Curriculum Guide for Educational Programs in Nuclear Medicine Technology
4th Edition

SNM
Advancing Molecular Imaging and Therapy

NMT Entry-Level Curriculum Guide, 4th Edition

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The Curriculum Guide for Educational Programs in Nuclear Medicine Technology 4th Edition has been revised to include the expanding and increasingly complex educational content that is necessary for preparing knowledgeable, competent, and qualified entry-level Nuclear Medicine Technologists.

Changes in this edition include the following:

- Increased emphasis on standardized general education requirements
- New sections:
    - Cross-sectional Anatomy
    - Health Science Research
    - Emerging Technologies
- Additions:
    - Administration of contrast media
    - Single-photon emission computed tomography (SPECT)/computed tomography (CT), positron emission tomography (PET)/CT, and CT throughout
    - X-ray production and X-ray beam physics
    - Radiation exposure to nuclear medicine patients
    - NUREG-1556, Volume 9, 2002: model procedures
    - Sr82/Rb82 generator
    - Splenic imaging with heat-denatured red blood cells
    - Technegas
    - Radiosynoviorthesis
    - Radiolabeled monoclonal antibody therapy
    - Y-90 microspheres
- Expanded sections:
    - Instrumentation: Counting Statistics
    - Nuclear Pharmacy and Pharmacology
    - Oncology—separate section
    - Nuclear Cardiology
- Revised in its entirety:
    - Nuclear Physics is now Radiation Physics
- Deletions:
    - Rb81/Kr81m generator
    - Schillings procedures
    - Radioassay

Society of Nuclear Medicine Technologist Section
Recommended Entry-Level Curriculum

Minimum Required General Education Courses

- General Physics (2 semesters or equivalent)
- General Chemistry (2 semesters or equivalent)
- Human Anatomy and Physiology (2 semesters or equivalent)
- College Algebra or higher
- Statistics
- Oral/Written Communications (2 semesters or equivalent)
- Humanities
- Social Sciences

Optional Preparatory Coursework:

- Biology
- Molecular Biology/Cellular Biochemistry
- Genetics
- Pathophysiology
- Immunology
- Biomedical Ethics
- Health Care Management Courses
- General Business Courses
- Medical Terminology
- Advanced Mathematics
- Computer Science

Professional Core Topics

- Patient Care
- Health Sciences Research
- Ethics and Law
- Cross-sectional Anatomy
- Systems-Based Practice
- Medical Informatics

Professional Topics

- Radiobiology
- Radiation Protection
- Radiation Physics
- Instrumentation
    - Nonimaging
    - Counting Statistics

  - Computers
  - Imaging
- Nuclear Pharmacy and Pharmacology
- Diagnostic Procedures
  - Skeletal
  - Cardiovascular
  - Central Nervous System
  - Digestive System
  - Endocrine/Exocrine System
  - Genitourinary System
  - Hematology and In Vitro
  - Respiratory System
  - Infection and Inflammation
  - Oncology
  - Pediatrics
- Clinical Education
- Radionuclide Therapy
- Emerging Technologies

Chapter 1

Minimum Required General Education Courses

Society of Nuclear Medicine Technologist Section General Education Core Curriculum

The profession of Nuclear Medicine Technology has experienced significant advancements in technology and molecular science. As the field has advanced, the scope of practice for Nuclear Medicine Technologists has increased. The need for critical thinking and the ability to respond to clinical, organizational, and fiscal demands facing the health care industry supports the creation of a multiskilled technologist to perform nuclear medicine imaging studies and provide assistance with radionuclide therapy treatments.

The Society of Nuclear Medicine Technologist Section Entry-Level Curriculum includes a general education core that lists required courses in math, science, and the liberal arts. These courses are intended to prepare students for entry into the professional component of the Nuclear Medicine Technologist Program. Also included is a list of optional preparatory coursework that could further enhance the educational curriculum for any Nuclear Medicine Technology program.

It is the belief of the Society of Nuclear Medicine Technologist Section that the general educational core curriculum will provide Nuclear Medicine Technologist students with the necessary foundation for the successful completion of the professional component of a Nuclear Medicine Technology program.

Chapter 2

Patient Care

Patient Care

As the role of the medical imaging professional continues to expand, more knowledge is needed in all areas. Patient care is no exception. Advanced patient care skills are essential elements of providing high-quality patient care. This section addresses patient care and safety, patient-technologist communication, age-specific needs, emergency care, and venipuncture. All students should be certified in cardiopulmonary resuscitation or basic life support.

Objectives:

1. Demonstrate effective communication and patient interaction
2. Identify, verify, and assess medical records
3. Practice proper patient transport and safety
4. Practice proper infection control techniques
5. Assess, respond to, and manage patient needs
6. Differentiate and perform various routes of radiopharmaceutical and pharmaceutical administration
7. Perform proper phlebotomy techniques

Patient Care

I. Patient Communication and Interaction
   A. Components of communication
      1. Verbal
      2. Nonverbal
      3. Written
   B. Problems in communication
      1. Effects of positive and negative methods of communication
      2. Barriers to effective communication
      3. Confrontational versus nonconfrontational communication
      4. Methods for communicating with patients demonstrating specific behaviors or moods
   C. Communication and interaction with specific groups
      1. Terminally ill
      2. Chronically ill
      3. Cancer
      4. Unconscious
      5. Developmentally or mentally impaired
      6. Physically impaired
      7. Sensory impaired
      8. Non-English speaking
      9. Multicultural
      10. Age-specific
         a. Infant
         b. Toddler
         c. Preschool and grade school
         d. Adolescent
         e. Early adulthood
         f. Middle adulthood
         g. Older adulthood
         h. Late adulthood
   D. Age-specific competency
      1. Developmental changes
      2. Impact of illness
      3. Adaptation to patient's age-specific needs
         a. Cognitive domain
         b. Affective domain
         c. Psychomotor domain

II. Patient Management
   A. Requisition process
      1. Receipt of order
      2. Verification of order
      3. Appropriateness of indication for procedure
         a. Correlation with history

b. Contraindications
B. Patient identification
C. Patient history
D. Medication reconciliation
E. Explanation of procedure
F. Assessment of the patient's needs as they relate to the procedure

III. Medical Records
A. Purpose
B. Contents and organization
C. Electronic medical record
D. Technologist's responsibilities
1. Documentation of procedure
2. Confidentiality

IV. Patient Transport and Safety
A. Transportation
1. Body mechanics
2. Lifting techniques
3. Transfer techniques
4. Special considerations
a. Casts
b. Traction devices
c. Intravenous lines and poles
d. Catheters
e. Oxygen cylinders and tubing
f. Chest tubes
g. Other
B. Safety
1. Safety devices for stretchers, scanning tables, wheelchairs
2. Immobilization techniques
3. Equipment safety

V. Infection Control
A. General principles
1. Medical asepsis
2. Surgical asepsis
B. Infections acquired in the course of medical care
1. Nosocomial
a. Iatrogenic
b. Other
2. Community acquired
C. Methods and sources of transmission
1. Direct contact
2. Aerial route
3. Fomites

4. Endogenous
5. Blood and blood products
6. Other body fluids

D. Risks to health care personnel
   1. Nosocomial infections
      a. Exogenous
      b. Endogenous
   2. Blood-borne pathogens
      a. Human immunodeficiency virus and acquired immunodeficiency syndrome
      b. Viral hepatitis
      c. Methicillin-resistant *Staphylococcus aureus*
   3. Airborne pathogens
      a. Tuberculosis
      b. Herpes zoster
      c. Methicillin-resistant *Staphylococcus aureus*
   4. Vectors
      a. Mechanical
      b. Biological

E. Controlling pathogenic contamination
   1. Standard precautions
   2. Sharps safety
   3. Hand-washing techniques
   4. Isolation
      a. Direct
      b. Reverse
   5. Disinfection and antiseptics
   6. Sterilization
      a. Autoclaving
      b. Dry heat
   7. Disposable equipment
   8. Injury reporting

F. Special techniques
   1. Masking, gowning, and gloving for isolation
   2. Sterile package opening
   3. Sterile field maintenance

VI. Patient Support

A. Patient assistance
   1. Dressing and undressing
   2. Security of patient property
   3. Bedpans, urinals, and diapers
   4. Emesis basins
   5. Comfort and modesty
   6. Psychological support

B. Support equipment
    1. Intravenous lines and pumps
    2. Intravenous catheters
        a. Peripheral inserted central catheter lines
        b. Central line catheter
        c. Other
    3. Urinary catheters
    4. Glucometer
    5. Oxygen delivery regulators
    6. Drainage tubes
    7. Suction devices
    8. Traction devices
    9. Removable and nonremovable braces

C. Vital signs
    1. Pulse
    2. Respiration
    3. Blood pressure
    4. Temperature

D. Emergencies
    1. Nausea and vomiting
    2. Reactions to medications
    3. Reactions to contrast media
    4. Syncope
    5. Seizures
    6. Diabetes-related hypoglycemia
    7. Hemorrhage
    8. Shock
    9. Cardiac/respiratory events
        a. Crash cart
        b. Codes
        c. Electrocardiogram
        d. Basic care life support for health care providers
            i. Signs and symptoms of respiratory or cardiac distress
            ii. Obstructed airway
            iii. Cardiopulmonary resuscitation
            iv. Automated external defibrillator

VII. Routes of Administration

A. Intravenous administration
    1. Site selection
        a. Location of commonly used sites
            i. Arm
            ii. Hand and wrist
            iii. Foot

   b. Factors affecting site selection
      i. Procedure requirements
      ii. Lumen size and quality
      iii. Scarring
      iv. Thrombosis
      v. Edema
      vi. Mastectomy
      vii. Loss of sensation
      viii. Arteriovenous fistula for dialysis
      ix. Patient preference
2. Injection supplies
   a. Needle types and gauges
   b. Angiocatheter types and gauges
   c. Types of intravenous tubing
   d. Three-way stopcock
   e. Other standard supplies
3. Patient preparation
   a. Explanation of procedure
   b. Aseptic technique
4. Procedure for intravenous access
   a. Placement of tourniquet
   b. Methods to enhance vessel access
   c. Patient position
   d. Selection of site
   e. Needle position and injection technique
   f. Assurance of free flow
   g. Determination of compatible intravenous fluids
   h. Catheter removal
5. Injecting radiopharmaceuticals and contrast media agents
   a. Manual techniques
      i. Routine injection
      ii. Bolus injection
      iii. Flushes
      iv. Heparin locks
      v. Injection through existing intravenous lines
   b. Automatic techniques
      i. Syringe infusion pumps
      ii. Contrast media injectors
   c. Intravenous flow rates
   d. Complications
      i. Air embolism
      ii. Extravasation
      iii. Adverse reaction
      iv. Thrombosis
      v. Tissue inflammation, damage, and necrosis
      vi. Loss of sensation

6. Proper disposal of used materials

B. Other methods of administration
    1. Oral
        a. Aseptic technique
        b. Techniques for assisting patients whom have difficulty swallowing
    2. Intramuscular injection
        a. Site selection
        b. Aseptic technique
        c. Injection technique
    3. Inhalation
        a. Equipment setup
        b. Administration technique
    4. Subcutaneous injection
        a. Site selection
        b. Aseptic technique
        c. Injection technique
    5. Intradermal injection
        a. Site selection
        b. Aseptic technique
        c. Injection technique
    6. Intrathecal injection
        a. Role of the technologist
        b. Equipment
        c. Maintenance of a sterile field
    7. Intracavitary
        a. Role of the technologist
        b. Equipment
        c. Maintenance of a sterile field

C. Contrast media agents
    1. Administration of contrast media
        a. Oral
        b. Intravenous
        c. Other
    2. Types of contrast media
        a. Iodinated
        b. Noniodinated
    3. Iodinated contrast materials
        a. Procedures requiring the use of iodinated contrast
        b. Instructions given to diabetic patients receiving antihyperglycemic agents (eg, metformin)
    4. Characteristics of iodinated contrast materials
        a. Water solubility and hydrophilicity
        b. Osmolality
            i. High osmolar contrast media
            ii. Low osmolar contrast media

iii. Ionic versus nonionic
c. Viscosity
d. Calcium binding
e. Iodine concentration

5. Dose calculations
   a. Indication
   b. Adult versus pediatric
   c. Concentration and volume
6. Adverse reactions
   a. Recognition
   b. Treatment
   c. Documentation

VIII. Phlebotomy

A. Procedure

1. Method of drawing and dispensing samples
2. Complications
3. Anticoagulant selection
4. Types and color coding of evacuated vials

Chapter 3

Health Sciences Research

Health Sciences Research

Research methods are important because the health care profession is continually changing, which requires the Nuclear Medicine Technologist to adapt procedures and practices to the changing environment. The Nuclear Medicine Technologist needs to contribute to the body of knowledge and be able to effectively analyze resources to promote best practice in the profession.

Objectives:

1. Apply the foundations of research methodology
2. Critique and analyze research articles to determine the accuracy and validity of research findings
3. Differentiate between qualitative and quantitative research methodologies
4. Evaluate and apply statistical models in research
5. Compose and present research findings
6. Differentiate and calculate sensitivity, specificity, prevalence, negative and positive predictive value, and accuracy of tests based on results

Health Sciences Research

I. Foundations of Health Science Research
   A. Research concepts applied to health sciences
   B. Types of research
      1. Basic research
      2. Applied research
   C. Evaluation of the literature

II. Identification of a Topic
   A. Identification of a reasonable question
   B. Purpose of the study
   C. Hypothesis of the study

III. Literature Review
   A. Literature search
   B. Resources
      1. Library resources
      2. Computer searches
   C. Organization of material

IV. Refinement of the Research Question
   A. Problem
   B. Background
   C. Purpose
   D. Significance
   E. Research question or hypothesis

V. Components of Research Study
   A. Abstract
   B. Introduction
   C. Methods
   D. Results
   E. Discussion
   F. Limitations
   G. References
   H. Style
   I. Communicating with tables and figures

VI. Research Methods
   A. Qualitative research
      1. Purpose
      2. Types
   B. Quantitative research
      1. Purpose
      2. Types

C. Parameters of a research study
    1. Defining and operationalizing terms
    2. Assumptions
    3. Scope of the study
    4. Limitations of the study
    5. Sampling methods
D. Examples of data collection techniques
    1. Observation
    2. Interview
    3. Written questionnaires
    4. Record and artifact review
    5. Instrumentation
    6. Tests, measures, and inventories
    7. Validity and reliability of test instruments
E. Data analysis
    1. Qualitative
        a. Patterns, categories, and descriptive units
        b. Grounded theory
    2. Quantitative
        a. Parametric data
        b. Interval data
        c. Ratio data
        d. Nonparametric data
        e. Nominal data
        f. Ordinal data
    3. Descriptive statistics
        a. Central tendency
        b. Variability
    4. Inferential statistics
        a. Significant differences
        b. Tests for correlation
        c. Comparison of more than 2 variables
    5. Biostatistics
        a. Sensitivity
        b. Specificity
        c. Positive predictive value
        d. Negative predictive value
        e. Accuracy
    6. Computer analysis
        a. Statistical Package for the Social Sciences
        b. Statistical Analysis System
        c. Biomedical Data Package
        d. Statistical Parametric Mapping MATLAB
        e. Minitab
        f. Other

Chapter 4

Ethics and Law

Ethics and Law

This section focuses on the interaction of Nuclear Medicine Technologists with their patients, coworkers, and community in accordance with ethical standards and laws of the health care professional. Technologists need to interact with and have respect for individuals from different cultures, beliefs, gender orientations, and socioeconomic backgrounds. Legal and compliance issues, scopes of practice, and patients' rights are addressed.

Objectives:

1. Assess situations to determine if a Nuclear Medicine Technologist performed ethically based on personal, professional, and societal standards within the United States
2. Analyze scenarios to determine if Nuclear Medicine Technologists are working within their scope of practice and using appropriate practice standards
3. Distinguish between the different types of law
4. Outline the legal proceedings and define the burden of proof
5. Appraise a scenario to determine if the Nuclear Medicine Technologist is violating the patient's rights
6. Differentiate between the employer's and employee's legal responsibilities
7. Argue and discuss medical-legal issues

Ethics and Law

I. Ethical Theories/Principles

II. Personal Ethics
- A. Values development
- B. Impact/effect on care
- C. Values clarification
- D. Moral development

III. Professional Ethics
- A. Professional code(s) of ethics
- B. Values conflict

IV. Societal Ethics
- A. Patient rights
- B. Impact on care
- C. Values conflict
- D. Cultural diversity
    1. Cultural beliefs and norms
    2. Societal and individual factors

V. Scope of Practice and Practice Standards

VI. Types of Law
- A. Civil law
- B. Civil liability intentional torts
    1. Assault
    2. Battery
    3. False imprisonment
    4. Emotional distress
    5. Fraud
    6. Invasion of privacy
    7. Defamation
        a. Slander
        b. Libel
    8. Vicarious liability
- C. Unintentional torts/negligence
    1. Standard of care
    2. Contributory
    3. Comparative
- D. Criminal law
    1. Criminal negligence
    2. Falsification of records
    3. Drugs
    4. Fraud

5. Theft

E. Administrative law
   1. Federal
      a. Health Insurance Portability and Accountability Act
      b. Equal Employment Opportunity
   2. State
   3. Local

F. Civil proceedings
   1. Pleading
   2. Summons and complaint
   3. Discovery
   4. Motions
   5. Trial procedure
   6. Evidence
   7. Verdict
   8. Appeals

G. Burden of proof
   1. Res Ipsa Loquitur
   2. Respondeat Superior

H. Patient consent
   1. Implied
   2. Informed
   3. Uninformed
   4. Research (institutional review board)

I. Advanced directives
   1. Living wills
   2. Do-not-resuscitate orders
   3. Power of attorney

J. Employer and employee responsibility
   1. Labor laws
   2. Discrimination law
   3. Harassment in the workplace
      a. Quid pro quo
      b. Hostile work environment
      c. Protected persons
      d. Unwelcome conduct
      e. Employer's liability
      f. Sexual harassment
      g. Harassment
      h. Assault and battery
      i. Infliction of emotional distress
      j. Invasion of privacy
      k. Wrongful discharge
   4. Conditions of employment
      a. Position descriptions
      b. Drug screening

c. Background checks
d. Misrepresentation

5. Liability coverage
   a. Employer
   b. Personal
   c. Institutional (students)
6. Equipment safety regulations
7. Facility safety/training
8. Risk management
9. Whistleblower protection

VII. Medical-Legal Issues
- A. Standard of care
- B. Scope of practice
- C. Malpractice
- D. Confidentiality
- E. Euthanasia
- F. False imprisonment
- G. Radiation protection laws

Chapter 5

Cross-sectional Anatomy

Cross-sectional Anatomy

The ability to locate and identify structures in the axial (transverse), sagittal, and coronal planes is critical in all imaging modalities. Volumetric data sets and 3-dimensional reconstruction of the body structures are increasingly important to the critical diagnosis and treatment of diseases. To enhance patient care and assist physicians with the prognosis, Nuclear Medicine Technology professionals must understand cross-sectional anatomy in each of the imaging modalities.

Objectives:

1. Distinguish normal anatomical structures on computed tomography, magnetic resonance imaging, ultrasonography, nuclear medicine, fusion interventional, and cardiac catheterization laboratory images in the transverse axial, coronal, sagittal, and orthogonal (oblique) cross-sectional imaging plane, within the
    a. Head
    b. Neck
    c. Thorax
    d. Abdomen
    e. Pelvis
    f. Body
    g. Extremities and large joints
2. Distinguish common pathologies recorded on multiplanar images

Cross-sectional Anatomy

I. Introduction to Sectional Anatomy
   A. Body planes
      1. Median
      2. Sagittal
      3. Coronal, frontal
      4. Transverse, cross-horizontal
   B. Anatomical directions and positions
      1. Cranial, superior
      2. Caudal, inferior
      3. Anterior, ventral
      4. Posterior, dorsal
      5. Medial
      6. Lateral
      7. Proximal
      8. Distal
   C. Body cavities
      1. Ventral
         a. Thoracic
         b. Abdominopelvic
      2. Dorsal
         a. Cranial
         b. Vertebral

II. Anatomy and Common Pathologies Recorded on Multiplanar Images of the Head
   A. Cranial bones
      1. Frontal
      2. Ethmoid
      3. Parietal
      4. Sphenoid
      5. Occipital
      6. Temporal
   B. Facial bones
      1. Nasal
      2. Zygomas
      3. Maxilla
      4. Mandible
      5. Lacrimal
   C. Temporomandibular joint
   D. Sinuses
      1. Frontal
      2. Maxillary
      3. Ethmoid
      4. Sphenoid

E. Orbit and eye
F. Muscles
G. Vascular structures

III. Anatomy and Common Pathologies Recorded on Multiplanar Images of the Brain
A. Frontal lobe
B. Parietal lobe
C. Temporal lobe
D. Occipital lobe
E. Cerebellum
F. Midbrain
G. Pons
H. Medulla oblongata
I. Thalamus
J. Hypothalamus
K. Limbic system fissures (sulci)
L. Convolutions (gyri)
M. Meninges
N. Ventricles
O. Vascular structures

IV. Anatomy and Common Pathologies Recorded on Multiplanar Images of the Neck
A. Organs
1. Pharynx
2. Larynx
3. Esophagus
4. Trachea
5. Thyroid
6. Parathyroid
7. Salivary
B. Cervical spine
C. Muscles
D. Vascular structures
E. Lymphatics

V. Anatomy and Common Pathologies Recorded on Multiplanar Images of the Thorax
A. Organs
1. Lungs
2. Diaphragm
3. Heart
4. Breasts
5. Thymus
B. Thoracic spine

C. Sternum
D. Ribs
E. Scapulae
F. Clavicles
G. Muscles
H. Vasculature structures
I. Lymphatics

VI. Anatomy and Common Pathologies Recorded on Multiplanar Images of the Abdomen
A. Organs
    1. Liver
    2. Gallbladder and biliary system
    3. Spleen
    4. Pancreas
    5. Stomach
    6. Kidneys and ureters
    7. Adrenals
    8. Intestines
B. Lumbar spine
C. Muscles
D. Vasculature structures
E. Lymphatics

VII. Anatomy and Common Pathologies Recorded on Multiplanar Images of the Pelvis
A. Organs
    1. Bladder/ureters
    2. Colon
    3. Rectum
B. Male organs
    1. Penis
    2. Testes/scrotum
    3. Prostate
C. Female organs
    1. Vagina
    2. Uterus
    3. Cervix
    4. Ovaries
D. Pelvic bones
    1. Ilium
    2. Ischium
    3. Pubis
    4. Sacrum
    5. Coccyx
E. Muscles

F. Vasculature structures
G. Lymphatics

VIII. Anatomy and Common Pathologies Recorded on Multiplanar Images of the Spine
A. Vertebral column
B. Spinal cord
C. Ligaments
D. Muscles
E. Vascular structures

IX. Anatomy and Common Pathologies Recorded on Multiplanar Images of the Upper Extremity
A. Clavicle
B. Scapula
C. Humerus
D. Ulna
E. Radius
F. Wrist
G. Hand muscles
H. Vasculature structures
I. Lymphatics

X. Anatomy and Common Pathologies Recorded on Multiplanar Images of the Lower Extremity
A. Hip
B. Femur
C. Patella
D. Tibia
E. Fibula
F. Ankle
G. Foot
H. Muscles
I. Vasculature structures
J. Lymphatics

Chapter 6

Systems-Based Practice

Systems-Based Practice

As the role of the health care professional continues to expand and systems-based practice continues to evolve, the fundamentals of health care policy and regulations of delivery systems must be understood. Factors for future key health policy and ethical viewpoints regarding the accessof health care must be explored.

Objectives:

1. Review and discuss the history and evolution of US health care systems
2. Review and discuss health care institutional economics and organization
3. Discuss and describe the role and function of present-day health care delivery systems
4. Describe the scope of practice of the Nuclear Medicine Technologist in relation to the interprofessional health care team
5. Describe and explore factors affecting the future of health care delivery systems

Systems-Based Practice

I. History of Health Care Delivery Systems
   A. Philanthropic
   B. Private, for-profit, not-for-profit, government
   C. Specialty services
   D. Affiliation: university teaching, community, nonaffiliated
   E. Alternative delivery systems
   F. Managed care

II. Health Care Institutions Economics and Organization
   A. Mission
      1. Vision
      2. Goals
      3. Objectives
   B. Administrative structure and governance
   C. Levels of care provided
      1. Primary
      2. Secondary
      3. Tertiary
   D. Regulatory agencies
      1. State
      2. Federal government
   E. Licensing and accreditation
      1. The Joint Commission
      2. Intersocietal Commission on the Accreditation of Nuclear Laboratories
      3. American College of Radiology
   F. Budgetary management/stakeholder association
      1. Fiscal management
      2. Operations management
      3. Asset management

III. Present-Day Health Care
   A. Managed care model
      1. Health maintenance organization
      2. Preferred providers organization
      3. Physician-hospital organization
      4. Insurance systems
   B. Legislation driven
      1. Patient rights
      2. Health Insurance Portability and Accountability Act
      3. Reimbursement
         a. Third-party payors
         b. Private commercial insurance
         c. Government-controlled reimbursement

d. Diagnostic Related Group (DRG)
e. Common Procedural Terminology (CPT)
f. Ambulatory Payment Codes (APC)
g. Healthcare Common Procedure Coding System (HCPCS)
h. International Classification of Disease, Ninth Revision (ICD-9) codes

4. Consumer demands
   a. Access to information
   b. Access to care
   c. Quality of care
   d. Health care costs
5. Health care team/organization relationships
   a. Professional roles
   b. Scope of practice
   c. Ethical responsibilities
   d. Interactions
6. Changes in the health care environment
   a. Outpatient clinics
   b. Emergency medical clinics
   c. Home health care
   d. Nursing home/assisted living facilities
   e. Telemedicine

IV. Factors Shaping the Future of Health care

A. Demographics
   1. Aging population
   2. Health care demand
   3. Utilization of acute and long-term care
   4. Ratio of younger to older workers

B. Technology
   1. Information and health care technology
      a. Picture archiving and communications systems (PACS)
      b. Radiology information systems (RIS)
      c. Digital Imaging and Communications in Medicine (DICOM)
      d. Other
      e. Lifetime Clinical Records
      f. Medical instruments and equipment
   2. Biomedical breakthroughs
      a. Immunology
      b. Brain research
      c. Genetic coding
      d. Other
   3. Changes in delivery and financing of health care

   a. Health care costs
   b. Expenditure control
   c. Access to care
   d. Efficacy, effectiveness, and efficiency
   e. Expenditures for prevention versus cure
4. Licensure
   a. Protection of the health care consumer
   b. Licensure and multicredentialing of the professional
   c. Consumer utilization monitoring
   d. Health outcome measures
5. Promotion of health and wellness
   a. Trend toward promotion of good health in our population
   b. Workplace wellness programs
   c. Life span and longevity

Chapter 7

Medical Informatics

Medical Informatics

Medical informatics is essential for the future implementation of clinical system data entry and development. The engaged process of enhancing the student's knowledge, experience, and training in the creation and utilization of patient data, administration, and medical quality assurance will be the focus of this specialty. Patients, caregivers, and the health care community at large will benefit from the accessibility of ongoing medical information and data into a computerized system. Ongoing health care information and technology for health care delivery systems and subsequent interfacing, in conjunction with mandatory patient-centered documentation for federal, state, regulatory, and credentialing agencies, must be studied and maintained.

Objectives:

1. Apply and practice Joint Commission standards in the health care environment
2. Apply and practice Health Insurance Portability and Accountability Act regulations in the health care environment
3. Recognize the different information systems used in the health care environment and manage patient information appropriately

Medical Informatics

I. The Joint Commission Standards
   A. Accountability for protecting patient information
   B. Consents
   C. Education regarding policies, rights, and responsibilities

II. Health Insurance Portability and Accountability Act
   A. Evolution of Health Insurance Portability and Accountability Act
   B. Impact on health care providers and personnel
   C. Disclosure
   D. Laws and regulations affecting the use of disclosure of health information

III. Patient Information
   A. Patient record
      1. Information systems and standards
         a. Hospital information systems
         b. Radiology information systems (RIS)
         c. Picture archiving and communications systems (PACS)
         d. Radiopharmacy information system
         e. Telemedicine
   B. Physical or electronic medical records content
      1. Elements of proper charting and documentation
      2. Legal ramifications of improper charting and documentation
   C. Ownership and release of the medical record

Chapter 8

Radiobiology

Radiobiology

This section covers the interactions of ionizing radiation with human tissue, its potential effects, and dosimetry. This is background knowledge needed to understand more fully the concepts and importance of radiation protection.

Objectives:

1. Review the characteristics and sources of different types of radiation
2. Differentiate appropriate radiation measurements, including internal and external exposure
3. Distinguish different types of radiation interactions with matter
4. Recognize cellular response of radiation on micro and macro level
5. Discuss the risk-to-benefit ratio of radiation exposure in terms of diagnostic and therapeutic nuclear medicine procedures
6. Recognize factors influencing absorbed dose to the general public and occupationally exposed workers
7. Explain radiation hazards and use protection techniques for pregnant women and breast-feeding mothers

Radiobiology

I. Characteristics of Radiation
   A. Types of ionizing radiation
      1. Alpha
      2. Beta-negative particles (negatrons)
      3. Beta-positive particles (positrons)
      4. Gamma rays
      5. X-rays
      6. Neutrons
   B. Half-life
   C. Energy

II. Sources of Radiation
   A. Environmental
      1. Natural
      2. Man-made
   B. Medical
   C. Occupational

III. Measurement of Radiation
   A. Exposure
   B. Absorbed dose
   C. Dose equivalent
   D. Effective dose equivalent
   E. Cumulative dose

IV. Cell Biology
   A. Cell structure
   B. Molecular components
      1. Water
      2. DNA
      3. Others
   C. Cell reproduction
      1. DNA synthesis
      2. Mitosis
      3. Meiosis
   D. Cell replication cycle

V. Interactions of Radiation with Matter
   A. Direct action
   B. Indirect action
   C. Linear energy transfer
   D. Relative biological effectiveness
   E. Free radicals
   F. Target theory

G. Deterministic versus stochastic effects

VI. Radiation Genetics
- A. Causes and effects of genetic mutations
  1. Spontaneous mutation
  2. Mutagenesis
  3. Carcinogenesis
  4. Gene mutations and cancer
- B. Effects of radiation on DNA
- C. Chromosome and chromatid aberrations
- D. Repair versus mutation

VII. Cellular Responses to Radiation
- A. Stage of cell replication cycle versus radiosensitivity
  1. Repair mechanism
  2. Apoptosis and suppressor gene p53
- B. Consequences of irradiation
  1. Restitution
  2. Division delays and cell synchrony
  3. Interphase death
  4. Reproductive failure
  5. Chromosome stickiness
- C. Survival curves
- D. Relative biological effectiveness and quality factor
- E. Lethal dose $(LD)_{50/30}$ and LD_{100}
- F. Oxygen enhancement ratio

VIII. Factors Affecting Cellular Response to Radiation
- A. Physical
- B. Chemical
- C. Biological

IX. Radiosensitivity and Cell Populations
- A. Law of Bergonie and Tribondeau
- B. Cell compartment categories
  1. Stem
  2. Transitional
  3. Differential
- C. Cell populations
- D. Cellular repair

X. Tissue and Systemic Responses to Radiation
- A. Acute versus late effects
  1. Acute radiation sickness syndrome
- B. Total-body irradiation
  1. Hematopoietic syndrome

2. Gastrointestinal syndrome
3. Central nervous system syndrome

C. Tissue repair

XI. Effects of In Utero Irradiation
- A. Radiosensitivity of embryo/fetus
- B. Phases of embryonic/fetal development
- C. Effects of radiation versus phase of development

XII. Late Effects of Radiation Exposure
- A. Relationship of radiation exposure to specific effects
  1. Dose versus effect models
  2. Problems associated with researching radiation-induced effects/disease
- B. Nonspecific life shortening
- C. Genetic effects (spontaneous mutation versus radiation-induced damage)
- D. Carcinogenesis
- E. Cataract formation
- F. Other diseases

XIII. Radiation doses
- A. Factors influencing absorbed dose from internal sources
  1. Concentration and organ masses
  2. Effective half-life
  3. Physical and chemical characteristics of radionuclide
  4. Absorbed fraction
  5. Cross-irradiation
- B. Organ with highest dose (critical organ) and target organs
  1. Target organs
  2. Nontarget critical organs
  3. Gonadal exposure
- C. Absorbed dose calculations
  1. Bioassay
  2. Total body counting
  3. Classic and Medical Internal Radiation Dose methods
  4. Formulas
  5. Charts and tables

XIV. Risk-to-Benefit Ratios
- A. Radiation hazard versus medical need
- B. Medical radiation exposures
  1. Comparative doses from diagnostic and therapeutic procedures
  2. Cumulative doses

XV. Radiation Exposure to Nuclear Medicine Patients

A. Factors affecting dose to individual
    1. Dose administered
    2. Types of radioactive emissions
    3. Physical half-life
    4. Chemical and physical states
    5. Pathologic conditions
    6. Age of patient
B. General dose levels in nuclear medicine
    1. General exposure ranges
    2. Benefit versus risk
C. Hazards and precautions for pregnant women
    1. Sources of irradiation to fetus
    2. Radiosensitivity of fetus
    3. Estimated dose to fetus from nuclear medicine procedures
    4. Actions after exposure
D. Hazards and precautions for breast-feeding mothers
    1. Secretion of radionuclides in breast milk
    2. Hazard to breast-feeding infant
    3. Estimated dose to fetus from nuclear medicine procedures
    4. Precautions

XVI. Advisory Agencies
A. International Commission on Radiation Units and Measurement
B. National Council on Radiation Protection and Measurement
C. National Academy of Sciences Advisory Committee on the Biologic Effects of Ionizing Radiation
D. United Nations Scientific Committee on the Effects of Atomic Radiation
E. Conference of Radiation Control Program Directors Inc
F. Biologic Effects of Ionizing Radiation Reports

Chapter 9

Radiation Protection

Radiation Protection

This section covers the principles and applications of radiation protection as well as applicable regulations, including an awareness of how to apply the “As Low As Reasonably Achievable” (ALARA) philosophy to ionizing radiation exposure. Individual regulations are also covered in detail in content areas where they apply, such as radiopharmacy, instrumentation, and radionuclide therapy.

Objectives:

1. Describe the characteristics of radiation and define radiation measurement units
2. Identify the agencies and interpret/comply with the appropriate regulations associated with radiation exposure and receipt, use, and disposal of radioactive materials
3. Define radiation exposure limits and apply safe radiation protection techniques in accordance with the ALARA philosophy
4. Utilize appropriate radiation detection and monitoring equipment and evaluate readings
5. Employ the practical and appropriate methods of radiation protection (time, distance, and shielding) and predict exposure levels based on calculations
6. Assess a scenario and utilize proper protocols to prevent a medical event
7. List what constitutes an error, excess exposure, and medical event and employ appropriate course of action
8. Identify and manage radioactive material spills and contamination
9. Describe the Nuclear Medicine Technologists’ role and responsibility in radionuclide therapy procedure

Radiation Protection

I. Characteristics of Radiation
   A. Types of ionizing radiation
      1. Alpha
      2. Beta-negative particles (negatrons)
      3. Beta-positive particles (positrons)
      4. Gamma rays
      5. X-rays
      6. Neutrons
   B. Half-life
   C. Energy
   D. Units
      1. Exposure
         a. Roentgen
         b. Coulomb/kilogram
      2. Absorbed dose
         a. Radiation absorbed dose
         b. Gray
      3. Relative biologic effectiveness and quality factors
      4. Dose equivalent
         a. Roentgen equivalent man
         b. Sievert
      5. Calculations and conversions

II. Regulation of Radiation Exposure and Use of Radioactive Materials
   A. Agencies
      1. Nuclear Regulatory Commission (NRC)
      2. Department of Transportation
      3. Food and Drug Administration
      4. Environmental Protection Agency
   B. Licensing
      1. Federal and state
      2. Institutional licenses
   C. Introduction to regulatory documents
      1. NRC, Title 10CFR20 (Standards for Protection Against Radiation)
      2. NRC, Title 10CFR35 (Medical Use of Byproduct Material)
      3. NRC, Title 10CFR19 (Notices, Instructions and Reports to Workers)
      4. NRC, Title 10CFR71 (Transport of Radioactive Material)
      5. Department of Transportation, Title 49CFR170 (Hazardous Material Training)
      6. NUREG-1556, Volume 9
      7. State regulations

III. Dose and Exposure Limit Recommendations and Regulations
- A. Definitions
  1. Effective dose equivalent
  2. Total effective dose equivalent
  3. Deep-dose equivalent
  4. Committed effective dose equivalent
  5. Shallow-dose equivalent
  6. Eye dose equivalent)
  7. Derived air concentration
  8. Annual limit on intake
  9. Occupational dose
  10. Public dose
  11. Restricted area
  12. Unrestricted area
- B. Occupational limits
  1. Whole body total effective dose equivalent
  2. Individual organs, except lens of eye
  3. Lens of eye
  4. Skin or any extremity
  5. Summation of internal and external exposures
  6. Planned special exposures
  7. Minors
  8. Embryo/fetus of occupationally exposed worker
  9. Emergency exposures
- C. Limits for individual members of the public
  1. Effective dose-equivalent limits
  2. Exposure rate limits for unrestricted areas
  3. Family members of radioactive patient
- D. ALARA philosophy
  1. Principles
  2. Recommended levels
  3. Radiation protection programs as described in Title 10CFR20
- E. Restricted and unrestricted areas
  1. Exposure rates
  2. Access
  3. Signage

IV. Radiation Detectors and Monitors
- A. Regulations concerning possession of instruments
- B. Survey instruments
  1. Geiger-Mueller counter
  2. Ionization chamber
  3. Liquid scintillation counter
  4. Well counter
  5. Scintillation probe (NaI probe)

C. Personnel monitors
    1. NRC regulations
    2. Thermoluminescent dosimeter
    3. Optically stimulated luminescence
    4. Pocket ionization chamber
    5. Care and use of devices

V. Personnel Monitoring
- A. Regulations
- B. Bioassay following use of radioiodine
- C. Personnel exposure records
    1. Report interpretation
    2. Notification of exposure levels
    3. Prior exposures

VI. Practical Methods of Radiation Protection
- A. Time
- B. Distance
- C. Shielding

VII. Possession of Radioactive Materials
- A. Licensed materials
    1. Radioactive materials for use in humans
    2. Controlled reference sources
    3. Exempt sources
- B. Activity inventory limits
- C. Sealed sources
    1. Regulations
    2. Inventory
    3. Leak tests
- D. Lost sources

VIII. Institutional Oversight According to NRC Regulations
- A. Radiation safety officer
    1. Responsibilities
    2. Training requirements
    3. Delegation of authority
- B. Radiation safety committee
    1. Responsibilities
    2. Composition
    3. Frequency of meetings
    4. Records
    5. Radiation safety program review
- C. Written directive
    1. Radionuclides and dosage
    2. Patient identification

3. Medical event
4. Records

IX. Radiation Safety Procedures
- A. Worker protection
  1. Regulations
  2. Posting notices
  3. Radiation safety education
  4. Notification and reports to workers
  5. Workers' rights
  6. Declaration of pregnancy
- B. General safety rules when working with unsealed radioactive sources
- C. Use of shields and labels
  1. Regulations
  2. Syringes
  3. Vials
- D. Radioactive liquids
  1. Regulations
  2. Preparation of kits and dose ranges
- E. Radioactive gases and aerosols
  1. Regulations
  2. Storage of volatiles and gases
  3. Room concentration limits
  4. Negative pressure requirements

X. Protection of the Patient
- A. Measurement of dose to be administered
  1. Regulations
  2. Calibration requirements
  3. Instrument requirements
  4. Instrument quality control
- B. Labeling of patient doses to be administered
  1. Regulations
  2. Methods
- C. Error or excess exposure
  1. Regulations
  2. Definitions
  3. Procedures
- D. Medical event
  1. Regulations
  2. Definitions
  3. Procedures

XI. Radioactive Material Packages
- A. Receipt

1. Regulation
2. Procedures

B. Shipping
1. Regulations
2. Procedures
3. Labels

XII. Waste Disposal Procedures and Regulation
A. Waste exempt from disposal regulations
B. Decay –in storage
C. Discharge into sewer system
D. Discharge into atmosphere
E. Transfer to authorized recipient

XIII. Contamination
A. Ambient dose rate survey
1. Regulations
2. Survey instrument requirements
3. Survey instrument quality control
4. Procedures
5. Action and trigger levels

B. Removable contamination survey
1. Regulations
2. Procedures
3. Action and trigger levels

C. Decontamination of minor spills
1. Definition
2. Procedure

D. Decontamination of major spill
1. Definition
2. Procedures

XIV. Radionuclide Therapy
A. Regulations
B. Responsibilities of radiation safety officer and authorized user
C. Dose administration
1. Patient identification
2. Written directives
3. Informed consent
4. Procedure

D. Release and isolation criteria
1. No restrictions
2. Limited restrictions
3. Isolation requirements

E. Limited restrictions
1. Restrictions

2. Instructions to patient

F. Safety precautions involving patients in radiation-based isolation
   1. Nursing instructions
   2. Instructions to patients
   3. Room preparation and sign postings
   4. Contamination control
   5. Room decontamination upon discharge
   6. Disposal of waste
   7. Patient care and control
   8. Visitor control
   9. Personnel monitoring
   10. Nursing precautions and restrictions
   11. Bioassay of personnel

G. Measurement of exposure rates
   1. Surveys of restricted and unrestricted areas
   2. Safe distance markers
   3. Calculated nursing time

H. Procedures in case of death, autopsy, or emergency surgery

XV. NRC Rules and Regulations

A. Title 10CFR19
   1. Posting of notices to workers
      a. Documents
      b. Location
   2. Instructions to workers
   3. Notification and reports to individuals
   4. Request for inspection
      a. Right
      b. Request
      c. Employee protection

B. Title 10CFR20
   1. Radiation protection programs
   2. Occupational dose limits
   3. Radiation dose limits for individual members of the public
   4. Surveys and monitoring
      a. General requirements for surveys
      b. Survey equipment
      c. Conditions requiring individual monitoring of external and internal occupational doses
   5. Control of exposure from external sources in restricted areas
   6. Respiratory protection and controls to restrict internal exposure in restricted areas
   7. Storage and control of licensed material
      a. Security of stored material
      b. Control of materials not in storage

8. Precautionary procedures
    a. Caution signs
    b. Posting requirements
    c. Exceptions to posting requirements
    d. Labeling containers
    e. Exceptions to labeling containers
    f. Procedures for receiving and opening packages
9. Waste disposal
    a. General requirements
    b. Decay in storage
    c. Release into sanitary sewerage
    d. Transfer for disposal
10. Records
    a. Surveys
    b. Prior occupational dose
    c. Individual monitoring results
    d. Dose to individual members of the public
    e. Waste disposal
    f. Form of records
11. Reports
    a. Reports of theft or loss of licensed material
    b. Notification of incidents
    c. Reports of excess exposure
    d. Reports of individual monitoring

C. Title 10CFR35
1. ALARA
    a. Model program
    b. Management commitment
    c. Radiation safety officer
    d. Investigational levels I and II
    e. Methods to meet ALARA goals
2. Radiation safety officer
    a. Responsibilities
    b. Training requirements
    c. Delegation of authority
3. Radiation safety committee
    a. Responsibilities
    b. Composition
    c. Frequency of meetings
    d. Records
4. Quality management program
    a. Radionuclide and dosage
    b. Written directives
    c. Patient identification
    d. Medical event
    e. Program review

   f. Records
5. Medical event
   a. Error and excess exposure
   b. Verbal and written reports
   c. Reporting process
   d. Records
6. NUREG-1556, Volume 9, 2002: Model Procedures
   a. Model Training Program
   b. Model Procedure for Calibrating Survey Instruments
   c. Model Procedure for Calibrating Dose Calibrator
   d. Model Personnel External Exposure Monitoring Program
   e. Model Procedure for Checking Equipment Used in Mobile Nuclear Medicine Services
   f. Model Radiation Safety Committee Charter and Radiation Safety Officer Delegation of Authority
   g. Model Program for Maintaining Occupational Radiation Exposure at Medical Institutions ALARA
   h. Model Procedure for Leak-Testing Sealed Sources
   i. Model Rules for Safe Use of Radiopharmaceuticals
   j. Model Spill Procedures
   k. Model Guidance for Ordering and Receiving Radioactive Material
   l. Model Procedure for Safely Opening Packages Containing Radioactive Material
   m. Records of Byproduct Material Use
   n. Model Procedure for Area Surveys
   o. Model Procedure for Monitoring, Calculating and Controlling Air Concentrations
   p. Model Procedure for Radiation Safety During Iodine Therapy over 30 Millicuries
   q. Model Procedure for Waste Disposal

Chapter 10

Radiation Physics

Radiation Physics

This section covers concepts and physical principles that govern radioactivity and the interactions of ionizing radiation with matter.

Objectives:

1. Define and describe basic atomic physics concepts
2. Illustrate modes of radioactive decay and decay schemes
3. Describe and calculate decay of radionuclides
4. Explain production methods of radionuclides and X-rays
5. Describe the characteristics of an X-ray beam
6. Compare and contrast photon and particulate interaction with matter
7. Perform calculations using the attenuation equation

Radiation Physics

I. Basic Review
- A. Definitions
  1. Electromagnetic radiation
  2. Particulate radiation
  3. Ions and ionization
- B. Composition of the atom
  1. Proton
  2. Neutron
  3. Electron
  4. Neutrinos
  5. Antineutrinos
  6. Other elemental particles
- C. Historical contributions
  1. Wilhelm Roentgen
  2. Henri Becquerel
  3. Marie and Pierre Curie
  4. Others associated with early inventions, developments, and applications to the field
- D. Electron shells and stability
  1. Terms
     a. Orbital electron
     b. Valence electron
     c. Auger electron
     d. Photoelectron
     e. Conversion electron
  2. Orbital and suborbital
  3. Pauli exclusion principle
  4. Energy states
  5. Periodic table
- E. Nuclear stability
- F. Neutron/proton ratio and the line of stability
- G. Binding energy
- H. Nuclear models
- I. Atomic nomenclature
  1. Symbol notation
  2. Relationship of mass and energy
  3. Mass energy equivalents
  4. Nuclide
  5. Isotopes
  6. Isobars
  7. Isotones
  8. Isomers
  9. Chart of nuclides

II. Modes of Radioactive Decay
- A. Alpha
- B. Beta
  1. Beta minus
  2. Positron
- C. Electron capture
- D. Gamma
  1. Isomeric transition
  2. Internal conversion
- E. Combination modes

III. Radionuclide Decay
- A. Decay equation
- B. Decay constant
- C. Decay factor
- D. Decay schemes
- E. Units of activity
- F. Specific activity
- G. Half-life
  1. Physical
  2. Biological
  3. Effective
  4. Mean
- H. Exponential graphs
  1. Plot of exponential equation
     a. Linear
     b. Semi-log
- I. Determination of half-life from graph

IV. Production of Nuclides
- A. Reactor
- B. Fission
- C. Fusion
- D. Particle accelerator
  1. Linear accelerator
  2. Cyclotron
- E. Generator
  1. Secular equilibrium
  2. Transient equilibrium

V. X-Ray Production
- A. Source of free electrons (eg, thermionic emission)
- B. Acceleration of electrons
- C. Focusing of electrons
- D. Deceleration of electrons
- E. Target interactions

1. Bremsstrahlung
2. Characteristics

VI. X-Ray Beam
- A. Frequency and wavelength
- B. Beam characteristics
- C. Quality
    1. Quantity
    2. Primary versus remnant
- D. Inverse square law
- E. Fundamental properties

VII. Photon Interaction With Matter
- A. Scatter mechanisms
    1. Coherent
    2. Compton effect
- B. Full absorption mechanisms
    1. Photoelectric
    2. Pair production
    3. Photodisintegration
- C. Secondary radiation
    1. Bremsstrahlung
    2. Characteristic radiation
    3. Auger electrons
- D. Interaction relationships
    1. Energy
    2. Atomic number
    3. Tissue density
- E. Specific ionization
- F. Linear energy transfer

VIII. Particulate Interaction With Matter
- A. Alpha
    1. Excitation
    2. Ionization
    3. Transmutation
- B. Beta minus particles
    1. Excitation
    2. Bremsstrahlung
    3. Ionization
- C. Positrons
- D. Specific ionization
- E. Linear energy transfer

IX. Attenuation Equation
- A. Linear attenuation

B. Mass attenuation
C. Half-value layer
D. Calculations

Chapter 11

Instrumentation

Instrumentation: Nonimaging

This section includes the principles of operation and quality control for nonimaging instruments, including monitoring equipment, dose calibrators, well counters, uptake probes, liquid scintillation systems, laboratory equipment, and the gamma probe. Laboratory and clinical experience should be included in the learning process.

Objectives:

1. Describe and apply the principles and operation of gas-filled detectors
2. Describe and apply the principles and operation of scintillation detectors
3. Describe and apply the principles and operation of laboratory equipment
4. Demonstrate operation of nonimaging equipment
5. Perform quality control procedures and analyze the results

Instrumentation: Nonimaging

I. Introduction
- A. Radioactive decay process
- B. Interaction of ionizing radiation
- C. Exposure and exposure rate

II. Gas-Filled Detector Systems
- A. Principles of operation
  1. Ionization
  2. Excitation
  3. Gas ionization curve
     - a. Recombination
     - b. Ionization
     - c. Proportional and nonproportional
     - d. Geiger-Mueller
     - e. Continuous discharge
- B. Ion chambers
  1. Dose calibrations
     - a. Operation
     - b. Quality control
       - i. Geometry
       - ii. Linearity
       - iii. Accuracy
       - iv. Constancy
  2. Handheld ionization chamber
     - a. Dead time
     - b. Daily quality control
     - c. Appropriate use
     - d. Calibration
  3. Pocket dosimeters
- C. Geiger-Mueller counter (survey meter)
  1. Dead time
  2. Daily quality control
  3. Types of Geiger-Mueller probes
  4. Appropriate use
     - a. Scale settings
     - b. Factors that influence observed exposure rate
       - i. Dose-response curve
       - ii. Probe geometry
  5. Calibration

III. Scintillation Detection Systems
- A. Solid scintillation detector (well counter and uptake probes)
  1. Principles of operation
  2. Component parts

a. Crystal
b. Photomultiplier tubes
    i. Photocathode
    ii. Focusing grid
    iii. Dynodes
    iv. Creation of the electron pulse
c. High-voltage power
d. Amplification
    i. Preamplification
    ii. Gain setting
e. Pulse-height analyzer
    i. Single channel
    ii. Multichannel
    iii. Components of an energy peak
    iv. Detection of an energy peak
f. Counters, timers, rate meters
g. Uptake probe
    i. Flat-field collimator
    ii. Isoresponse curve

3. Energy resolution and full width at half of maximum
4. Modulation transfer function
    a. Relation to resolution
    b. Comparison to full width at half of maximum
5. Energy calibration
6. Dead time versus activity
7. Efficiency
8. Pulse height analyzer window determination
9. Effects of geometry
10. Quality control

B. Liquid scintillation systems
    1. Principle of operation
    2. Use of liquid scintillation systems
C. Gamma probe
    1. Principles of operation
    2. Clinical uses
        a. Sentinel node localization
        b. Other uses
D. Future development in nonimaging technology detection

IV. Laboratory Equipment
A. Centrifuge
B. Thermometers
C. Pipettes and automatic pipettors
D. Water baths
E. Refrigerators/freezers
F. Microscope

G. Hemocytometer
H. Glucose meter (glucometer)

Instrumentation: Counting Statistics

This section includes the principles and applications of statistics as they relate to nuclear medicine instrumentation. The learning experience should include laboratory and clinical experience.

Objectives:

1. Analyze and apply statistical data used in Nuclear Medicine Technology

Instrumentation: Counting Statistics

I. Nuclear Medicine Statistics
   A. Precision versus accuracy
   B. Graphing
      1. Linear plots
      2. Semilog plots
      3. Histogram
      4. Time activity curve
      5. Least squares-best fit curve (regression analysis)
   C. Standard deviation
      1. Series of values
      2. Single value
      3. Counting rate
      4. Net counts
   D. Confidence intervals
   E. Levy-Jennings plot
   F. Coefficient of variation (percent standard deviation)
   G. Gaussian and Poisson distributions
   H. Percent error and percent difference
   I. Chi-square test
   J. T-test
   K. Count rate determination
      1. Gross counts
      2. Background counts
      3. Net counts
   L. Determining the number of counts required for statistical significance

Instrumentation: Computers

This section covers the configuration, function, and application of computers and networks in nuclear medicine. Students should have extensive laboratory and clinical experience performing data acquisition, manipulation, and processing.

Objectives:

1. Describe the configuration, function, and application of picture archiving and communications systems (PACS)
2. Acquire, manipulate, and process information using nuclear medicine computer systems

Instrumentation: Computers

I. PACS
- A. Acquisition device
- B. Types of system interfaces
- C. Digital Imaging and Communications in Medicine (DICOM) compatible
- D. Networking and servers
    1. Centralized servers
    2. Distribution servers
    3. Hybrids
    4. Virtual private network
- E. Imaging display
- F. Archiving
- G. Internet
- H. Integration with other systems
    1. Radiology information systems (RIS)
    2. Hospital information systems

II. Nuclear Medicine Computer Systems
- A. Gamma camera/computer interface
    1. Analog-to-digital converters
        a. Purpose
        b. Types
    2. Buffer
    3. Zoom
        a. Magnification versus resolution
        b. Interpolation
- B. Acquisition modes
    1. Types
        a. Frame
        b. List
        c. Multiple gated
        d. Tomographic
        e. Whole body
    2. Matrix types and sizes
        a. Byte versus word
        b. Number and size of pixels
        c. Voxel
    3. Memory requirements
        a. Addresses
        b. Counts per address
- C. Video display systems
- D. Planar filter options
    1. Temporal
    2. Spatial/smoothing
- E. Single-photon emission computed tomography (SPECT)

reconstruction techniques
    1. Back projection
    2. Fourier reconstruction
    3. Iterative reconstruction
    4. Slice-thickness selection
    5. Reorientation

F. SPECT filters
    1. Filter design and selection
        a. Selection criteria
        b. Types
        c. Cutoff
        d. Frequency
    2. Nyquist frequency
    3. Multicamera head reconstruction techniques

G. Data processing programs
    1. Field uniformity correction
    2. Background and foreground correction
    3. Attenuation correction
    4. Motion correction
    5. Contrast enhancement
    6. Scaling and normalization
    7. Image arithmetic
    8. Display manipulations
    9. Dead time corrections
    10. Center of rotation error corrections
    11. Regions of interest
        a. Selection
        b. Comparison ratios and percentages
        c. Effects of poorly drawn regions of interest
    12. Curve generation and manipulation
        a. Image profiles
        b. Time-activity curves
        c. Harmonic analysis
    13. Automatic edge detection
    14. Gray scales
    15. Color scales
    16. Image registration and coregistration
    17. Three-dimensional reconstruction
    18. Polar map generation
    19. Standard uptake values

H. Use of computers in quality control programs
    1. Linearity
    2. Sensitivity
    3. Gain
    4. Analog versus digital conversion
    5. Resolution

6. Spatial distortion
7. Integration with imaging systems
8. Validation of software
9. Radiopharmacy management systems
10. Center of rotation
11. Test patterns
12. Pixel sizing (x, y gain setting)

I. Radiopharmacy/hot lab computers
   1. Hot lab and patient management
   2. Health physics
   3. Pharmacy management

Instrumentation: Imaging

This section deals with in-depth information on the components, use, and quality control of the various types of systems used for gamma, positron, and X-ray imaging. The learning experience should include laboratory and clinical experience.

Objectives:

1. Describe and apply the principles and operation of Anger scintillation cameras
2. Describe and apply the principles and operation of multicrystal scintillation cameras
3. Describe and apply the principles and operation of solid state detector systems
4. Describe and apply the principles and operation of SPECT and SPECT/computed tomography (CT)
5. Describe and apply the principles and operation of positron emission tomography (PET)/CT
6. Describe and apply the principles and operation of CT
7. Demonstrate operation of imaging equipment
8. Perform quality control procedures and analyze the results

Instrumentation: Imaging

I. Anger Scintillation Cameras
   A. Principles and system configurations
      1. Collimator
         a. Geometric characteristics
            i. Resolution
            ii. Efficiency
         b. Selection considerations
      2. Crystal
         a. Types
         b. Resolution
         c. Efficiency
      3. Photomultiplier tubes
         a. Cathode
         b. Dynode
         c. Anode
         d. Electron multiplication
      4. Light pipe
      5. Analog-to-digital converters
      6. Preamplifier/amplifier
      7. Positioning circuitry
      8. Ratio circuits
      9. Summation circuitry
      10. Pulse-height analyzer
         a. Window width
         b. Centerline versus nonsymmetrical window
         c. Z-pulse
      11. Scalers and rate meters
      12. Digital-to-analog converters
      13. Imaging
         a. Static
            i. Length
            ii. Time/counts per frame
            iii. Matrix size
            iv. Collimation
            v. Spatial resolution

         b. Whole body acquisition
            i. Body contouring
            ii. Information density
            iii. Scan speed
            iv. Matrix size
         c. Dynamic
            i. Length
            ii. Time per frame

iii. Matrix size
iv. Collimation
v. Temporal resolution

d. Gated
e. SPECT

14. Image display
    a. Static
    b. Cine
    c. 3-dimensional/volumetric
15. Data recording
    a. Disk
    b. Film
    c. Printer
    d. Other
16. Mobile camera systems

B. Performance characteristics
    1. Collimators
        a. Types
        b. Parallel-hole
            i. Low energy all purpose or general all purpose
            ii. High resolution versus high sensitivity
            iii. Ultrahigh resolution
            iv. Medium energy
            v. High energy
            vi. High sensitivity
        c. Diverging/converging
        d. Pinhole
        e. Slant-hole
        f. Fan-beam
    2. Characteristics
        a. Spatial resolution
        b. Sensitivity
        c. Field of view
        d. Image size (magnification/minification)
        e. Image distortion
        f. Energy characteristics
    3. Camera
        a. Spatial resolution
            i. Full width half maximum
            ii. Modulation transfer function
        b. Sensitivity
        c. Linearity
        d. Uniformity
            i. Specifications (differential/integral)
            ii. Factors affecting uniformity

iii. Uniformity versus intrinsic resolution
e. Energy resolution
f. Dead time
g. Count rate
h. Image contrast

II. Multicrystal Scintillation Cameras
A. Principles of operation
B. Performance characteristics
1. Spatial resolution
2. Sensitivity
3. Uniformity
4. Energy
5. Count rate

III. Solid State Detector Systems
A. Principles of operation
B. Performance characteristics
1. Spatial resolution
2. Sensitivity
3. Uniformity
4. Energy
5. Count rate

IV. SPECT and SPECT/CT
A. Basic designs and principles
1. Orbit design
a. Circular
b. Body contour
c. Elliptical
2. Collimator design
3. Multihead systems
a. Fixed
i. 180 degrees with 2 detectors
ii. 90 degrees with 2 detectors
b. Variable
4. Attenuation correction
a. Attenuation filters
b. Sealed/rod source
c. X-ray
5. Acquisition parameters
a. Matrix size and linear sampling
b. Degrees of rotation
c. Number of projections (angular sampling)
d. Time per projection
e. Time per acquisition

f. Image density versus image contrast

6. Factors that limit statistics
   a. Radiopharmaceutical dose limits
   b. Time restraints
   c. Source-to-detector distance
   d. Attenuation
7. Reconstruction: analytical and iterative
   a. Filtered (convoluted) back-projection
      i. Collection of planar images (2-dimensional format)
      ii. Sum of the images
      iii. Pixels and voxels
   b. Fourier
      i. Spatial and frequency domain
      ii. Elimination of the star defect
   c. Iterative reconstruction
      i. Maximum likelihood expectation maximization
      ii. Ordered subsets expectation maximization
      iii. Other
   d. Reconstruction parameters
      i. Center of rotation correction
      ii. Uniformity correction
      iii. Attenuation correction
      iv. Filters and filter selection
      v. Attenuation correction with external transmission sources
      vi. Motion correction and linograms/sinograms

V. PET Systems
   A. Basic principles of operation
   B. Sensitivity/dead time
   C. Spatial resolution
   D. System configurations
   E. Time of flight
   F. Coincidence detection
   G. Projection of data collection
   H. Crystal characteristics
   I. Limits of resolution
      1. Range of the positron
      2. Angulation
      3. Detector size
         a. Size of the ring diameter
         b. Size of the detector elements
      4. Detector design
         a. Block detector

b. Detector cassettes
c. Ring architecture

J. Signal-to-noise ratio
1. True coincident event
2. Compton scatter
3. Random event

K. Imaging
1. 2-dimensional
2. 3-dimensional

L. Absolute calibration (standard uptake value)

M. Attenuation and correction methods
1. Transmission
a. Orbiting rod sources
b. CT
i. Image segmentation
2. Coregistration

N. Iterative reconstruction
1. Maximum likelihood expectation maximization
2. Ordered subsets expectation maximization
3. Other

VI. CT Systems

A. Basic principles of operation
1. History and development
2. CT X-ray tube design
a. Voltage variation
b. X-ray filter
3. CT scanner design
a. Detectors
b. Collimation
c. Rotational speed

B. Multislice helical CT

C. Image data acquisition

D. Image reconstruction

E. Image display

F. Display of volumetric data

G. Image quality
1. Contrast resolution
2. Image noise

H. CT protocols
1. Low-dose CT for PET attenuation correction
2. Diagnostic CT

I. CT acquisitions
1. Neck CT
2. Chest CT
3. Abdomen CT

a. Pelvis CT
b. Extremity CT
4. CT contrast media
5. Types
6. Administration

J. Integrated PET/CT protocols
K. CT artifacts
1. Operation
2. Scanner
3. Patient
L. CT radiation safety
1. Room construction
2. Personnel safety
3. Patient dose

VII. Quality Control of Imaging Systems
A. Anger scintillation camera
1. Flood uniformity
2. Positioning circuitry
3. Spatial resolution
4. Linearity
5. Sensitivity
6. Pixel sizing
7. Energy resolution
8. Energy calibration
9. Environmental control
10. Intrinsic versus extrinsic measurements
11. Collimator
a. Septal penetration
b. Damage detection

B. SPECT systems
1. Center of rotation
2. Cylindrical phantoms
3. High count flood uniformity

C. PET imaging systems
1. Characterization
2. Correction calibrations

D. CT (on a PET/CT or SPECT/CT system)
1. Scanner
2. Image
3. Dose

Chapter 12

Nuclear Pharmacy and Pharmacology

Nuclear Pharmacy and Pharmacology

This section covers the theory and practice of radiopharmacy, including preparation and calculation of the dose to be administered, quality control, radiation safety, and applicable regulations. In addition, it deals with nonradioactive interventional drugs and contrast media that are used as part of nuclear medicine procedures. For all administered materials, it addresses the routes of administration, biodistribution mechanisms, interfering agents, contraindications, and adverse effects. Students need to have experience in laboratories, the clinical setting, or a centralized radiopharmacy in order to become proficient in this area.

Objectives:

1. Explain the basic concepts of radionuclides and radiopharmaceuticals
2. Identify and list the characteristics of the ideal radiopharmaceutical
3. Describe the Food and Drug Administration and US Pharmacopeia control of pharmaceuticals and radiopharmaceuticals
4. Describe the basic concepts of radiochemistry
5. Describe generator kinetics in the production of radionuclides
6. Demonstrate appropriate generator elution techniques
7. Describe quality control procedures, including radionuclide purity, radiochemical purity, and chemical impurities
8. Demonstrate proper compounding of radionuclide-labeled kits
9. Discuss the production and characteristics of positron emitters and positron-labeled radiopharmaceuticals
10. Prepare and store radioactive volatiles and gases in accordance with federal regulations
11. Determine and calculate appropriate patient doses
12. Explain the normal and altered biodistribution properties of radiopharmaceuticals
13. Describe the characteristics, proper use, and pharmacokinetics of radiopharmaceuticals, pharmaceuticals, and contrast media
14. Analyze patient information to determine adverse reactions, interfering drugs, and contraindications for administration of radiopharmaceuticals, pharmaceuticals, and contrast media

Nuclear Pharmacy and Pharmacology

I. Introduction
- A. Definitions
  1. Nuclide versus isotope
  2. Radionuclide and radioactivity
  3. Radioactive drug (legal definition)
  4. Units of radioactivity
  5. Specific activity
  6. Specific concentration
  7. Carrier content
  8. Half-life
- B. Basic characteristics of a radiopharmaceutical
  1. Radioactive component
  2. Pharmaceutical component
- C. Desirable characteristics for a radionuclide
  1. Limiting agents
     a. Patient's radiation dose
     b. "As Low As Reasonably Achievable" (ALARA)
     c. Sufficient photon flux and activity for imaging
     d. Speed of uptake and imaging times
     e. Instrument limitations
     f. Diagnostic versus therapeutic requirements
  2. Ideal characteristics for diagnostic nuclide
     a. Type of radiation
     b. Energy
     c. Monoenergetic versus multiple energies
     d. Half-life
  3. Ideal characteristics for a therapeutic nuclide
     a. Type of radiation
     b. Energy
     c. Half-life
  4. Desirable characteristics for a radiopharmaceutical
     a. Noninvasive, nonpharmacologic
     b. Clearance time
        i. Plasma clearance
        ii. Target uptake
        iii. Target clearance
        iv. Biological half-life
     c. Target-to-background ratio
     d. Ease of preparation
     e. Shelf life
  5. Routes of administration
     a. Oral
     b. Intravenous injection
     c. Inhalation

d. Intrathecal injection
e. Intracavitary injection
f. Subcutaneous injection
g. Urethral infusion

II. Radiation Protection and Regulations in Reference to Radiopharmacy

III. Food and Drug Administration and US Pharmacopeia Control of Pharmaceuticals
A. Scope of control
B. Research requirements
1. Basic research
2. Investigational New Drug
3. New Drug Application and approval
C. Regulations for use of Investigational New Drug or New Drug Application in nuclear medicine facility

IV. Radiochemistry
A. Definitions
1. Types of aqueous solutions
2. Chemical species
B. Reactivity
1. Valence state
2. Free radicals
3. Oxidation numbers
4. Oxidation/reduction reactions
C. Chemical bonds
D. Technetium chemistry
1. Terminology and chemical formulas
2. Oxidation states
a. Desirable states
b. Reducing agents
c. Reoxidation
3. Radiolabeling with Tc-99m
a. Types of compounds
b. Types of bonds
4. Undesirable technetium complexes
5. Free pertechnetate
6. Hydrolyzed-reduced technetium
a. Radiolabeling with long-lived radionuclides
b. Tagging blood components
i. Anticoagulants
ii. Blood withdrawal/reinjection techniques
iii. Sources of error

V. Radionuclide Generators

A. Principles
    1. Parent/daughter relationship
    2. Equilibrium
    3. Transient versus secular equilibrium
    4. Effects of elution
B. Mo99/Tc99m generators
    1. Components and configuration
    2. Changes in activity with time and elution
    3. Elution efficiency
    4. Yield calculation
    5. Elution technique
    6. Wet versus dry
    7. Causes of fluctuation in yield
        a. Molybdenum loading inconsistencies
        b. Channeling
        c. Radiolysis
        d. Mechanical problems
C. Sr82/Rb82 generators
    1. Configuration
    2. Changes in activity with time and elution
    3. Useful life span

VI. Quality Control
A. Radionuclidic purity
    1. Definition
    2. Basic calculation
    3. Effects of impurities
    4. Sources
    5. Test methods
        a. Shield method
        b. Spectrometry
    6. Limits
        a. Mo99 in Tc99m
        b. Other nuclides
    7. Effect of decay
B. Radiochemical purity
    1. Definition
    2. Basic calculation
    3. Effects of impurities
    4. Causes of impurities
        a. Radiolysis
        b. Time
    5. Sources
    6. Test methods
        a. Radiochromatography
        b. Solid-phase extraction (eg, Sep-Pak®)

7. Limits

C. Chemical impurity
   1. Definition
   2. Alumina in Tc99m generator eluate
      a. Test method
      b. Limits
      c. Interpretation
      d. Significance
   3. Impurities in other radiopharmaceuticals

D. Ph
   1. Definition
   2. Test method
   3. Limits
   4. Interpretation
   5. Significance

E. Particle size
   1. Test method
   2. Limits
   3. Interpretation
   4. Significance

F. Visual appearance
   1. Color
   2. Clarity

G. Sterility
   1. Definition
   2. Effects of contaminants
   3. Sources of contaminants
   4. Sterilization methods
   5. Test methods
   6. Maintenance of sterility

H. Apyrogenicity
   1. Definition
   2. Effects of contaminants
   3. Sources of contaminants
   4. Test methods
      a. Rabbit test
      b. Bacterial endotoxin test
      c. Comparison

VII. Tc99m-Labeled Kit Preparation

A. Kit components
   1. Ligand
   2. Reducing agent
   3. Antioxidant
   4. pH buffer
   5. Atmosphere

B. Kit production
    1. Sterilization
    2. Lyophilization
C. Kit Preparation
    1. Compounding technique
    2. Diluent
    3. Factors to be considered
        a. Volume limits
        b. Activity limits
        c. Postreconstitution shelf life
        d. Storage requirements
D. Record keeping

VIII. Preparation of Positron Emitters
A. Production
    1. Generator systems
    2. Cyclotron systems
B. Characteristics of positron emitters
    1. Physical
    2. Chemical
C. Biochemical characteristics
    1. ^{11}C
    2. ^{15}O
    3. ^{13}N
    4. ^{18}F
    5. Other
D. Synthesis of radiopharmaceuticals
E. Quality control of radiopharmaceuticals

IX. Radioactive volatiles and gases
A. Storage requirements
B. Room concentration limits
C. Calculation of room clearance time
D. Negative pressure requirements
E. Postings
F. Special considerations for radioiodine

X. Dose Determination
A. Dose range
    1. Factors affecting dose determination
    2. Organ or system size
    3. Photon flux
    4. Radiation dose
B. Nuclear Regulatory Commission acceptable ranges
C. Nuclear Regulatory Commission calibration requirements

XI. Calculation of Patient Dose
- A. Specific concentration
- B. Volume to be administered
- C. Dilution of doses
- D. Unit dose adjustment
- E. Consideration for decay
    1. Decay calculation
    2. Decay factor tables
    3. Universal decay table
- F. Calculation of pediatric doses
    1. Factors affecting pediatric dose administration
        a. Minimum and maximum
        b. Body surface area
        c. Administration per unit weight
    2. Other

XII. Biodistribution
- A. Clearance and uptake times
    1. Plasma clearance
    2. Organ/tissue uptake and retention
    3. Organ clearance and redistribution
    4. Excretion routes
    5. Biological half-life
- B. Common mechanisms of localization
    1. First transit
    2. Simple exchange diffusion
    3. Active transport
    4. Capillary blockage
    5. Compartment localization
    6. Electrostatic binding
    7. Phagocytosis
    8. Antibody and antibody fragment localization
    9. Receptor localization
    10. Cellular sequestration
    11. Metabolism
    12. Other

XIII. Individual Radiopharmaceuticals
- A. For each radiopharmaceutical on the Nuclear Medicine Technology Certification Board Pharmacy List, the following elements will be examined:
    1. Clearance and uptake
    2. Method of localization
    3. Alternate names
    4. Indications for use
    5. Dose range

6. Route of administration
7. Specific chemical and physical properties
8. Method of preparation
9. Biodistribution mechanisms, including initial uptake, redistribution, and excretion
10. Critical organ doses, gonadal dose, whole body dose
11. Target organ
12. Quality control consideration and limit
13. Interfering agents and their effects
14. Adverse reactions
    a. Vasovagal reaction
    b. Pyrogenic
    c. Allergic
    d. Anaphylactic
    e. Reporting mechanism

XIV. Pharmaceuticals

A. Administration by Nuclear Medicine Technologists
    1. Regulations
    2. Ethical implications
    3. Training
    4. Procedural considerations

B. Interventional agents
    1. Class of drug
    2. Alternate names
    3. Indications
    4. Mechanism of action
    5. Pharmacokinetics
    6. Dosage range
    7. Precautions and contraindications
        a. Other drugs
        b. Pathologic conditions

C. Adverse reactions
    1. Vasovagal reaction
    2. Allergic
    3. Anaphylactic
    4. Reporting mechanism

D. Common interventional drugs used in nuclear medicine
    1. Dipyridamole
    2. Adenosine
    3. Dobutamine
    4. Aminophylline
    5. Captopril
    6. Enalaprilat
    7. Furosemide
    8. Insulin

9. Acetazolamide
10. Cholecystokinin/sincalide/CCK
11. Morphine
12. Cimetidine/ranitidine/famotidine
13. Glucagon
14. Pentagastrin
15. ACD solution
16. Heparin
17. Ascorbic acid
18. Hetastarch
19. Lugol's solution/SSKI
20. Thyroid-stimulating hormone
21. Ethylenediaminetetraacetic acid
22. Lidocaine
23. Lidocaine (EMLA) cream
24. Atropine
25. Recombinant human thyroid-stimulating hormone
26. Nitroglycerin
27. Acetaminophen
28. Diphenhydramine hydrochloride
29. Aspirin
30. Other

XV. Contrast Media
- A. Class of drug
- B. Alternate names
- C. Indications
- D. Mechanism of action
- E. Pharmacokinetics
- F. Dosage range
- G. Precautions and contraindications
    1. Other drugs
    2. Pathologic conditions
- H. Adverse reactions
    1. Vasovagal reaction
    2. Allergic
    3. Anaphylactic
    4. Reporting mechanism
- I. Calculation of patient dose
    1. Specific concentration
    2. Volume to be administered
    3. Dilution of doses
    4. Unit dose
- J. Calculation of pediatric doses
    1. Factors affecting pediatric dose administration
        a. Minimum and maximum

   b. Body surface area
   c. Administration per unit weight
2. Other

K. Intravenous
1. High-osmolality ionic agents
   a. Sodium/meglumine diatrizoate
   b. Sodium/meglumine metrizoate
2. Low-osmolality nonionic
   a. Iopamidol
   b. Iopromide
   c. Iohexol
3. Low-osmolality ionic agents
   a. Sodium/meglumine ioxaglate
   b. Other
   c. Oral
4. Barium sulfate
5. Sodium amidotrizoate
6. Meglumine amidotrizoate
7. Other
   a. Air

Chapter 13

Diagnostic Procedures

Diagnostic Procedures

This section covers diagnostic procedures, including anatomy and physiology, pathophysiology, and protocols for routine and non-routine nuclear medicine procedures. Some of the procedures addressed may not be assessed by credentialing agencies but are included as essential to the theory and understanding of nuclear medicine. Clinical experience must be acquired to enhance the didactic learning of all commonly performed diagnostic procedures.

Objectives:

1. Review anatomy and physiology for each organ system
2. Describe the pathology and pathophysiology associated with each organ system
3. Recognize and explain clinical indications for diagnostic procedures
4. Describe and apply the appropriate diagnostic protocols
5. Evaluate images and quantitative data for technical quality, including artifacts and normal variants

Diagnostic Procedures: Skeletal

I. Anatomy and Physiology
- A. Matrix structure and composition
- B. Bone growth
- C. Bone repair
- D. Hormonal control of blood/bone calcium

II. Pathology: For each of the following disease states, these topics will be covered: characteristics, causes, population, and treatment
- A. Malignant diseases
- B. Benign neoplasms
- C. Inflammatory diseases
- D. Skeletal fractures
- E. Skeletal pain
- F. Bone viability
- G. Bone density
- H. Vascular abnormalities

III. Whole-Body Bone Scan
- A. Indications
- B. Radiopharmaceuticals
    1. Tracer
        a. Tc-99m methylene diphosphonate (MDP)
        b. Tc-99m hydroxymethylene diphosphonate (HDP)
    2. Route of administration
    3. Biodistribution
        a. Distribution
        b. Excretion
    4. Dosimetry
- C. Contraindications and adverse reactions
    1. Physical and pathologic conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
- D. Patient preparation
- E. Imaging equipment
- F. Protocol
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
- G. Interpretation of images and data

1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

IV. Multiphase Bone Imaging
- A. Indications
- B. Radiopharmaceuticals
    1. Tracer
        a. Tc-99m MDP
        b. Tc-99m HDP
    2. Route of administration
    3. Biodistribution
        a. Distribution
        b. Excretion
    4. Dosimetry
- C. Contraindications and adverse reactions
    1. Physical and pathologic conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
- D. Patient preparation
- E. Imaging equipment
- F. Protocol
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. 6- to 24-hour delay (fourth phase)
    5. Data processing
    6. Image display/format
    7. Sources of error
- G. Interpretation of images and data
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging

b. Nonimaging

V. Single-Photon Emission Computed Tomography (SPECT) and SPECT/Computed Tomography (CT) Bone Scan
- A. Indications
- B. Radiopharmaceuticals
  1. Tracer
     a. Tc-99m MDP
     b. Tc-99m HDP
  2. Route of administration
  3. Biodistribution
     a. Distribution
     b. Excretion
  4. Dosimetry
- C. Contraindications and adverse reactions
  1. Physical and pathologic conditions
  2. Interfering studies
  3. Possible interfering drugs
  4. Precautions
  5. Adverse reactions
- D. Patient preparation
- E. Imaging equipment
- F. Protocol
  1. Dose range and administration technique
  2. Acquisition parameters
  3. Positioning and views
  4. Data processing
  5. Image display/format
  6. Sources of error
- G. Interpretation of images and data
  1. Normal
  2. Normal variants
  3. Abnormal
  4. Artifacts
  5. Diagnostic/prognostic value of the study
  6. Evaluation of technical quality
  7. Correlative tests
     a. Imaging
     b. Nonimaging

VI. Positron Emission Tomography (PET) and PET/CT
- A. Indications
- B. Radiopharmaceuticals
  1. Tracer
     a. F-18
  2. Route of administration

3. Biodistribution
    a. Distribution
    b. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical and pathologic conditions
2. Interfering studies
3. Possible interfering drugs
4. Precautions
5. Adverse reactions

D. Patient preparation

E. Imaging equipment
1. Emission
2. Transmission

F. Protocol
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error

G. Interpretation of images and data
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

VII. Bone Density/Absorptiometry
A. Indications
B. Radionuclide method
C. Radiographic method

Diagnostic Procedures: Cardiovascular

I. Review of Anatomy and Physiology
- A. Gross anatomy and function
  1. Heart chambers
  2. Tissue layers
     a. Endocardium
     b. Myocardium
  3. Epicardium
  4. Pericardium
- B. Cellular physiology
- C. Blood flow
  1. Coronary
  2. Systemic
- D. Conduction system and pathways
- E. Cardiac cycle
- F. Functional parameters
  1. Ejection fraction
  2. Stroke volume
  3. Cardiac output
  4. Other

II. Pathology: For each of the following disease states, these topics will be covered: characteristics, causes, population, and treatment
- A. Spectrum of coronary artery disease
- B. The heart and great vessels
  1. Coronary artery disease
     a. Ischemia
     b. Infarction
     c. Hibernating or stunned myocardium
     d. Zones if ischemia, injury, and infarction
     e. Coronary artery spasm
     f. Angina
     g. Congestive heart failure
  2. Congenital abnormalities
     a. Transposition of the great vessels
     b. Dextrocardia
     c. Situs inversus
     d. Septal defects
  3. Valve disease
     a. Mitral valve prolapse/stenosis/regurgitation
     b. Tricuspid stenosis/regurgitation
  4. Infectious disease
  5. Pericardial effusion
  6. Cardiomyopathy
  7. Chemotherapeutic toxicity

8. Arrhythmias
9. Transplant rejection
10. Thyroid-related heart disease
11. Cardiac tumors
12. Coarctation of aorta

C. Systemic vasculature
1. Arteriosclerosis
2. Aneurysms
3. Phlebitis
4. Deep vein thrombosis
5. Hypertension

III. Cardiac Stress Testing Methods
A. Indications
B. Contraindications and adverse reactions
1. Physical or pathologic conditions
2. Possible interfering drugs
3. Precautions
4. Adverse reactions
C. Patient preparation (including consent if applicable)
D. Equipment
1. Treadmill
2. Supine cycle
3. Upright cycle
4. Hand ergometer
5. Electrocardiogram (ECG) monitor
6. Blood pressure monitor
7. Infusion pump
E. Basic procedure
1. Protocols
2. ECG
a. Skin preparation
b. Electrode placement
3. End points
F. Interventional procedures
1. Pharmacologic intervention
a. Pharmaceuticals and mechanisms of action
i. Dipyridamole
ii. Adenosine
iii. Dobutamine/arbutamine/atropine
iv. A2A agents
b. Indications/contraindications and adverse effects
c. Antidotes for the reversal of the adverse effects
d. Administration protocols
e. Patient preparation
f. Infusion pump

g. Pharmacologic intervention with low-level physical exercise
    i. Indications/contraindications and adverse effects
    ii. Positive effects of introducing low-level physical exercise
h. Administration protocols

G. Cardiac electrophysiology
1. Leads
a. 3-lead
b. 12-lead
2. ECG interpretations
a. ECG strip measurements
b. Patterns
i. Normal rhythm
ii. Segment changes
iii. Basic arrhythmias
iv. Other ECG abnormalities

IV. Myocardial Perfusion/Viability
A. Indications
B. Radiopharmaceuticals
1. Tracers
a. Thallium-201
b. Technetium-99m sestamibi
c. Technetium-99m tetrofosmin
d. Fluorine-18 fluorodeoxyglucose
e. Nitrogen-13 ammonia
f. Rb-82 chloride
g. Dual nuclide: Thallium-201 and a Tc-99m agent
h. O-15 water
2. Route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
d. Extraction fraction
4. Dosimetry
C. Contraindications and adverse reactions
1. Physical and pathologic conditions
2. Interfering studies
3. Possible interfering drugs
4. Precautions
5. Adverse reactions
D. Patient preparation
E. Equipment

1. Imaging equipment
2. Ancillary equipment
    a. Immobilization devices
    b. Comfort devices
    c. Rb-82 infusion cart
    d. Gating devices

F. Protocol
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
    a. Cineangiograms
    b. Ejection fraction determination
    c. Functional images
    d. Heart-lung ratios
    e. Image manipulation techniques
    f. Image filtering
    g. Polar plot analysis
    h. Wall motion analysis
    i. Attenuation correction
    j. Time-activity curves
    k. Summed stress score, summed rest score, summed difference score
    l. Quantitative software techniques
5. Image display/format
    a. Short axis
    b. Vertical long axis
    c. Horizontal long axis

G. Artifacts
1. Radiopharmaceutical distribution and attenuation factors
2. Acquisition parameters
    a. Uniformity
    b. Energy window
    c. Gating
    d. Motion
    e. COR
    f. Attenuation
3. Processing parameters

H. Interpretation of images and data
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests

a. Imaging
b. Nonimaging

V. Equilibrium Radionuclide Angiocardiography, Also Known as Multigated Blood Pool Acquisition, Gated Blood Pool Scan, or Radionuclide Ventriculography
A. Indications
B. Radiopharmaceuticals
1. Tc-99m tagged red blood cells (RBCs)
a. In vivo
b. In vitro
c. Modified in vivo/in vitro
2. Route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
4. Dosimetry
C. Contraindications and adverse reactions
1. Physical or pathologic conditions
2. Interfering studies
3. Possible interfering drugs
4. Precautions
5. Adverse reactions
D. Patient preparation
E. Equipment
1. Imaging equipment
2. Ancillary equipment
a. Cardiac monitor for gating
b. Supine bicycle for exercise if applicable
c. Infusion pump if applicable
d. Blood pressure monitor
e. ECG monitor
F. Protocol
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
a. Ejection fraction calculations
b. Cine display
c. Other measurements
5. Image display/format
6. Sources of error
G. Interventional procedures
1. Supine bicycle exercise
2. Dobutamine

H. Interpretation of images and data
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

VI. First-Pass Radionuclide Angiography
A. Indications
B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m DTPA (penetrate)
        b. Tc-99m pertechnetate
        c. Any Tc-99m labeled radiopharmaceutical of at least 15 mCi (except macroaggregated albumin [MAA])
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
C. Contraindications and adverse reactions
    1. Physical or pathologic conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
D. Patient preparation
E. Equipment
    1. Imaging
    2. Upright bicycle or treadmill if applicable
    3. Gating devices
F. Protocol
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
        a. Ejection fraction calculations
        b. Functional images
        c. Cine display
        d. Left-to-right shunt quantification
        e. Other measurements

5. Image display/format
6. Sources of error

G. Interpretation of images and data
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
a. Imaging
b. Nonimaging

VII. Infarct Imaging
A. Indications
B. Radiopharmaceuticals
1. Tracers
a. Tc-99m pyrophosphate
b. In-111 antimyosin
2. Route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
4. Dosimetry
C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Precautions
4. Adverse reactions
D. Patient preparation
E. Imaging equipment
F. Protocol
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error
G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality

7. Correlative tests
    a. Imaging
    b. Nonimaging

VIII. Major Vessel Flow Study (eg, Superior Vena Cava Obstruction Study)
A. Indications
B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m DTPA (pentetate)
        b. Tc-99m pertechnetate
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Precautions
    4. Adverse reactions
D. Patient preparation
E. Imaging equipment
F. Protocol
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Image display/format
    5. Sources of error
G. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

IX. Venogram/Thrombus Localization
A. Indications
B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m MAA
        b. Other

2. Route of administration
3. Biodistribution
    a. Uptake
    b. Distribution
    c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Precautions
4. Adverse reactions

D. Patient preparation

E. Imaging equipment

F. Protocol
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Image display/format
5. Sources of error

G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

Diagnostic Procedures: Central Nervous System

I. Review of Anatomy and Physiology
- A. Gross anatomy
- B. Cellular anatomy
- C. Blood-brain barrier
- D. Cerebrospinal fluid (CSF) production and flow

II. Pathology
- A. Dementia
- B. Epilepsy
- C. Stroke
- D. Transient ischemic attack
- E. Trauma
- F. Movement disorders
- G. Psychiatric disorders
- H. Brain death
- I. Tumor imaging
- J. CSF disorders/leaks/patency

III. Cerebral Vascular Flow
- A. Indications
- B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m sodium pertechnetate
        b. Tc-99m DTPA
        c. Tc-99m GH
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
- C. Contraindications and adverse reactions
        a. Physical conditions
        b. Interfering studies
        c. Possible interfering drugs
        d. Precautions
        e. Adverse reactions
- D. Patient preparation
- E. Protocol
    1. Acquisition parameters
    2. Dose range and administration technique
    3. Positioning and views
    4. Data processing
    5. Image display/format

6. Sources of error

F. Interpretation of images
   1. Normal
   2. Normal variants
   3. Abnormal
   4. Artifacts
   5. Diagnostic/prognostic value of the study
   6. Evaluation of technical quality
   7. Correlative tests
      a. Imaging
      b. Nonimaging

IV. Planar Brain Imaging

A. Indications

B. Radiopharmaceuticals
   1. Tracers
      a. Tc-99m sodium pertechnetate
      b. Tc-99m DTPA
      c. Tc-99m GH
   2. Route of administration
   3. Biodistribution
      a. Uptake
      b. Distribution
      c. Excretion
   4. Dosimetry

C. Contraindications and adverse reactions
   1. Physical conditions
   2. Interfering studies
   3. Possible interfering drugs
   4. Precautions
   5. Adverse reactions

D. Patient preparation

E. Imaging equipment

F. Protocol
   1. Dose range and administration technique
   2. Acquisition parameters
   3. Positioning and views
   4. Image display/format
   5. Sources of error

G. Interpretation of images
   1. Normal
   2. Normal variants
   3. Abnormal
   4. Artifacts
   5. Diagnostic/prognostic value of the study
   6. Evaluation of technical quality

7. Correlative tests
    a. Imaging
    b. Nonimaging

V. Functional Brain SPECT
A. Indications
B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m HMPAO
        b. Tc-99m ECD
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
D. Patient preparation
E. Imaging equipment
F. Protocol
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
G. Interventional protocols
    1. Vasodilators (acetazolamide)
    2. Psychological stress studies
    3. Sensory stimulation studies
H. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

VI. PET and PET/CT Imaging of the Brain
- A. Indications
- B. Radiopharmaceuticals
    1. Tracers
        a. Fluorine-18 fluorodeoxyglucose
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
- C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reaction
- D. Patient preparation
- E. Equipment
    1. Imaging
        a. Emission
        b. Transmission
    2. Accessory
        a. Head immobilizer
- F. Protocol
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
- G. Interventional protocols
    1. Vasodilators (acetazolamide)
    2. Psychological stress studies
    3. Sensory stimulation studies
- H. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

VII. Brain Tumor Imaging
- A. Indications
- B. Radiopharmaceuticals
  1. Tracers
     a. Thallium-201
     b. Tc99m sestamibi
     c. Fluorine-18 fluorodeoxyglucose
  2. Route of administration
  3. Biodistribution
     a. Uptake
     b. Distribution
     c. Excretion
  4. Dosimetry
- C. Contraindications and adverse reactions
  1. Physical conditions
  2. Interfering studies
  3. Possible interfering drugs
  4. Precautions
  5. Adverse reactions
- D. Patient preparation
- E. Imaging equipment
- F. Protocol
  1. Dose range and administration technique
  2. Acquisition parameters
  3. Positioning and views
  4. Data processing
  5. Image display/format
  6. Sources of error
- G. Interpretation of images
  1. Normal
  2. Normal variants
  3. Abnormal
  4. Artifacts
  5. Diagnostic/prognostic value of the study
  6. Evaluation of technical quality
  7. Correlative tests
     a. Imaging
     b. Nonimaging

VIII. CSF Studies
- A. Cisternography
  1. Indications
  2. Radiopharmaceuticals
     a. Tracers
        i. Ytterbium-169 DTPA
        ii. Indium-111 DTPA

iii. Tc-99m DTPA for pediatrics
b. Route of administration
c. Biodistribution
i. Uptake
ii. Distribution
iii. Excretion
d. Dosimetry
3. Contraindications and adverse reactions
a. Physical conditions
b. Interfering studies
c. Possible interfering drugs
d. Precautions
e. Adverse reactions
4. Patient preparation
5. Imaging equipment
6. Protocol
a. Dose range and administration technique
b. Acquisition parameters
c. Positioning and views
d. Data processing
e. Image display/format
f. Sources of error
7. Interpretation of images
a. Normal
b. Normal variants
c. Abnormal
d. Artifacts
e. Diagnostic/prognostic value of the study
f. Evaluation of technical quality
g. Correlative tests
i. Imaging
ii. Nonimaging

IX. CSF Leak Study
A. Indications
B. Radiopharmaceuticals
1. Tracers
a. Indium-111 DTPA
2. Biodistribution
a. Uptake
b. Distribution
c. Excretion
3. Dosimetry
C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies

3. Possible interfering drugs
4. Precautions
5. Adverse reactions

D. Patient preparation
E. Equipment
1. Imaging
2. Ancillary
a. Pledgets
b. Well counter
c. Laboratory equipment for plasma sample counting

F. Protocol
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error

G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
a. Imaging
b. Other

X. CSF Shunt Patency (Ventriculoperitoneal or Ventriculoatrial Shunt Study)
A. Indications
B. Radiopharmaceuticals
1. Tracers
a. Tc-99m DTPA
2. Route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
4. Dosimetry

C. Patient preparation
D. Contraindications and adverse reactions
1. Physical condition
2. Interfering studies
3. Possible interfering drugs
4. Precautions

5. Adverse reactions

E. Patient preparation
F. Imaging equipment
G. Protocol
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
H. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Other

Diagnostic Procedures: Digestive System

I. Review of Anatomy and Physiology
   A. Gross anatomy and function
   B. Cellular anatomy and function
   C. Blood flow
   D. Bile production and flow

II. Pathology: For each of the following disease states, these topics will be covered: characteristics, causes, population, and treatment
   A. Primary and metastatic neoplasms
   B. Salivary gland disorders
      1. Sjögren's disease
      2. Warthin's tumor
      3. Obstruction
      4. Space-occupying lesions
   C. Disorders of the esophagus
      1. Gastroesophageal reflux disease
      2. Esophagitis
      3. Achalasia
      4. Scleroderma
      5. Barrett's esophagus
   D. Gastric disorders
   E. Liver and gallbladder
   F. Splenic disease
   G. Gastrointestinal bleeding
   H. Meckel's diverticulum

III. Salivary Gland Imaging
   A. Indications
   B. Radiopharmaceutical
      1. Tracers
         a. Tc-99m pertechnetate
      2. Route of administration
      3. Biodistribution
         a. Uptake
         b. Distribution
         c. Excretion
      4. Dosimetry
   C. Contraindications and adverse reactions
      1. Physical and pathologic conditions
      2. Interfering studies
      3. Possible interfering drugs
      4. Precautions
      5. Adverse reactions
   D. Patient preparation

E. Imaging equipment
F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
    7. Interventional procedures
G. Interpretation of images and data
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

IV. Esophageal Motility/Transit and Reflux
A. Indications
B. Radiopharmaceutical
    1. Tracers
        a. Tc-99m sulfur colloid
    2. Route of administration
    3. Biodistribution
        a. Distribution
        b. Excretion
    4. Dosimetry
C. Contraindications and adverse reactions
    1. Physical and pathologic conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
D. Patient preparation
E. Imaging equipment
F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
        a. Motility and transit
        b. Reflux
        c. Pulmonary aspiration
    4. Data processing

5. Image display/format
6. Sources of error

G. Interventional procedures
H. Interpretation of images and data
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
a. Imaging
b. Nonimaging

V. Gastric Emptying
A. Indications
B. Radiopharmaceuticals
1. Tracer
a. Tc-99m sulfur colloid (solid or liquid)
b. In-111 DTPA (liquid)
2. Meal composition
3. Route of administration
4. Biodistribution
a. Distribution
b. Excretion
5. Dosimetry
C. Contraindications and adverse reactions
1. Physical and pathologic conditions
2. Interfering studies
3. Possible interfering drugs
4. Precautions
5. Adverse reactions
D. Special radiation safety conditions
E. Patient preparation
F. Imaging equipment
G. Protocol
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error
H. Interpretation of images and data
1. Normal
2. Normal variants
3. Abnormal

4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

VI. *Helicobacter pylori* Detection
- A. Indications
- B. Radiopharmaceutical
    1. Tracers
        a. Carbon-14–labeled urea
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
- C. Special radiation safety conditions
- D. Patient preparation
- E. Equipment
    1. Collecting device
    2. Liquid scintillation counter
- F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Sources of error
- G. Interpretation of images and data
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Sources of error
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

VII. Liver/Spleen
- A. Indications
- B. Radiopharmaceutical
    1. Tracers
        a. Tc-99m sulfur colloid
    2. Route of administration
    3. Biodistribution
        a. Uptake

b. Distribution
c. Excretion

4. Dosimetry

C. Contraindications and adverse reactions
1. Physical and pathologic conditions
2. Interfering studies
3. Precautions
4. Adverse reactions

D. Patient preparation
E. Imaging equipment
F. Protocol
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error

G. Interpretation of images and data
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
a. Imaging
b. Nonimaging

VIII. Splenic Imaging With Heat-Denatured RBCs
A. Indications
B. Radiopharmaceuticals
1. Tracers
a. Tc-labeled denatured RBCs
2. Dose range and route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Possible interfering drugs
4. Precautions
5. Adverse reactions

D. Patient preparation

E. Imaging equipment
F. Protocol
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
G. Interpretation of images and data
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

IX. Hemangioma Detection
A. Indications
B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m–labeled RBCs
        b. Tc-99m sulfur colloid
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
D. Patient preparation
E. Imaging equipment
F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error

G. Interpretation of images and data
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

X. Hepatobiliary Imaging
A. Indications
B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m iminodiacetic acid derivatives
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
C. Contraindications and adverse reactions
    1. Physical and pathologic conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
D. Patient preparation
E. Imaging equipment
F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
G. Interventional procedures
    1. Morphine augmented
    2. Cholecystokinin pretreatment and intervention
    3. Phenobarbital
H. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts

5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

XI. Gastrointestinal Bleed
- A. Indications
- B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m sulfur colloid
        b. Tc-99m–labeled RBCs
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
- C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
- D. Patient preparation
- E. Imaging equipment
- F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
- G. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

XII. Meckel's Diverticulum
- A. Indications

B. Radiopharmaceutical
    1. Tracers
        a. Tc-99m pertechnetate
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
D. Patient preparation
E. Imaging equipment
F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Image display/format
    5. Sources of error
G. Interventional procedures
    1. Glucagon
    2. Cimetidine
    3. Pentagastrin
H. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

XIII. LeVeen Shunt
A. Indications
B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m MAA
        b. Tc-99m sulfur colloid
    2. Route of administration
    3. Biodistribution

a. Uptake
b. Distribution
c. Excretion

4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Precautions
4. Adverse reactions

D. Special radiation safety conditions
E. Patient preparation
F. Imaging equipment
G. Protocols
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Image display/format
5. Sources of error

H. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
a. Imaging
b. Nonimaging

XIV. Intrahepatic Pump Study
A. Indications
B. Radiopharmaceuticals
1. Tracers
a. Tc-99m MAA
b. Tc-99m sulfur colloid
2. Route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Precautions
4. Adverse reactions

D. Patient preparation
E. Imaging equipment
F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Image display/format
    5. Sources of error
G. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

Diagnostic Procedures: Endocrine/Exocrine System

I. Review of Anatomy and Physiology
- A. Gross anatomy and function
  1. Thyroid
  2. Parathyroids
  3. Adrenals
  4. Lacrimal glands
- B. Cellular anatomy and function
- C. Thyroid hormone production and function
- D. Hypothalamus-pituitary-thyroid feedback system
- E. Other feedback systems

II. Pathology: For each of the following disease states, these topics will be covered: characteristics, causes, population, and treatment
- A. Thyroid
  1. Benign diseases
     a. Hyperthyroidism
     b. Hypothyroidism
  2. Malignancy
- B. Parathyroid
  1. Hyperparathyroidism
  2. Hypoparathyroidism
- C. Adrenal
  1. Addison's disease and other hypofunctional diseases
  2. Cushing's disease and other hyperfunctional diseases
  3. Pheochromocytoma
  4. Neuroblastoma
- D. Lacrimal duct obstruction

III. Thyroid Uptake Study
- A. Indications
- B. Radiopharmaceuticals
  1. Tracers
     a. I-123 sodium iodide
     b. I-131 sodium iodide
     c. Tc-99m sodium pertechnetate
  2. Route of administration
  3. Biodistribution
     a. Uptake
     b. Distribution
     c. Excretion
  4. Dosimetry
- C. Contraindications and adverse reactions
  1. Physical conditions
  2. Interfering studies

3. Possible interfering drugs
4. Precautions
5. Adverse reactions

D. Patient preparation
E. Equipment
1. Uptake probe
2. Neck phantom
3. Gamma camera

F. Protocols
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning
4. Data processing
5. Sources of error

G. Interpretation of data
1. Normal
2. Abnormal
3. Diagnostic/prognostic value of the study
4. Evaluation of technical quality
5. Correlative tests
a. Imaging
b. Nonimaging

IV. Thyroid Scan
A. Indications
B. Radiopharmaceuticals
1. Tracers
a. I-123 sodium iodide
b. I-131 sodium iodide
c. Tc-99m sodium pertechnetate
2. Route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Possible interfering drugs
4. Precautions
5. Adverse reactions

D. Patient preparation
E. Imaging equipment
F. Protocols
1. Dose range and administration technique

2. Acquisition parameters
3. Positioning and views
4. Image display/format
5. Sources of error

G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
a. Imaging
b. Nonimaging

V. Parathyroid Imaging
A. Indications
B. Radiopharmaceuticals
1. Tracers
a. Tc-99m sestamibi
b. Tc-99m sestamibi/I-123 sodium iodide
c. Tc-99m sestamibi/Tl-201 thallous chloride
d. Tc-99m sodium pertechnetate/Tl-201 thallous chloride
2. Route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical and pathologic conditions
2. Interfering studies
3. Possible interfering drugs
4. Precautions
5. Adverse reactions

D. Patient preparation
E. Imaging equipment
F. Protocols
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error

G. Interpretation of images and data
1. Normal

2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

VI. Adrenal Imaging
- A. Indications
- B. Radiopharmaceuticals
    1. Tracers
        a. I-123 metaiodobenzylguanidine
        b. I-131 metaiodobenzylguanidine
        c. I-131 norcholesterol
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
- C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
- D. Patient preparation
- E. Imaging equipment
- F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
- G. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging

b. Nonimaging

VII. Lacrimal Duct Imaging (Dacryoscintigraphy)
- A. Indications
- B. Radiopharmaceuticals
  1. Tracers
     a. Tc-99m pertechnetate
  2. Route of administration
  3. Biodistribution
     a. Uptake
     b. Distribution
     c. Excretion
  4. Dosimetry
- C. Patient preparation
- D. Equipment
  1. Imaging
  2. Ancillary
     a. Head immobilization device
     b. Dose administration device
- E. Protocols
  1. Dose range and administration technique
  2. Acquisition parameters
  3. Positioning and views
  4. Sources of error
- F. Contraindications and adverse reactions
  1. Physical conditions
  2. Interfering studies
  3. Possible interfering drugs
  4. Precautions
  5. Adverse reactions
- G. Interpretation of images
  1. Normal
  2. Normal variants
  3. Abnormal
  4. Artifacts
  5. Diagnostic/prognostic value of the study
  6. Evaluation of technical quality
  7. Correlative tests
     a. Imaging
     b. Nonimaging

Diagnostic Procedures: Genitourinary System

I. Review of Anatomy and Physiology
- A. Gross anatomy and function
- B. Cellular anatomy and function
- C. Blood flow

II. Pathology
- A. Acute inflammatory disease
- B. Chronic inflammatory disease
- C. Acute tubular necrosis
- D. Congenital abnormalities
- E. Space-occupying lesions
- F. Renal cancers
- G. Renovascular disease
- H. Obstructive uropathies
- I. Renal transplant and rejection
- J. Vesicoureteral reflux
- K. Testicular torsion
- L. Inflammatory disease of the testes

III. Renal Perfusion (Functional Imaging)
- A. Indications
- B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m sodium pertechnetate
        b. Tc-99m DTPA
        c. Tc-99m GH
        d. Tc-99m MAG3
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
- C. Kit and preparation
- D. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
- E. Patient preparation
- F. Imaging equipment
- G. Protocol
    1. Dose range and administration technique

2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error

H. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
   a. Imaging
   b. Nonimaging

IV. Glomerular Filtration Rate and Effective Renal Plasma Flow

A. Indications
B. Radiopharmaceutical
1. Tracers
   a. Tc-99m DTPA
   b. Tc-99m MAG3
   c. I-125 Iothalamate
2. Route of administration
3. Biodistribution
   a. Uptake
   b. Distribution
   c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Possible interfering drugs
4. Precautions
5. Adverse reactions

D. Patient preparation
E. Equipment
1. Imaging equipment
2. Laboratory equipment

F. Protocol
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error

G. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

V. Morphological Imaging
A. Indications
B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m DMSA
        b. Tc-99m GH
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
D. Patient preparation
E. Imaging equipment
F. Protocol
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
G. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests

a. Imaging
b. Nonimaging

VI. Voiding Cystogram
A. Indications
B. Radiopharmaceuticals
1. Tracers
a. Tc-99m DTPA
b. Tc-99m sulfur colloid
c. Tc-99m sodium pertechnetate
2. Route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
4. Dosimetry
C. Contraindications and adverse reactions
a. Physical conditions
b. Interfering studies
c. Possible interfering drugs
d. Precautions
e. Adverse reactions
D. Patient preparation
E. Equipment
1. Imaging equipment
2. Laboratory equipment
F. Protocol
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error
G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
a. Imaging
b. Nonimaging

VII. Testicular Imaging
A. Indications

B. Radiopharmaceuticals
    1. Tracer
        a. Tc-99m sodium pertechnetate
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Precautions
    4. Adverse reactions
D. Patient preparation
E. Imaging equipment
F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Image display/format
    5. Sources of error
G. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

Diagnostic Procedures: Hematology and In Vitro

I. Review of Anatomy and Function
- A. Gross anatomy and function
- B. Cellular anatomy and function
- C. Life cycle of red and white blood cells

II. Total Blood Volume
- A. Red cell mass
  1. Indications
  2. Radiopharmaceutical
     a. Cr-51 sodium chromate
  3. Contraindications and adverse reactions
  4. Patient preparation
  5. Equipment
  6. Well counter
  7. Pipette
  8. Protocol
  9. Interpretation of results
- B. Plasma volume
  1. Indications
  2. Radiopharmaceutical
     a. I-125 human serum albumin/RISA
  3. Contraindications and adverse reactions
  4. Patient preparation
  5. Equipment
     a. Well counter
     b. Pipette
  6. Protocol
  7. Interpretation of results

III. Red Cell Survival and Sequestration
- A. Indications
- B. Radiopharmaceutical
  1. Cr-51 sodium chromate
- C. Contraindications and adverse reactions
- D. Patient preparation
- E. Equipment
  1. Uptake probe
  2. Anger camera
  3. Well counter
  4. Pipette
- F. Protocol
- G. Interpretation of results

Diagnostic Procedures: Respiratory System

I. Anatomy and Physiology
- A. Gross anatomy and function
- B. Cellular anatomy and function
- C. Blood flow

II. Pathology: For each of the following disease states, these topics will be covered: characteristics, causes, population, and treatment
- A. Pulmonary embolism
- B. Primary and secondary neoplasms
- C. Chronic obstructive pulmonary disease
    1. Asthma
    2. Emphysema
    3. Pneumoconiosis
    4. Chronic bronchitis
- D. Infectious diseases
    1. Tuberculosis
    2. Pneumonia
- E. Pulmonary edema
- F. Pleural effusion
- G. Sarcoidosis
- H. Atelectasis
- I. Congenital heart disease involving right-to-left cardiac shunt

III. Perfusion
- A. Indications
- B. Radiopharmaceutical
    1. Tracer
        a. Tc-99m MAA
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
- C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
- D. Patient preparation
- E. Imaging equipment
- F. Protocols

1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
    a. Standard lung imaging
    b. Right-to-left cardiac shunt
4. Data processing
5. Image display/format
6. Sources of error

G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

IV. Gas Ventilation

A. Indications

B. Radiopharmaceuticals
1. Tracers
    a. Xenon-133
    b. Krypton-81m
2. Route of administration
3. Biodistribution
    a. Uptake
    b. Distribution
    c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Precautions
4. Adverse reactions

D. Patient preparation

E. Equipment
1. Imaging
2. Accessory
    a. Ventilation/trapping system
    b. Negative pressure room
    c. Room air monitor

F. Protocols
1. Dose range and administration technique
2. Acquisition parameters

3. Positioning and views
4. Image display/format
5. Sources of error

G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
a. Imaging
b. Nonimaging

V. Aerosol Ventilation

A. Indications

B. Radiopharmaceutical
1. Tracers
a. Nebulized Tc-99m DTPA
b. Tc-99m Technegas
2. Route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical and pathologic conditions
2. Interfering studies
3. Precautions
4. Adverse reactions

D. Patient preparation

E. Equipment
1. Imaging
2. Aerosol system
3. Technegas generator

F. Protocols
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Image display/format
5. Sources of error

G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal

4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

VI. Combined Ventilation/Perfusion Study
- A. Order of studies
- B. Interpretative criteria (probabilities)
- C. Diagnostic/prognostic value of the study

VII. Quantitative Lung Study
- A. Indications
- B. Protocols
    1. Dose range and administrative technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
- C. Interpretation of images and data
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

Diagnostic Procedures: Infection and Inflammation

I. Anatomy and Physiology
- A. Immune process
- B. Lymph node distribution
- C. Inflammatory processes

II. Pathology: These topics will be covered: characteristics, causes, population, and treatment
- A. Inflammatory and infectious diseases

III. Radiolabeled White Blood Cell Studies
- A. Indications
- B. Radiopharmaceuticals
    1. Tracers
        a. In-111 oxine–tagged white blood cells
        b. Tc-99m hexametazime (HMPAO)-tagged white blood cells
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
        d. Dosimetry
- C. Contraindications and adverse reactions
    1. Physical or pathologic conditions
    2. Interfering studies
    3. Precautions
    4. Adverse reactions
- D. Patient preparation
- E. Equipment
    1. Imaging
    2. Laboratory equipment for tagging process
- F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
- G. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study

6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

IV. Gallium Imaging for Infection
- A. Indications
- B. Radiopharmaceutical
    1. Tracer
        a. Gallium-67 citrate
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
- C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies
    3. Possible interfering drugs
    4. Precautions
    5. Adverse reactions
- D. Patient preparation
- E. Imaging equipment
- F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
    3. Positioning and views
    4. Data processing
    5. Image display/format
    6. Sources of error
- G. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

V. Bone Marrow Imaging
- A. Indications
- B. Radiopharmaceutical
    1. Tracer
        a. Tc-99m sulfur colloid

2. Route of administration
3. Biodistribution
    a. Uptake
    b. Distribution
    c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Possible interfering drugs
4. Precautions
5. Adverse reactions

D. Patient preparation

E. Imaging equipment

F. Protocols
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error

G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

Diagnostic Procedures: Oncology

I. Anatomy and physiology
- A. Immune process
- B. Lymph node distribution
- C. Receptor physiology
- D. Malignant processes

II. Pathology: These topics will be covered: characteristics, causes, population, and treatment
- A. Malignant diseases

III. Gallium Imaging for Tumors
- A. Indications
- B. Radiopharmaceutical
  1. Tracer
     a. Gallium-67 citrate
  2. Route of administration
  3. Biodistribution
     a. Uptake
     b. Distribution
     c. Excretion
  4. Dosimetry
- C. Contraindications and adverse reactions
  1. Physical conditions
  2. Interfering studies
  3. Possible interfering drugs
  4. Precautions
  5. Adverse reactions
- D. Patient preparation
- E. Imaging equipment
- F. Protocols
  1. Dose range and administration technique
  2. Acquisition parameters
  3. Positioning and views
  4. Data processing
  5. Image display/format
  6. Sources of error
- G. Interpretation of images
  1. Normal
  2. Normal variants
  3. Abnormal
  4. Artifacts
  5. Diagnostic/prognostic value of the study
  6. Evaluation of technical quality
  7. Correlative tests

a. Imaging
b. Nonimaging

IV. Antibody Imaging
A. Indications
B. Radiopharmaceuticals
1. Tracers
a. In-111 capromab pendetide (for prostate cancer)
b. Other approved radiopharmaceuticals
2. Route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
4. Dosimetry
C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Precautions
4. Adverse reactions
D. Patient preparation
E. Imaging equipment
F. Protocols
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error
G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
a. Imaging
b. Nonimaging

V. Receptor Imaging
A. Indications
B. Radiopharmaceuticals
1. Tracers
a. In-111 pentetreotide
b. Other approved radiopharmaceuticals

2. Route of administration
3. Biodistribution
    a. Uptake
    b. Distribution
    c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Possible interfering drugs
4. Precautions
5. Adverse reactions

D. Patient preparation
E. Imaging equipment
F. Protocols
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error

G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

VI. Breast Imaging (Scintimammography and Breast-Specific Gamma Imaging)

A. Indications
B. Radiopharmaceutical
1. Tracer
    a. Tc-99m sestamibi
2. Route of administration
3. Biodistribution
    a. Uptake
    b. Distribution
    c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions

2. Interfering studies
3. Precautions
4. Adverse reactions

D. Patient preparation
E. Equipment
    1. Imaging
    2. Palette—table overlay
F. Protocols
    1. Dose range and administration technique
    2. Acquisition parameters
        a. Positioning
        b. Views
        c. Breast-specific gamma imaging
            i. Oblique
            ii. Cranial/caudal
            iii. Medial/lateral
        d. Scintimammography
            i. Anterior
            ii. Lateral
    3. Image display/format
    4. Sources of error
G. Interpretation of images
    1. Normal
    2. Normal variants
    3. Abnormal
    4. Artifacts
    5. Diagnostic/prognostic value of the study
    6. Evaluation of technical quality
    7. Correlative tests
        a. Imaging
        b. Nonimaging

VII. Sentinel Node Imaging
A. Indications
B. Radiopharmaceuticals
    1. Tracers
        a. Tc-99m filtered sulfur colloid
    2. Route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
    4. Dosimetry
C. Contraindications and adverse reactions
    1. Physical conditions
    2. Interfering studies

3. Precautions
4. Adverse reactions

D. Patient preparation
E. Imaging equipment
F. Protocols
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Image display/format
5. Sources of error

G. Interpretation data
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
a. Imaging
b. Nonimaging

VIII. Lymphoscintigraphy
A. Indications
B. Radiopharmaceutical
1. Tracer
a. Tc-99m filtered sulfur colloid
2. Route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Precautions
4. Adverse reactions

D. Patient preparation
E. Imaging equipment
F. Protocols
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Image display/format
5. Sources of error

G. Interpretation data

1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

IX. PET Imaging (PET and PET/CT)

A. Indications
1. Solitary pulmonary nodule
2. Non–small cell lung cancer
3. Small cell lung cancer
4. Mesothelioma
5. Myeloma
6. Lymphoma
7. Colorectal cancer
8. Head and neck cancer
9. Esophageal cancer
10. Breast cancer
11. Brain cancer
12. Prostate cancer
13. Cervical cancer
14. Ovarian cancer
15. Testicular cancer
16. Thyroid cancer
17. Pancreatic cancer
18. Future indications

B. Radiopharmaceutical
1. Tracer
    a. Fluorine-18 fluorodeoxyglucose
2. Route of administration
3. Biodistribution
    a. Uptake
    b. Distribution
    c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Precautions
4. Adverse reactions

D. Patient preparation

E. Equipment

1. Imaging
    a. Emission
    b. Transmission
2. Glucometer

F. Protocols
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views
4. Data processing
5. Image display/format
6. Sources of error

G. Interpretation of images
1. Normal
2. Normal variants
3. Abnormal
4. Artifacts
5. Diagnostic/prognostic value of the study
6. Evaluation of technical quality
7. Correlative tests
    a. Imaging
    b. Nonimaging

X. Thyroid Metastatic Survey (Whole Body Imaging)

A. Indications

B. Radiopharmaceutical
1. Tracer
    a. Iodine-131 sodium iodide
    b. Iodine-123 sodium iodide
    c. Thallium-201
2. Route of administration
3. Biodistribution
    a. Uptake
    b. Distribution
    c. Excretion
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical conditions
2. Interfering studies
3. Possible interfering drugs
4. Adverse reactions

D. Patient preparation

E. Imaging equipment

F. Protocols
1. Dose range and administration technique
2. Acquisition parameters
3. Positioning and views

4. Image display/format
5. Sources of error

G. Interpretation of images
   1. Normal
   2. Normal variants
   3. Abnormal
   4. Artifacts
   5. Diagnostic/prognostic value of the study
   6. Evaluation of technical quality
   7. Correlative tests
      a. Imaging
      b. Nonimaging

Diagnostic Procedures: Pediatrics

I. Technical Considerations
   A. Instrumentation
   B. Patient safety and care
   C. Immobilization techniques
   D. Patient-parent interaction
   E. Injection technique
   F. Radiopharmaceutical administered dose
   G. Positioning

II. Clinical Applications
   A. Skeletal system
   B. Genitourinary system
   C. Gastrointestinal system
   D. Cardiovascular system
   E. PET imaging

III. Potential Sources of Error in Pediatric PET

Chapter 14

Clinical Education

Clinical Education

Clinical experience integrates didactic learning into the practical setting. During their clinical education, students shall be under the supervision of certified or licensed technologists. Clinical experience should include rotations through general, cardiac, pediatric, positron emission tomography and positron emission tomography/computed tomography, single-photon emission computed tomography, and single-photon emission computed tomography/computed tomography. Ancillary rotations in magnetic resonance imaging and computed tomography to include the administration of contrast media are recommended. Students should observe and/or participate in the administration of contrast media. Students should progress through levels of responsibility/involvement moving from observation to performing as an entry-level technologist. They should become proficient in all aspects of Nuclear Medicine Technology.

Objectives:

1. Comply with relevant policies and procedures
2. Provide safe and proper patient care
3. Act in a professional and ethical manner
4. Practice safe and effective radiation protection techniques
5. Select the appropriate instrumentation for imaging procedure, perform quality control, and set up the proper protocol for use
6. Select the appropriate instrumentation for nonimaging procedure, perform quality control, and set up the proper protocol for use
7. Use the computer for processing and data analysis, perform quality control, and display the data in the appropriate format
8. Receive, prepare, administer, and properly dispose of the appropriate radiopharmaceutical in accordance with federal regulations
9. Perform diagnostic procedures according to accepted protocol
10. Participate in radionuclide therapy procedures according to accepted protocol

Clinical Education

I. Orientation
- A. Program policies and procedures
  1. Student handbook
  2. Evaluation mechanism/forms
- B. Other policies and procedures
  1. Facility/department
     a. Department protocol manual
     b. Facility layout and organization
     c. Day-to-day operations
  2. Fire safety
  3. Emergency codes
  4. Emergency cart and other emergency supplies
  5. Disaster procedures
  6. Occupational Safety and Health Administration Policies
  7. Health Insurance Portability and Accountability Act
  8. Sexual harassment
  9. Diversity training
  10. Other policies
- C. Departmental Organization and Administration
  1. Supplies
     a. Procurement
     b. Inventory/location
  2. Patient scheduling
  3. Records management (eg, patient records, quality control documents)
  4. Licenses

II. Patient Care
- A. Patient communications and interactions
  1. Explanation of procedures
  2. Age/group-specific competencies
  3. Situation specific
- B. Verification of requisition/order
- C. Patient identification
- D. Patient assessment
  1. Patient history
     a. Medications
     b. Clinical laboratory values
     c. Pertinent physical history
  2. Preprocedural preparation
  3. Identification of possible contraindications
- E. Infection control
- F. Contamination control
- G. Patient support

1. Basic needs
2. Ancillary support equipment
    a. Intravenous lines and pumps
    b. Oxygen delivery regulators
    c. Glucometer
    d. Treadmill
    e. Pulse oximeter
    f. Catheters
        i. Peripheral inserted central catheter lines recognition
        ii. Central line catheter recognition
        iii. Other
    g. Drainage tubes
    h. Suction devices
    i. Traction devices
    j. Removable and nonremovable braces

H. Patient care competencies
    1. Vital signs
        a. Pulse
        b. Respiration
        c. Blood pressure
        d. Temperature
    2. Cardiopulmonary resuscitation with automatic external defibrillator certification
    3. Venipuncture
    4. Electrocardiograph
        a. Lead placement
        b. Recognition of normal sinus rhythm
        c. Recognition of common arrhythmias
I. Routes of administration in compliance with facility policy and state regulations
    1. Intravenous
    2. Intravenous catheter setup
    3. Oral
    4. Intramuscular
    5. Intrathecal
    6. Intracavitary
    7. Inhalation
    8. Subcutaneous
    9. Intradermal
    10. Topical
J. Adverse reactions
    1. Identification
    2. Response
    3. Report

III. Affective Domain
- A. Professional relationships
    1. Cooperation and teamwork
    2. Professional etiquette
    3. Conflict management
- B. Professional skills and behaviors
    1. Dependability
    2. Critical thinking
    3. Integrity
    4. Communication
    5. Adaptability
    6. Cooperation
    7. Interpersonal skills
    8. Self-confidence
    9. Initiative
    10. Efficiency
    11. Cultural competency
- C. Professional appearance
- D. Ethics and medicolegal considerations
    1. Respect for patient privacy
    2. Patient confidentiality
    3. Consent forms as applicable

IV. Radiation Protection
- A. Proper use of a survey meter
- B. Personnel monitoring
    1. Proper use of monitoring devices
    2. Personnel contamination surveys
    3. Knowledge and interpretation of radiation exposure reports
- C. Practical methods of radiation protection
- D. Radioactive package receipt and shipping
- E. Radioactive waste disposal
- F. Contamination monitoring
- G. Decontamination procedures
- H. Radionuclide therapy room preparation and cleanup
- I. Proper labeling of and posting for radioactive materials and radiation areas
- J. “As Low As Reasonably Achievable” philosophy

V. Instrumentation: Nonimaging
- A. Geiger-Mueller counter operation and quality control
- B. Well counter operation and quality control
- C. Uptake probe operation and quality control
- D. Dose calibrator operation and quality control
- E. Portable ionization chamber operation and quality control

VI. Instrumentation: Imaging
- A. Selection of appropriate camera and collimator
- B. Selection of acquisition parameters on camera/computer
- C. Performance of quality control
    1. Uniformity
    2. Linearity
    3. Resolution
    4. Uniformity correction map
    5. Center of rotation

VII. Instrumentation: Computers
- A. Data processing
    1. Regions of interest
    2. Cardiac axis orientation
    3. Histogram/curve production
    4. Filter algorithms
    5. Reconstruction algorithms
    6. Comparative display of images
    7. Subtraction studies
    8. Contrast adjustment
    9. Motion correction
    10. Attenuation correction
    11. Coregistration
    12. Other
- B. Image display

VIII. Radiopharmacy
- A. Selection and confirmation of the appropriate radiopharmaceutical
- B. Quality control procedures
- C. Generator elution
- D. Syringe and vial labeling
- E. Kit preparation
- F. Equipment
    1. Centrifuge
    2. Pipettes
    3. Fume hood
    4. Microscope/hemocytometer
- G. Dose calculation and preparation
- H. Record management

IX. Diagnostic Procedures
- A. Imaging procedures
    1. Patient safety considerations
    2. Image acquisition at appropriate time
    3. Camera projections and patient positioning

4. Acquisition of additional views when applicable
5. Data processing
6. Image display
7. Image and data analysis for artifacts and errors
8. Image labeling
9. Presentation of completed study

B. Nonimaging procedures
1. In vivo and in vitro counting
2. Standard preparation
3. Data calculation
4. Presentation of completed study

X. Radionuclide Therapy: Due to liability and state/federal regulations and facility policy, students may only be able to observe these procedures
A. Confirmation of patient identification
B. Confirmation of written directive
C. Dose verification
D. Patient instructions

Chapter 15

Radionuclide Therapy

Radionuclide Therapy

There are an increasing number of clinical nuclear medicine procedures involving radionuclide therapy. These procedures demand special expertise for safe use and proper care of the patient. Students should understand the technologist's role in the administration of radiopharmaceuticals in therapeutic doses, as well as associated imaging protocols.

Objectives:

1. Describe the common causes of pathologies of malignant diseases as they relate to radionuclide therapy
2. Recognize and explain clinical indications for therapeutic procedures
3. Describe and apply the appropriate therapeutic protocols
4. Evaluate images and/or quantitative data for technical quality, including artifacts, normal variants, and normal and altered biodistribution

Radionuclide Therapy

I. Introduction to Radionuclide Therapy
   A. Radionuclide physical properties
   B. Radiobiology

II. Review of Anatomy and Physiology
   A. Malignant processes
   B. Metastatic processes

III. Pathology: For each of the following, topics to be covered include characteristics, causes, population, and treatment
   A. Body cavities
      1. Malignancies
      2. Cavitary effusions
   B. Bone and bone marrow
      1. Leukemia
      2. Polycythemia vera
      3. Metastatic bone cancer
      4. Lymphoma
      5. Joint disease
   C. Thyroid
      1. Hyperthyroidism
      2. Thyroid carcinoma
   D. Non-Hodgkin's lymphoma

IV. Intracavitary Palliation
   A. Clinical indications
   B. Radiopharmaceuticals
      1. Tracers
         a. Phosphorus-32 chromic phosphate
      2. Dose range and route of administration
      3. Biodistribution
         a. Uptake
         b. Distribution
         c. Excretion
         d. Factors affecting biodistribution
      4. Dosimetry
   C. Contraindications and adverse reactions
      1. Physical and pathologic conditions
      2. Precautions
      3. Adverse reactions
   D. Radiation safety considerations and regulations
   E. Patient preparation including consent
   F. Equipment
   G. Basic procedure and processing

1. Protocols
2. Dose range and administration technique
3. Acquisition parameters
4. Positioning and views, including adaptations
5. Image formatting
6. Sources of error

H. Interpretation of images
1. Evaluation of tracer distribution
2. Prognostic value (outcome)

V. Bone Marrow Palliation
A. Clinical indications
B. Radiopharmaceuticals
1. Tracers
a. Phosphorus-32 sodium phosphate
2. Dose range and route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
d. Factors affecting biodistribution
4. Dosimetry
C. Contraindications and adverse reactions
1. Physical and pathologic conditions
2. Precautions
3. Adverse reactions
D. Radiation safety considerations and regulations
E. Patient preparation including consent
F. Basic procedure
1. Protocols
2. Dose range and administration technique
3. Sources of error
G. Prognostic value
1. Outcomes
2. Treatment decisions
3. Prognostic risk factors based on diagnosis

VI. Ablation for Hyperthyroidism
A. Clinical indications
B. Radiopharmaceuticals
1. Tracers
a. Iodine-131 sodium iodide
2. Dose range and route of administration
3. Biodistribution
a. Uptake
b. Distribution

c. Excretion
4. Factors affecting biodistribution
5. Dosimetry

C. Contraindications and adverse reactions
1. Physical and pathologic conditions
2. Interfering studies
3. Interfering drugs
4. Precautions
5. Adverse reactions

D. Radiation safety considerations and regulations
E. Patient preparation including consent
F. Basic procedure
1. Protocols
2. Dose range and administration technique
3. Sources of error

G. Prognostic value
1. Outcomes
2. Treatment decisions
3. Prognostic risk factors based on diagnosis

VII. Thyroid Carcinoma Ablation
A. Clinical indications
B. Radiopharmaceuticals
1. Tracers
a. Iodine-131 sodium iodide
2. Dose range and route of administration
3. Biodistribution
a. Uptake
b. Distribution
c. Excretion
d. Factors affecting biodistribution
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical and pathologic conditions
2. Interfering studies
3. Interfering drugs
4. Precautions
5. Adverse reactions

D. Radiation safety considerations and regulations
E. Patient preparation including consent
F. Basic procedure
1. Protocols
2. Dose range and administration technique
3. Sources of error

G. Prognostic value
1. Outcomes

2. Treatment decisions
3. Prognostic risk factors based on diagnosis

VIII. Palliation of Metastatic Bone Pain
- A. Clinical indications
- B. Radiopharmaceuticals
  1. Tracers
     a. Strontium-89 chloride
     b. Samarium-153 EDTMP
     c. P-32 sodium phosphate
  2. Dose and route of administration
  3. Biodistribution
     a. Uptake
     b. Distribution
     c. Excretion
     d. Factors affecting biodistribution
  4. Dosimetry
- C. Contraindications and adverse reactions
  1. Physical and pathologic conditions
  2. Interfering studies
  3. Interfering drugs
  4. Precautions
  5. Adverse reactions
- D. Radiation safety considerations and regulations
- E. Patient preparation including consent
- F. Equipment (if applicable)
- G. Basic procedure and processing
  1. Protocols
  2. Dose range and administration technique
  3. Acquisition parameters
  4. Positioning and views, including adaptations
  5. Image formatting
  6. Sources of error
- H. Interpretation of images (if applicable)
  1. Distribution
  2. Artifacts
- I. Diagnostic/prognostic value of the study
  1. Outcomes
  2. Treatment decisions
  3. Prognostic risk factors based on diagnosis

IX. Radiosynoviorthesis
- A. Clinical indications
- B. Radiopharmaceuticals
  1. Tracers
     a. Colloidal Phosphorus-32

2. Dose range and route of administration
3. Biodistribution
    a. Uptake
    b. Distribution
    c. Excretion
    d. Factors affecting biodistribution
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical and pathologic conditions
2. Interfering studies
3. Interfering drugs
4. Precautions
5. Adverse reactions

D. Radiation safety considerations and regulations
E. Patient preparation including consent
F. Basic procedure
1. Protocols
2. Dose range and administration technique
3. Sources of error

G. Prognostic value
1. Outcomes
2. Treatment decisions
3. Prognostic risk factors based on diagnosis

X. Radiolabeled Monoclonal Antibody Therapies
A. Clinical indications
B. Radiopharmaceuticals
1. Tracers
    a. I-131 tositumomab
    b. Y-90 ibritumomab with In-111 ibritumomab
2. Dose and route of administration
3. Biodistribution
    a. Uptake
    b. Distribution
    c. Excretion
    d. Factors affecting biodistribution
4. Dosimetry

C. Contraindications and adverse reactions
1. Physical and pathologic conditions
2. Interfering studies
3. Interfering drugs
4. Precautions
5. Adverse reactions

D. Radiation considerations and regulations
E. Patient preparation including consent
F. Equipment

G. Basic procedure and processing
    1. Protocols
    2. Dose range and administration techniques
    3. Acquisition parameters
    4. Positioning and views
    5. Image formatting
    6. Sources of error
H. Interpretation of images
    1. Rationale for imaging
    2. Biodistribution
I. Prognostic value
    1. Outcomes
    2. Treatment decisions
    3. Prognostic risk factors based on diagnosis

XI. Y-90 Microspheres
A. Clinical indications
B. Radiopharmaceuticals
    1. Tracers
        a. Y-90 microspheres
    2. Dose and route of administration
    3. Biodistribution
        a. Uptake
        b. Distribution
        c. Excretion
        d. Factors affecting biodistribution
    4. Dosimetry
C. Contraindications and adverse reactions
    1. Physical and pathologic conditions
    2. Interfering studies
    3. Interfering drugs
    4. Precautions
    5. Adverse reactions
D. Radiation considerations and regulations
E. Patient preparation including consent
F. Equipment
G. Basic procedure and processing
    1. Protocols
    2. Dose range and administration techniques
    3. Acquisition parameters
    4. Positioning and views
    5. Image formatting
    6. Sources of error
H. Prognostic value
    1. Outcomes
    2. Treatment decisions

3. Prognostic risk factors based on diagnosis

Chapter 16

Emerging Technologies

Emerging Technologies

The field of Nuclear Medicine Technology is experiencing change at an exponential rate. While it is difficult to anticipate what new and emerging technologies will become tomorrow's standard of practice, the student should be given an introduction to these ideologies.

Objectives:

1. Describe and discuss instrumentation in emerging technologies and how it relates to current practice
2. Describe and discuss diagnostic and therapeutic procedures in emerging technologies and how they relate to current practice
3. Describe and discuss radiopharmaceuticals in emerging technologies and how they relate to current practice
4. Recognize and identify artifacts and their causes found in emerging technologies
5. Discuss issues related to schedule sequence, reimbursement, and regulations associated with emerging technologies

Emerging Technologies

I. Positron Emission Tomography/Magnetic Resonance Imaging
- A. Magnetic physics
- B. Instrumentation
  1. Theory of operation
  2. Acquisition modes
  3. Image formation and reconstruction
- C. Diagnostic procedures
  1. Radiopharmaceuticals
  2. Contrast agents
- D. Artifacts
  1. Normal variants
  2. Physiologic artifacts
  3. Image registration
- E. Other
  1. Scheduling sequence
  2. Reimbursement Issues
  3. Regulations

II. Positron Emission Mammography
- A. Instrumentation
  1. Theory of operation
  2. Acquisition modes
  3. Image formation and reconstruction
- B. Diagnostic procedures
  1. Radiopharmaceuticals
  2. Contrast agents
- C. Artifacts
  1. Normal variants
  2. Physiologic artifacts
  3. Image registration
- D. Other
  1. Scheduling sequence
  2. Reimbursement issues
  3. Regulations

III. Optical Imaging
- A. Instrumentation
  1. Theory of operation
  2. Acquisition modes
  3. Image formation and reconstruction
- B. Diagnostic procedures
  1. Radiopharmaceuticals
  2. Contrast agents
- C. Artifacts

1. Normal variants
2. Physiologic artifacts
3. Image registration

D. Other
1. Scheduling sequence
2. Reimbursement issues
3. Regulations

IV. Other Technologies
A. Radiation therapy treatment planning
1. Positron emission tomography/computed tomography
2. Positron emission tomography/magnetic resonance imaging
B. Nanotechnology
1. Production of radiopharmaceuticals
C. New radiopharmaceuticals
D. Other technology

Society of Nuclear Medicine Technologist Section Code of Ethics

Nuclear Medicine Technologists, as members of the health care profession, must strive as individuals and as a group to maintain the highest of ethical standards. The principles (Society of Nuclear Medicine Technologist Section Code of Ethics) listed below are not laws, but standards of conduct to be used as ethical guidelines by Nuclear Medicine Technologists.

Principle 1
: The Nuclear Medicine Technologist will provide services with compassion and respect for the dignity of the individual and with the intent to provide the highest quality of patient care.

Principle 2
: The Nuclear Medicine Technologist will provide care without discrimination regarding the nature of the illness or disease, gender, race, religion, sexual preference or socioeconomic status of the patient.

Principle 3
: The Nuclear Medicine Technologist will maintain strict patient confidentiality in accordance with state and federal regulations.

Principle 4
: The Nuclear Medicine Technologist will comply with the laws, regulations, and policies governing the practice of nuclear medicine.

Principle 5
: The Nuclear Medicine Technologist will continually strive to improve their knowledge and technical skills.

Principle 6
: The Nuclear Medicine Technologist will not engage in fraud, deception, or criminal activities.

Principle 7
: The Nuclear Medicine Technologist will be an advocate for their profession.

SNMTS Code of Ethics Revised 6/17/2004.

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Online Resources

American Society of Radiation Technologists Bachelor of Science in Radiologic Sciences Curriculum
https://www.asrt.org/content/Educators/Curricula/BSRS/BSRS.aspx

Aunt Minnie
http://www.auntminnie.com/index.asp?sec=ref&sub=ncm

Mallinckrodt Teaching Files
http://gamma.wustl.edu/allknown.html

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