery of photons including the target and flattening filter*.
4. *benefits and limitations of multileaf collimator (MLC) collimators and cerrobend and hand-block.*
5. *the production and collimation of superficial photons*.
6. *the production of low-energy X-rays for imaging*.
7. *the differences in film and other imaging modalities for simulation*.

8. *digitally reconstructed radiograph (DRR) production and use*.
   - A. Linear accelerators
     - Operational theory of wave guides
     - Bending magnet systems
     - Photon beam delivery
     - Electron beam delivery
     - Beam energy
     - Monitor chamber
   - B. Linac collimation systems and other teletherapy
     - Primary and secondary collimators
     - Multileaf collimators
     - Other collimation systems
     - Radiation and light fields (including field size definition)
     - Cobalt units
     - Therapeutic X-ray (<300 kVp)
   - C. Simulators
     - Mechanical and radiographic operation
     - Fluoroscopy and intensifiers
     - Computed tomography (CT) simulation machinery
     - CT simulation operation

5. Radiation Beam Quality and Dose (2 lectures)

Learning objectives

The resident should learn:

1. *the physical characteristics of monoenergetic and heteroenergetic photon and particle beams, the terms such as energy spectrum, effective energy, filtration, geometry, and homogeneity that are used to describe such beams*.
2. *definitions and units for kerma, exposure, absorbed dose, dose equivalent, and RBE dose, the conditions under which each quantity applies, and the physical basis for measuring or computing each quantity*.
   - A. Monoenergetic and heteroenergetic Bremsstrahlung beams
     - Energy spectra for Bremsstrahlung beams
     - Effects of electron energy, filtration, beam geometry
     - Homogeneity coefficient
     - Effective energy
     - Clinical indices for megavoltage beams (e.g., percent depth dose (PDD) at reference depth)
   - B. Dose quantities and units
     - Kerma
     - Exposure
     - Absorbed dose
     - Dose equivalent
     - RBE dose
     - Calculation of absorbed dose from exposure
     - Bragg-Gray cavity theory

6. Radiation Measurement and Calibration (4 lectures)

Learning objectives

The resident should learn:

1. *the units and definitions associated with radiation absorbed dose*.
2. *the relationship between kerma, exposure, and absorbed dose*.
3. *how absorbed dose can be determined from exposure, and the historical development of this approach*.
4. *Bragg-Gray cavity theory and its importance in radiation dosimetry*.
5. *stopping power ratios, and the effective point of measurement for radiation dosimetry*.
6. *how photon and electron beams are calibrated, the dose calibration parameters, and the calibration protocols for performing linac calibrations*.
7. *how to determine exposure and dose from radioactive sources*.
8. *the various methods by which to measure absorbed dose; these should include calorimetry, chemical dosimetry, solid-state detectors, and film dosimetry*.
   - A. Dose and relationships
     - Radiation absorbed dose—definition and units
     - Relationship between kerma, exposure, and absorbed dose
     - Bragg-Gray cavity theory—stopping powers
   - B. Ionization chambers
     - Cylindrical
     - Parallel-plate
     - Effective points of measurement
   - C. Calibration of megavoltage beams
     - Photon beams
     - Electron beams
     - Dose calibration parameters
     - Task Group-21 and Task Group-51
   - D. Other methods of measuring absorbed dose
     1. Calorimetry
     2. Chemical dosimetry
     3. Solid state detectors
        - Thermoluminiscent Dosimeter (TLD)
        - Diode detectors
        - Scintillation detectors
        - Diamond detectors
     4. Film dosimetry
        - Xonat Verification (XV)-2 film
        - Extended Dose Range (EDR)-2 film
        - Radiochromic film

7. Photons and X-rays (7 lectures)

Learning objectives

The resident should learn:

1. *basic dosimetric concepts of photon beams*.
2. *how these concepts relate to calculation concepts*.
3. *basic calculation parameters*.
4. *how these parameters relate to one another and how to cross convert*.
5. *parameters used for calculations and their dependencies for source-to-skin distance (SDD) and source-to-axis distance (SAD) setups*.
6. *how beam modifiers affect beams and calculations*.

7. *basic treatment planning arrangements and strategies.*
8. *how beam shaping affects isodose maps.*
9. *surface and exit dose characteristics.*
10. *the effect and use of beam modifiers including bolus.*
11. *heterogentity corrections and effects on isodoses.*
12. *beam matching techniques and understanding of peripheral dose.*
13. *special considerations for pacemaker, pregnant patients.*

A. External beam dosimetry concepts (part I)
  1. Dosimetric variables
     Inverse square law
     Backscatter factor
     Electron buildup
     Percent depth dose
     Mayneord F-factor
     Tissue Air Ratio correction to F-factor
     Equivalent squares

B. External beam dosimetry concepts (part II)
   Tissue-air ratio
   Scatter-air ratio
   Tissue-phantom ratio
   Tissue-maximum ratio

C. System of dose calculations
  1. Monitor unit calculations
     (a) Output factor
     (b) Field size correction factors
     (c) Collimator scatter factor and phantom scatter factor
     (d) Beam modifier factors
     (e) Patient attenuation factors
  2. Calculations in practice
     (a) SSD technique
        1. SSD treatment same as SSD of calibration
        2. SSD treatment different from SSD of calibration
        3. SSD treatment and SAD calibration
     (b) SAD technique
        1. SAD treatment and SAD calibration
        2. SAD treatment and SSD calibration
        3. SAD rotational treatment

D. Translation of planning to calculations
  1. Beam parameters
  2. Beam weighting
  3. Arc rotation therapy
  4. Irregular fields

E. Computerized treatment planning
  1. Isodose curves (beam characteristics)
  2. Surface dose
  3. Parallel opposed beam combination
  4. Wedge isodose curves
     (a) Wedge angle and hinge angle
     (b) Wedge factor
  5. Wedge techniques
     (a) Wedge pair
     (b) Open and wedged field combination
     (c) Skin compensation
  6. Beam combination (3-, 4-, 6- field techniques)

F. Surface corrections and hetereogeneities
  1. Corrections for surface obliquities
  2. Corrections for inhomogeneities
     (a) Linear (1-D) attenuation method
        1. Two-dimensional methods
        2. Volumetric methods
        3. Dose perturbations at interfaces

G. Adjoining fields and special dosimetry problems
  1. Two-field problem
  2. Three-field problem
  3. Craniospinal gapping
  4. Pacemaker
  5. Gonadal dose
  6. Pregnant patient

8. Electron Beam (3 lectures)

Learning objectives

The resident should learn:

1. *the basic characteristics of electron beams for therapy, including components of a depth-dose curve as a function of energy, electron interactions, isodoses, oblique incidence, and electron dose measurement techniques.*
2. *the nature of treatment planning with electrons, including simple rules for selecting energy based on treatment depth and range, effect of field size, dose to skin and bolus, and effects of field shaping, especially for small fields.*
3. *about field matching with photons and other electron fields, internal shielding, backscatter, and the effects of inhomogeneities on electron isodoses.*

A. Basic characteristics
   Depth-dose/isodose characteristics
   Electron interactions
   Coulomb scattering and range
   Dose vs. depth
   Isodoses
   Oblique incidence
   AAPM TG-25

B. Treatment planning with electrons
  1. Rules of thumb
  2. Selection of energy, field size
  3. Electron skin dose
  4. Electron bolus
  5. Electron field shaping

C. Field matching and other considerations
  1. Electron-electron gapping
  2. Electron-photon gapping
  3. Electron backscatter
  4. Inhomogeneities
  5. Internal shielding

9. External Beam Quality Assurance (2 lectures)

Learning objectives

The resident should learn:

1. *the goals of a departmental quality assurance (QA) program, the staffing required to perform these QA activities, and the duties and responsibilities of the individuals associated with the QA program.*
2. *what is entailed in making equipment selections in radiation therapy and the content of equipment specification.*
3. *what is involved in acceptance testing of a linear accelerator and in commissioning both a linear accelerator and a treatment planning system.*
4. *what linear accelerator quality assurance is required on a daily, monthly, and yearly basis and the acceptance tolerances associated with these tests.*

A. Overview of quality assurance in radiation therapy
   - Goals
   - JCAHO
   - ACR
   - AAPM TG-40
   - Staffing
   - Roles, training, duties and responsibilities of individuals
   - Equipment selection and specifications

B. Linac quality assurance
   1. Acceptance testing—Linac
   2. Commissioning—Linac
      - Data required
      - Computer commissioning
   3. Routine QA and tolerances
      - Daily QA
      - Monthly QA
      - Yearly QA

10. Radiation Protection and Shielding (2 lectures)

Learning objectives

The resident should learn:

1. *the general concept of shielding, including "As Low As Reasonably Achievable" (ALARA) and Federal regulations.*
2. *the units of personnel exposure, sources of radiation (manmade and natural), and means of calculating and measuring exposure for compliance with regulations.*
3. *components of a safety program, including Nuclear Regulatory Commission (NRC) definitions and the role of a radiation safety committee.*

A. Radiation safety
   1. Concepts and units
      - Radiation protection standards
      - Quality factors
      - Definitions for radiation protection
      - Dose equivalent
      - Effective dose equivalent
   2. Types of radiation exposure
      - Natural background radiation
      - Manmade radiation
      - National Council on Radiation Protection (NCRP) #91 recommendations on exposure limits
   3. Protection regulations
      (a) NRC definitions
         (1) Medical event
         (2) Authorized user
      (b) NRC administrative requirements
         (1) Radiation safety program
         (2) Radiation safety officer
         (3) Radiation safety committee
      (c) NRC regulatory requirements
      (d) Personnel monitoring

B. Radiation shielding
   1. Treatment room design
      (a) Controlled/uncontrolled areas
      (b) Types of barriers
      (c) Factors in shielding calculations
         (1) Workload (W)
         (2) Use factor (U)
         (3) Occupancy factor (T)
         (4) Distance
   2. Shielding calculations
      (a) Primary radiation barrier
      (b) Scatter radiation barrier
      (c) Leakage radiation barrier
      (d) Neutron shielding for high-energy photon and electron beams
   3. Sealed source storage
   4. Protection equipment and surveys
      (a) Operating principles of gas-filled detectors
      (b) Operating characteristics
      (c) Radiation monitoring equipment
   (1) Ionization chamber (Cutie Pie)
   (2) Geiger-Mueller counters
   (3) Neutron detectors

11. Imaging for Radiation Oncology (4 lectures)

Learning objectives

The resident should learn:

1. *the physical principles associated with good diagnostic imaging techniques.*
2. *the rationale behind taking port films, how port films are used in the clinic, and the response characteristics of common films used in the radiation therapy department.*
3. *the types of portal imaging devices that are available in radiation therapy, the operating characteristics of these various devices, and the clinical application of this technology in daily practice.*
4. *the physical principles of ultrasound, its utility and limitations as an imaging device, and its application to diagnosis and patient positioning.*
5. *the physical principles behind CT, magnetic resonance imaging (MRI), and positron emission tomography (PET) scanning, how these modalities are applied to treatment planning, and their limitations.*

6. *the advantages of one imaging modality over another for various disease and body sites*.
7. *image fusion, its advantage in treatment planning, the difficulties and limitations associated with image fusion, and how image fusion can be accomplished*.
   A. Routine imaging
      Diagnostic imaging physical principles
      Port films
      XV-2 film, EDR-2 film characteristics
      Processors
   B. Other imaging
      1. Electronic portal imaging
         Overview of electronic portal imaging devices (EPID)
         Types of portal imaging devices
         Clinical applications of EPID technology in daily practice
      2. Ultrasonography
         Physical principles
         Utility in diagnosis and patient positioning
   C. Image-based treatment planning
      1. CT scans
         Physical principles
         Hounsfield units, CT numbers, inhomogeneity corrections based on CT scan images
      2. MRI scanning
         Physical principles
         T1, T2, TE, TR imaging characteristics
         Advantages and limitations of MRI images for diagnosis and computerized treatment planning
   D. PET imaging
      1. Physical principles
      2. Utility for radiation therapy
      3. Image fusion
         (a) Advantages
         (b) Challenges
         (c) Techniques
         (d) Limitations

12. Three-dimensional Conformal Radiation Therapy (3D-CRT) Including International Commission on Radiation Units (ICRU) Concepts and Beam-Related Biology (3 lectures)

Learning objectives

The resident should learn:

1. *the concepts, goals, and technologies needed for planning and delivering 3D-CRT compared with conventional RT*.
2. *concepts and definitions associated with 3D-CRT planning including optimization strategies, uniform vs. nonuniform tumor dose distributions, nonbiologic and biologic models for computing dose-volume metrics, beam shaping techniques, and magnitudes, sources, and implications of day-to-day treatment variabilities*.
3. *ICRU definitions and reporting recommendations for tumor-related volumes such as gross tumor volume (GTV), clinical target volume (CTV), and planning target volume (PTV)*.
   A. 3D-CRT concepts and goals vs. traditional RT, comparison with protons
      Technology and methods for planning
      Multiple volume images (CT, MR, PET, MRSI, etc.)
      Image processing (registration, segmentation)
      Virtual simulation
      DRRs
      Multiple beams (>4)
      Noncoplanar beams
   B. Optimization methods
      Biologic implications of uniform vs. nonuniform dose delivery
      Nonbiologic and biologic dose-volume metrics (Dose Volume histograms [DVHs], tumor control probability [TCPs], Normal Tissue Complication Probability [NTCP])
      Margins
   C. Implications of treatment variabilities (systematic and random setup variabilities, patient breathing)
      ICRU 50 prescribing, recording, and reporting
      ICRU report 62 (supplement to ICRU report 50)

13. Assessment of Patient Setup and Verification (2 lectures)

Learning objectives

The resident should learn the principles of and devices for:

1. *patient immobilization and positioning*.
2. *imaging methods for monitoring patient geometry in the treatment position and how such images can be used for correcting patient alignment and modifying the initial treatment plan via an adaptive planning strategy*.
   A. Immobilization devices and methods
      Table positions, lasers, distance indicators
      Immobilization methods
      Positioning methods (calibrated frames, optical and video guidance, etc.)
   B. In-the-room intratreatment imaging (cont'd)
      Cone-beam
      Ultrasound
      Internal markers (e.g., implanted seeds)
      On-line correction of setup errors
      Adaptive planning concepts

14. Intensity-Modulated Radiation Therapy (2 lectures)

Learning objectives

The resident should learn:

1. *details on the different delivery system including advantages, differences, and limitations*.
2. *the differences for simulation and positioning compared with conventional therapy*.
3. *principles of inverse planning and optimization algorithms*.
4. *systematic and patient specific quality assurance*.
   A. IMRT delivery systems

1. Segmental MLC (SMLC) and dynamic MLC (DMLC)
2. Serial tomotherapy (MIMiC)
3. Helical tomotherapy
4. Robotic Linac
5. Simulation and immobilization/repositioning

B. Dose prescription and inverse planning
1. Treatment calculations
2. IMRT quality assurance

15. Special Procedures (3 lectures)

Learning objectives

The resident should learn:

1. *the basis of stereotaxic frame systems.*
2. *the frame placement, imaging, and treatment logistics.*
3. *differences in the stereotactic radiosurgery (SRS) systems and accuracy requirements.*
4. *dosimetry of small-field irradiation.*
5. *Total Body Irradiation (TBI) techniques and large-field dosimetry.*
6. *Logistics and dosimetric considerations for Total Skin Electron Radiotherapy (TSET) and e-arc*

A. Stereotactic radiosurgery
1. SRS delivery systems
2. Linac based
3. Gamma knife
4. Robotic Linac
5. Simulation and immobilization/repositioning

B. SRS Dose prescription and treatment planning
1. Treatment calculations
2. SRS quality assurance

C. Other special procedures
1. Photon total body irradiation
   - Patient setup
   - Dosimetry
   - Selection of energy, field size, distance
   - Monitor unit calculations
2. TSET
3. Electron arc

16. Brachytherapy (7 lectures)

Learning objectives

The resident should learn about:

1. *characteristics of the individual sources: Half-life, photon energy, half-value layer shielding, exposure rate constant, and typical clinical use.*
2. *source strength units: Activity, apparent activity, air kerma strength, exposure rate, equivalent of mg h of radium, and National Institute of Science and Technology (NIST) standards for calibration.*
3. *High-dose rate vs. low-dose rate in terms of alpha/beta ratios, fractionation, dose equivalence.*
4. *Specification of linear and point sources.*
5. *Implant dosimetry for planar implants vs. volume implant, including Patterson-Parker, Quimby, Memorial, Paris, and computational optimizations and calculations.*
6. *Implantation techniques for surface and interstitial implants, the sources used, and how they are optimized.*
7. *Uterine cervix applicators: Fletcher-Suit applicators (tandem and ovoids), high-dose rate applicators (tandem and ovoids/ring), and vaginal cylinders, and the treatment planning systems for each applicator.*
8. *Cervix dosimetry conventions: Milligram-h, Manchester system, bladder and rectum dose, and the ICRU system (point A and point B).*
9. *Radiation detectors used for calibration and patient safety.*
10. *Remote afterloading units, including dose rates and devices for delivery, safety concerns and emergency procedures, and shielding for patient and personnel.*
11. *Discuss NRC and state regulations regarding use, storage, and shipping of sources.*

A. Radioactive sources (general information)
   - Radium
   - Cesium-137
   - Cobalt-60
   - Iridium-192
   - Gold-198
   - Iodine-125
   - Palladium-103

B. Calibration of brachytherapy sources
   - Specification of source strength
   - Radium substitutes and radioactive isotopes currently used in brachytherapy
   - Linear sources
   - Seeds
   - Exposure rate calibration

C. Calculations of dose distributions
   - Biologic considerations of dose, dose rate, and fractionation
   - Calculation of dose from a point source
   - Calculation of dose from a line source

D. Systems of implant dosimetry
   - Paterson-Parker
   - Quimby
   - Memorial
   - Paris
   - Computer

E. Implantation techniques
   - Surface molds/plaques
   - Interstitial therapy
   - Intracavitary therapy
   - Uterine cervix
   - Milligram-h
   - Manchester system
   - Bladder and rectum dose
   - ICRU system
   - Absorbed dose at reference points

F. Gynecological implants
   - General information (advantages/disadvantages)
   - Remote afterloading units
   - High-dose rate (HDR) vs. Low-dose-rate (LDR)

G. Radiation protection for brachytherapy

Detectors
Regulatory requirements
Surveys
Inventory and wipe tests
Shipping and receiving

17. Hyperthermia

Learning objectives

The resident should learn:

1. *basic physics of hyperthermia and how this applies clinically*.
2. *hyperthermia systems*.
3. *Thermometry*.

A. Physics aspects of hyperthermia
The bio-heat equation and simplified solutions
Specific absorption rate (SAR).
Thermal aspects of blood flow/perfusion
Basic physics of ultrasound
Important technical considerations with microwaves and ultrasound devices

B. Elements of clinical hyperthermia physics
External superficial electromagnetic hyperthermia applicators.
Interstitial electromagnetic hyperthermia applicators.
Electromagnetic applicators for regional hyperthermia.
Thermometry performance criteria, tests, and artifacts.

C. Ultrasound hyperthermia systems

17. Particle Therapy

Learning objectives

The resident should learn:

1. *basic physics of neutron and proton beams*.
2. *configurations of proton and neutron delivery systems*.
3. *treatment planning considerations for particle therapy*.

A. Protons
Proton beam energy deposition
Equipment for proton beam therapy
Clinical beam dosimetry
Clinical proton beam therapy
Treatment planning
Treatment delivery
Clinical applications

B. Neutrons
Fast neutron production
Basic interactions
Accelerator requirements
Clinical beam dosimetry
Treatment planning
Treatment delivery
Clinical applications
Boron neutron capture

DISCUSSION AND CONCLUSION

The curriculum was completed and approved by the ASTRO Board of Directors in late 2003. It is our hope that teaching physicists will adopt the recommended curriculum and simultaneously, that the ABR for its written physics examination, and the ACR for its training examination, will use the recommended curriculum as the basis for subject matter and depth of understanding. For this reason, the curriculum will be updated every 2 years. The committee strategically did not make recommendations as to textbooks to be used, as this is left to the institution. It is anticipated that future curricula will be available on-line and will include teaching materials and examination questions.

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