Nuclear Medicine Technology Competency-Based Curriculum Guide

5th Edition

SOCIETY OF NUCLEAR MEDICINE AND MOLECULAR IMAGING

TECHNOLOGIST SECTION

Introduction

Competency-based education in nuclear medicine technology focuses on those elements necessary to become an entry-level nuclear medicine technologist. Emphasizing competencies communicates entry-level knowledge, skills, attitudes, and behaviors that the nuclear medicine technology curriculum must address and that employers can expect of graduates. Competency-based education allows more flexibility in pedagogical approaches to achieve these essential competencies.

The competencies are divided into eight sections:

1. Radiation Safety
2. Instrumentation, Quality Control and Quality Assurance
3. Radiopharmacy and Pharmacology
4. Diagnostic and Therapeutic Procedures
5. Patient Care
6. Professionalism and Interpersonal Communication Skills
7. Organization Systems-Based Practice
8. Research Methodology

Each section lists the competencies that must be achieved by the entry level nuclear medicine technologist.

The rigor of the nuclear medicine technologist entry-level competencies is such that a significant body of knowledge, skills, and experience is necessary to achieve them. This level of rigor is consistent with the Society of Nuclear Medicine and Molecular Imaging—Technologist Section's (SNMMI-TS) recommendation that the entry-level degree for a nuclear medicine technologist should be at the baccalaureate level.

The content listed under the competencies is intended to be used as a guide for what may be included in a program's curriculum to achieve minimal competency in each area. The specific content listed should be used at the program's discretion to meet individual curricular and accreditation needs. The content in its entirety is not considered mandatory, and other pedagogies may equally meet each program's needs.

Recommended Entry-Level 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 multi-skilled technologist to perform nuclear medicine imaging studies and provide assistance with radionuclide therapy treatments.

Foundational knowledge needed to achieve the competency based curriculum may include, but is not necessarily limited to:

Minimum Post-Secondary Education:

- General Physics (2 semesters or equivalent)
- General Chemistry (2 semesters or equivalent)
- Human Anatomy and Physiology (2 semesters or equivalent)
- Quantitative Reasoning
- Statistics
- Oral/Written Communications (2 semesters or equivalent)
- Humanities
- Social Sciences
- Medical Terminology
- Pathophysiology

Aspects relevant to the competencies needed for an entry level nuclear medicine technologist:

- Biology
- Molecular Biology/Cellular Biochemistry
- Genetics
- Immunology
- Biomedical Ethics
- Health Care Management Courses
- 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
- Nuclear Pharmacy and Pharmacology
- Diagnostic Procedures
- Clinical Education
- Radionuclide Therapy
- Emerging Technologies

Acknowledgements

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Section 1: Radiation Safety

General Definition:

Radiation safety incorporates the principles and practices of employing radiation protection techniques. These techniques are based on maintaining radiation exposure to ionizing radiation according to the "As Low As Reasonably Achievable" (ALARA) philosophy. This philosophy uses the basic tenets of time, distance and shielding and applies to the radiation exposure of occupationally exposed individuals, patients, and the general public. Radiation safety practices also involves adherence to federal, state and institutional regulations.

Entry level nuclear medicine technology graduates are expected to:

1.1 Demonstrate understanding of radiation physics including radioactive decay, various types of radiation, modes of radioactive decay and radiation interaction with matter.

1.2 Describe radionuclide production from a reactor, particle accelerator, and generators.

1.3 List and recognize the effects of radiation in living tissue including cellular, tissue, and systemic responses as well as factors affecting radiosensitivity.

1.4 Utilize the proper radiation dose range to obtain the information necessary to address the indication for the procedure while minimizing the patient's radiation exposure.

1.5 Comply with current federal, state, and institutional regulations regarding ionizing radiation.

1.6 Maintain effective radiation safety practices to minimize patient, occupational and public exposure including special populations (i.e. pediatric, pregnant and/or breast feeding).

1.7 Recognize a radioactive spill and perform the proper decontamination steps in cleaning a radioactive spill.

1.8 Employ the proper radiation detection equipment to monitor levels of radioactivity or exposure.

1.9 Utilize appropriate radiation safety practices for the receipt, use, administration, storage, and disposal of ionizing radiation sources.

I. Radiation
    A. Sources of Radiation
        1. Environmental
        2. Natural
        3. Man-made
            a. Medical
            b. Occupational
    B. Types
        1. Electromagnetic Radiation
        2. Particulate Radiation
        3. Ionizing and non-ionizing
    C. Units
        1. SI units
        2. United States units

II. Composition of the Atom
    A. Quantum Theory
    B. Bohr Model of an Atom
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        2. Neutron
        3. Electron
        4. Neutrinos
        5. Antineutrinos
    C. Other elemental particles
        1. Orbital electron
        2. Valence electron
        3. Auger electron
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        5. Conversion electron
        6. Orbital and suborbital
        7. Quantum Numbers
        8. Pauli exclusion principle
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    A. Nuclear stability
    B. Neutron/proton ratio and the line of stability
    C. Binding energy
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        1. Symbol notation
        2. Relationship of mass and energy
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- A. Alpha
- B. Beta
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- C. Gamma
    1. Isomeric transition
    2. Internal conversion
- D. Combination modes
- E. Decay schemes

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- B. Decay constant
- C. Decay factor
- D. Decay schemes
- E. Half-life
    1. Physical
    2. Biological
    3. Effective
    4. Mean
- F. Exponential graph of radioactive decay
- G. Specific Activity
- H. Specific Weight
- I. Parent/daughter decay
    1. Secular equilibrium
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VI. Production of Radionuclides
- A. Reactor
- B. Accelerator
- C. Generator

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- A. Source of free electrons
- B. Acceleration of electrons
- C. Focusing of Electrons

D. Deceleration of Electrons
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B. Beam characteristics
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    2. Primary versus remnant
D. Inverse square law
E. Fundamental Properties

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    1. Photoelectric
    2. Compton Scattering
    3. Pair Production
    4. Coherent Scattering
B. Range
    1. Energy of photon
    2. Atomic number of matter
    3. Density of matter
C. Specific Ionization
D. Linear Energy Transfer
E. Attenuation Law
    1. Linear attenuation coefficient
    2. Mass attenuation coefficient

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A. Ionization versus Excitation
B. Bremsstrahlung production
C. Range
    1. Energy of particle
    2. Atomic number of matter
    3. Density of matter
    4. Charge of particle

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B. Absorbed dose
C. Dose equivalent
D. Effective dose equivalent

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XII. 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

XIII. Interactions of Radiation with Biological Matter
- A. Direct action
- B. Indirect action
- C. Linear energy transfer
- D. Specific ionization
- E. Relative biological effectiveness
- F. Free radicals
- G. Target theory
- H. Deterministic versus stochastic effects

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  1. Spontaneous mutation
  2. Mutagenesis
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  4. Gene mutations and cancer
- B. Effects of radiation on DNA
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- D. Repair versus mutation

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    2. Problems associated with researching radiation-induced effects/disease

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B. National Council on Radiation Protection and Measurement
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D. United Nations Scientific Committee on the Effects of Atomic Radiation
E. Conference of Radiation Control Program Directors Inc
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1. Nuclear Regulatory Commission (NRC)
2. Department of Transportation

3. Food and Drug Administration
4. Environmental Protection Agency
5. Recommendations from the United States Pharmacopeia
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C. Regulatory Resources
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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)
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8. Chemical and physical states
9. Pathologic conditions
10. Age of patient
11. Pregnancy status

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1. General exposure ranges
2. Benefit versus risk

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2. Estimated dose to fetus from nuclear medicine procedures
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    5. Summation of internal and external exposures
    6. Planned special exposures
    7. Minors
    8. Embryo/fetus of occupationally exposed worker
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    2. Recommended levels
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B. Survey instruments
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D. Regulations
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    3. Delegation of authority
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    2. Composition
    3. Radiation safety program review
C. Written directive procedure
    1. Radionuclides and dosage
    2. Patient identification

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

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    1. Instrument and calibration requirements

2. Direct assay vs. decay calculation
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D. Medical event

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B. Shipping
C. Documentation

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B. Decay –in storage
C. Discharge into sewer system
D. Discharge into atmosphere
E. Transfer to authorized recipient
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1. Instrument and calibration requirements
2. Procedures
3. Action and trigger levels
B. Removable contamination survey
1. Instrument and calibration requirements
2. Procedures
3. Action and trigger levels
C. Decontamination of spills
1. Major spills
2. Minor spills
3. Documentation

XXXV. 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
5. Instruction to patients
D. Release and isolation criteria
1. No restrictions
2. Limited restrictions

3. Isolation requirements

E. Safety precautions involving patients in radiation-based isolation
    1. Ancillary staff instructions, precautions and restrictions
    2. Room preparation and sign postings
    3. Contamination control
    4. Room decontamination upon discharge
    5. Disposal of waste
    6. Patient care and control
    7. Visitor control
    8. Personnel monitoring
    9. Bioassay of personnel
F. Measurement of exposure rates
    1. Surveys of restricted and unrestricted areas
    2. Safe distance markers
    3. Calculated nursing time
G. Procedures in case of death, autopsy, or emergency

Section 2: Instrumentation, Quality Control, and Quality Assurance:

General Definition:

Nuclear medicine technologists will be able to operate, monitor, and troubleshoot a variety of instruments. These include not only "standard" nuclear medicine instruments such as Geiger counters, gamma cameras, and PET tomographs, but also nuclear medicine computers, CT tomographs, and various instruments used for patient care and laboratory work. In addition, greater expectations for quality, as mandated by accrediting agencies and reimbursement policies, now require nuclear medicine technologists to consider and improve the overall operation of the nuclear medicine department. Technologists will utilize the scientific literature to assess departmental operation relative to current standards, implement changes to protocols, and assure the highest levels of patient care, nuclear medicine imaging, and safety.

Entry level nuclear medicine technology graduates are expected to:

2.1 Operate nuclear medicine equipment.
2.2 Utilize nuclear medicine equipment to detect radiation.
2.3 Utilize nuclear medicine imaging systems, including cameras, tomographs, computed tomography systems, and computers, for clinical imaging and research.
2.4 Perform quality control on all types of nuclear medicine instrumentation.
2.5 Analyze quality control and quality assurance results, using subjective, quantitative, and statistical methods.
2.6 Evaluate image quality and other data.
2.7 Perform nuclear medicine studies according to departmental protocol, and to continually monitor the quality of study results and patient interactions.
2.8 Assess department operations using common measures of effectiveness such as comparison to accreditation guidelines, patient satisfaction surveys, and tracking of sentinel events, and common tools such as graphical and statistical analyses.
2.9 Utilize information provided by comparative effectiveness research/evidence-based medicine.
2.10 Incorporate current standards of practice and new practice initiatives.
2.11 Implement continuous quality improvement plans.

I. Basic Radiation Information
    A. Atomic structure
    B. Radioactive decay processes
    C. Interactions of ionizing radiation
        1. Charged particles
        2. Photons
        3. Consequences of radiation interactions
    D. Concepts of radiation measurement and protection
        1. Time, distance and shielding
        2. Gamma constant
        3. Exposure and exposure rate
        4. Inverse square law

II. Gas-Filled Detectors
    A. Principles of operation
        1. Components, basic operation
        2. Current mode vs. pulse mode
        3. Limitations
        4. Gas ionization (voltage-response) curve
            a. Recombination
            b. Ionization
            c. Proportional
            d. Nonproportional (limited proportionality)
            e. Geiger-Mueller
            f. Continuous discharge
    B. Ion chambers
        1. Dose calibrator
            a. Operation
            b. Quality control
                i. Constancy
                ii. Linearity
                iii. Accuracy
                iv. Geometry
        2. Handheld ionization chamber (ionization survey meter)
            a. Operation
            b. Appropriate use
            c. Daily quality control
            d. Calibration
        3. Pocket dosimeter
    C. Geiger counter (survey meter)
        1. Operation
        2. Types of Geiger-Mueller probes
        3. Appropriate use
            a. Scale settings

b. Factors that influence observed exposure rate
i. Dose-response curve
ii. Time constant
iii. Probe geometry
4. Dead time
5. Daily quality control
6. Calibration

III. Scintillation Detectors
A. Solid scintillation detector
1. Principles of operation
2. Component parts
a. Sodium iodide crystal
b. Photomultiplier tubes
i. Photocathode
ii. Focusing grid
iii. Dynodes
iv. Creation of the electron pulse
v. High-voltage power
c. Amplification
i. Preamplifier
ii. Amplifier/gain setting
d. Pulse-height analyzer
i. Single channel
ii. Multichannel
iii. Components of an energy spectrum
iv. Energy window calculations
e. Counters or scalers, timers, rate meters
3. Energy calibration and daily constancy determination
4. Energy spectrum analysis
5. Detection efficiency factors
a. Detector composition
b. Geometry
c. Gamma ray energy and energy window width
6. Count rate determination
a. Gross counts
b. Background counts
c. Net counts
B. Types
1. Uptake probe
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b. Isoresponse curve
2. Well counter
a. Geometry

b. Dead time versus activity
7. Multi-hole automated counter

C. Quality control
1. Energy resolution - full width at half of maximum
a. Definition
b. Measurement
c. Variation with gamma ray energy
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IV. Semiconductor Detectors
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2. Radiation detection
3. Semiconductor materials
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6. Collimation and shielding
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B. Graphing
1. Linear plots
2. Semilog plots
3. Histogram plots and frequency distributions
4. Least squares-best fit curve (regression analysis)
C. Standard deviation
1. Series of measurements and mean value
2. Single measurement and Poisson statistical model
3. Coefficient of variation (percent standard deviation)
4. Gaussian and Poisson distributions
5. Confidence intervals and percent error
6. Determining the number of counts required for statistical significance
D. Levy-Jennings plot
E. Chi-square test

VI. Anger-Type Scintillation Cameras
A. Principles of operation
1. Collimator
a. Purpose
b. Design parameters
c. Selection considerations

2. Crystal
    a. Efficiency
    b. Light pipe
3. Photomultiplier tubes
    a. Scintillation photon detection and electron multiplication
    b. Preamplifier/amplifier
    c. Analog-to-digital converters
    d. Removal of light pipe and position determination via computer
4. Camera head circuits
    a. Positioning circuits
    b. Summation circuit and Z-pulse
    c. Ratio or division circuit
5. Pulse-height analyzer
    a. Window width
    b. Centered versus asymmetrical window
    c. Unblank pulse
6. Scalers and rate meters
7. Corrections
    a. Energy correction
    b. Linearity correction
    c. Uniformity correction
    d. Autotuning of photomultiplier tubes

B. System configurations
1. Single head
2. Dual head
3. Triple head
4. Mobile

C. Imaging modes
1. Static
    a. Time/counts per frame
    b. Matrix size
2. Whole body acquisition
    a. Body contouring
    b. Information density
    c. Scan speed
    d. Matrix size
3. Dynamic
    a. Time per frame
    b. Matrix size
    c. Collimation
    d. Temporal resolution
4. Gated
    a. Gated acquisition technique
    b. Frames and time per frame

c. Beat rejection
5. SPECT (see below)
6. Selection of collimator and acquisition parameters

D. Image display
1. Static
2. Cine
3. 3-dimensional/volumetric

E. Data recording
1. Computer memory/display device
2. Film

F. Performance characteristics
1. Collimators
a. Manufacturing techniques
b. Design parameters, effect on resolution and sensitivity:
i. Hole diameter
ii. Hole length
iii. Septal thickness
c. Effect of collimator design on:
i. Spatial resolution
ii. Sensitivity
iii. Field of view
iv. Image size (magnification/minification)
v. Image distortion
vi. Energy characteristics and septal penetration/star artifact
3. Types
i. Parallel-hole
- High sensitivity
- Low energy all purpose or general all purpose
- High resolution versus high sensitivity
- Ultrahigh resolution
- Medium energy
- High energy

ii. Fan-beam
iii. Diverging/converging
iv. Pinhole
v. Slant-hole

b. Camera
1. Spatial resolution
a. Repeating-pattern phantoms and linearity testing
b. Line spread function and full width half maximum
c. Modulation transfer function
2. Uniformity
a. NEMA uniformity calculation
b. Specifications (differential/integral, UFOV/CFOV)

c. Factors affecting uniformity
d. Uniformity versus intrinsic resolution
3. Energy resolution
4. Sensitivity
5. Dead time
6. Count rate
7. Image contrast

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b. Semiconductor materials
2. Pixelated (multicrystal) architecture
a. Position-sensitive PMTs
b. Avalanche photodiodes
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2. Three-dimensional axes
3. Orbit design
a. Circular
b. Body contour
c. Elliptical
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5. Multihead systems
a. Fixed
i. 180 degrees with 2 detectors
ii. 90 degrees with 2 detectors
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6. Attenuation correction
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    b. X-ray
7. Effect of acquisition parameters
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    b. Degrees of rotation
    c. Number of projections (angular sampling)
    d. Zoom
    e. Distance and orbit choice
    f. Time per projection

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1. Filtered (convoluted) back-projection
    a. Collection of planar images (2-dimensional format)
    b. Sum of the images (backprojection)
    c. Fourier transformation
        i. Spatial and frequency domain
        ii. Nyquist frequency
        iii. Filters and filter selection
2. Iterative reconstruction
    a. Concepts
    b. Incorporation of physics and camera parameters
    c. Maximum likelihood expectation maximization
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3. Reconstruction parameters
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    b. Uniformity correction
    c. Attenuation correction
    d. Motion correction and linograms/sinograms
4. 3D image matrix
    a. Voxels
    b. Tomographic planes
        i. Standard body planes
        ii. American College of Cardiology cardiac planes
    c. Other image display formats
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        ii. Surface rendering
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C. Factors that limit statistics and/or spatial resolution
1. Radiopharmaceutical dose limits
2. Time constraints
3. Source-to-detector distance
4. Attenuation
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1. Attenuation correction
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    b. Measured attenuation correction
2. Scatter compensation
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4. Noise regularization

E. Performance characteristics
1. Spatial resolution
2. Cylindrical phantom assessment
    a. Uniformity
    b. Volume sensitivity
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F. Artifacts
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IX. PET Systems

A. Basic principles of operation
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2. Scintillators for annihilation photons
3. Coincidence imaging
4. Types of events
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    b. True coincidences
    c. Random coincidences
    d. Scatter coincidences
5. Need for attenuation correction
6. Time-of-flight concepts

B. System configurations
1. Gantry and ring arrangement of crystals
2. Detectors, blocks, buckets
3. Coincidence detection
    a. Sinograms
    b. Energy window
    c. Electronic detection of coincidences
    d. Randoms estimation
4. Iterative reconstruction with corrections
    a. Dead time
    b. Randoms
    c. Scatter
    d. Normalization
    e. Attenuation

        f. Decay
    5. Absolute calibration (well counter correction)
C. Imaging
    1. Scout image/topogram
    2. Bed positions
    3. Data collection
        a. Direct and cross planes
        b. Prompt and delayed sinograms
        c. Transmission and emission images
    4. Acquisition modes
        a. 2D imaging
        b. 3D imaging
        c. Dynamic imaging
        d. Gated imaging
    5. Attenuation correction methods
        a. Transmission sources
            i. Orbiting rod or point sources
            ii. CT
            iii. MRI
        b. Image segmentation
        c. Coregistration
    6. Reconstruction
        a. Iterative reconstruction
        b. Matrix size
D. Performance characteristics
    1. Spatial resolution
        a. Effect of spatial resolution on PVE and SUV
        b. Limits of resolution
            i. Range of the positron
            ii. Angulation/parallax/depth-of-interaction effect
            iii. Detector size
            iv. Ring gantry
    2. Count rate issues
        a. Sensitivity
        b. Scatter fraction
        c. Dead time
        d. Noise-equivalent count rate
    3. Quantitative values
        a. Why PET is more quantitative than gamma camera imaging
        b. Absolute activity units (cps/voxel $\Rightarrow$ kBq/ml conversion)
        c. Standardized uptake value
            i. Meaning
            ii. Display unit
E. Instrumentation-related artifacts

1. Electronic
2. Hot spot
3. Misregistration
4. Motion
5. PVE artifacts and effect on SUV

F. Organ-specific PET devices

X. CT Systems

A. Basic principles of operation
1. History and development
2. CT X-ray tube design
a. Components and operation
b. Energy spectrum and X-ray filter
c. Voltage variation
d. Current variation
3. CT scanner design
a. Gantry arrangement
b. X-ray tube and detectors
c. Collimation
d. Data acquisition system
e. Rotational speed
f. Multislice helical CT
g. Interpolation to transverse slices

B. Image acquisition and display
1. Patient positioning
2. Breast/thyroid shielding (for diagnostic CT only)
3. Contrast administration
4. Automated exposure control
5. Image reconstruction to show specific tissue types
6. Image display
a. CT numbers, Hounsfield units
b. Standard body orthogonal slices
c. Display of volumetric data
7. Protocols
a. Low-dose (SPECT/CT and PET/CT)
b. Integrated PET/CT protocols
c. Diagnostic CT

C. Image quality
1. Contrast
2. Spatial resolution
3. Image noise

D. Artifacts
1. Beam hardening
2. Truncation

3. Noise
4. Patient motion – streak artifact
5. Metal
6. Partial volume averaging
7. Insufficient views – aliasing

E. Radiation safety
1. Room construction
2. Personnel safety
3. Patient dose
a. CT dose index ($CTDI_{100}$)
b. Dose-length product (DLP)
c. Dose reporting requirements
4. Public health concerns

XI. Quality Control of Imaging Systems

A. Standard-setting organizations
1. NEMA standards
2. Joint Commission on Healthcare Organizations
3. American College of Radiology
4. Intersocietal Commission

B. Environmental controls
1. Electrical
2. Temperature
3. Cleanliness

C. Acceptance testing
1. Testing of newly purchased systems
a. Gamma camera
b. SPECT system
c. PET system
d. CT system
2. Benchmarking

D. Anger scintillation camera
1. General parameters
a. Intrinsic versus extrinsic measurements
b. Sources
2. Peaking
3. Flood uniformity
a. Calculation
b. Integral versus differential uniformity
4. Spatial resolution
a. Bar phantoms
b. Line spread measurements and FWHM
5. Linearity
6. Sensitivity

7. Pixel sizing
8. Multiple-window spatial registration
9. Collimator integrity

E. SPECT systems
    1. High count flood uniformity
    2. Center of rotation
    3. Spatial resolution determination
    4. Cylindrical phantoms
    5. Reference scan for attenuation correction

F. PET systems
    1. Quality control testing
        a. Daily operation/blank scan
        b. Normalization correction
        c. Well counter calibration
        d. Bed indexing and alignment with CT system
        e. Energy window calibration and detector identification maps
        f. Coincidence timing calibration
    2. System characterizations
        a. Spatial resolution
        b. System sensitivity
        c. Scatter fraction
        d. Noise-equivalent count rate
        e. Image uniformity
    3. Correction calibrations
        a. Cylindrical and anthropomorphic phantoms
        b. Dead time
        c. Scatter
        d. Contrast
        e. Well counter correction and SUV accuracy

G. CT (on a PET/CT or SPECT/CT system)
    1. Daily
        a. Tube output and detector response at various kVp/mA levels
        b. CT number of water and standard deviation
    2. Weekly
        a. Contrast
        b. Lesion detectability
        c. Noise
        d. Slice thickness
    3. Annually or biannually
        a. Low- and high-contrast resolution
        b. Uniformity
        c. Radiation dose rates
        d. Accuracy of sizing/distance measurements
        e. Alignment with PET or SPECT bed

f. Safety features

H. Troubleshooting and artifact recognition
   1. Gamma cameras
   2. SPECT systems
   3. PET systems
   4. CT systems

XII. Nuclear Medicine Computer Systems

A. Concepts
   1. Digital (vs. analog) information
   2. Boolean algebra
   3. Binary number system
   4. Bits, bytes, words

B. Components of computers
   1. Central processing unit
      a. Control unit
      b. Arithmetic logic unit
      c. Registers
      d. Clock
   2. Memory
      a. CPU memory
      b. Cache memory
      c. Hard drive memory
      d. External memory devices
   3. Software
      a. Operating system
      b. Graphical user interface
      c. Application programs
   4. Video display systems
      a. Video display terminal
      b. Liquid crystal monitor
      c. Display buffer
   5. Peripheral devices
   6. Computer networks
      a. Local-area network topologies
      b. Picture Archiving and Communications System (PACS)
      c. Radiology information systems

C. Gamma camera/computer interface
   1. Analog-to-digital converters
      a. Purpose
      b. Types
   2. Image buffers
   3. Digital zoom
   4. Software implementation of SPECT image improvement algorithms

D. Image Display
    1. Gray scales
    2. Color scales
    3. Exponential and logarithmic modifications
    4. Standard nuclear medicine display conventions; making image display scales comparable
    5. Screen capture
E. Acquisition modes
    1. Types
        a. Frame mode
            i. Static
            ii. Dynamic
            iii. Whole body
        b. List mode
        c. Multi-gated mode
    2. Matrix choices
        a. Matrix dimension
        b. Byte vs. word mode; pixel saturation
        c. Trade-offs
        d. 3D image matrix and voxels
    3. Memory requirements
        a. Addresses
        b. Counts per address
        c. Memory calculations
F. Planar filters
    1. Spatial/smoothing
    2. Temporal
G. SPECT filters
    1. Filter design and selection
        a. Selection criteria
        b. Types
        c. Cutoff or critical frequency
        d. Effect of changing filter parameters
    2. Nyquist frequency
        a. Calculation
        b. Importance
    3. Reconstruction techniques for fan-beam and cone-beam collimators
H. Data processing programs
    1. Field uniformity correction
    2. Image arithmetic
        a. Background subtraction
        b. Geometric mean determination
        c. Scaling and normalization
    3. Display manipulations

a. Background suppression
b. Foreground correction (contrast enhancement)

4. Regions of interest
    a. Selection
    b. Automatic edge detection
    c. Comparison ratios and percentages
    d. Effects of poorly drawn regions of interest
5. Curve generation and manipulation
    a. Image profiles
    b. Time-activity curves
    c. Harmonic analysis
6. Three-dimensional applications
    a. Motion correction
    b. Center of rotation error corrections
    c. Image registration and coregistration
    d. Polar map generation

I. Use of computers in quality control programs
1. Count profiles
2. Graphical displays of QC data
3. Analysis using regions of interest
4. Integration of software with imaging systems
5. Validation of software
6. Test patterns

XIII. Quality Assurance

A. Concepts
1. Procedural quality assurance
2. Departmental quality assurance
3. Risk analysis/management
4. Quality assurance as evidence for high-quality practice
5. Tools for QA assessment
    a. Focus groups, quality circles, multivoting
    b. Performance improvement cycles (e.g., Plan/Do/Check/Act, Focus/Analyze/Develop/Execute)
    c. Statistical analysis
    d. Flowcharts, cause-and-effect diagrams, scatter plots, change-over-time graphs

B. Common measures of quality practice
1. Compliance with federal/state regulations, radiation protection inspections, etc.
2. Tracking of processes (e.g., why does this process include this step?)
3. Tracking of errors
4. Corrective actions
    a. Dose administration
    b. Scheduling
    c. Image display/analysis
5. Timeliness

a. Study scheduling
b. Reporting

6. Patient satisfaction surveys
7. Standards of practice
    a. Departmental protocol manual
    b. Instrumentation quality control
    c. Staffing
8. Sentinel event indicators

C. Hospital/clinic/laboratory accreditation
1. Accrediting organizations
2. Operational aspects assessed:
    a. Department organization
    b. Protocol manual
    c. Staff credentials
    d. Equipment performance
        i. Quality control results
        ii. Planar image quality
        iii. Tomographic image quality
    e. Clinical image quality
    f. Reporting
    g. Patient satisfaction

D. Practice Improvement
1. Practice guidelines and community standards of practice
2. Critical assessment of literature
3. Interaction with other medical professionals
    a. Attendance at grand rounds, tumor boards, etc.
    b. Diagnosis/treatment pathways for various disease entities – where does nuclear medicine fit in?
4. Implementation of operational changes
5. Continuous quality improvement

XIV. Emerging Technologies

A. PET/MR
B. PEM
C. Other Molecular Imaging

Section 3: Radiopharmacy and Pharmacology

General Definition:

Radiopharmacy and pharmacology includes the preparation and calculation of the dose to be administered, quality control of radiopharmaceutical preparation, and following radiation safety and radiopharmacy regulations. It includes nonradioactive interventional pharmaceuticals and contrast media that are used as part of nuclear medicine procedures.

Entry level nuclear medicine technology graduates are expected to:

- 3.1 Follow radiation safety procedures and applicable regulations in a radiopharmacy
- 3.2 Prepare radiopharmaceuticals
- 3.3 Perform quality control on radiopharmaceuticals
- 3.4 Evaluate radiopharmaceutical properties in terms of ideal characteristics for the diagnostic or therapeutic procedure.
- 3.5 Calculate and prepare patient doses
- 3.6 Prepare non-radioactive pharmaceuticals and contrast media that are used as part of a nuclear medicine procedure
- 3.7 Determine the appropriate route of administration for radiopharmaceuticals and nonradioactive pharmaceuticals, including contrast, that are used as part of nuclear medicine procedures..
- 3.8 List and recognize possible adverse reactions associated with radiopharmaceuticals and nonradioactive pharmaceuticals, including contrast, that are used as part of nuclear medicine procedures

I. Desirable characteristics for a radionuclide
    A. Ideal characteristics for diagnostic nuclide
        1. Type of radiation
        2. Energy
        3. Monoenergetic versus multiple energies
        4. Half-life
    B. Ideal characteristics for a therapeutic nuclide
        1. Type of radiation
        2. Energy
        3. Half-life

II. Desirable characteristics for a radiopharmaceutical
    A. Noninvasive, nonpharmacologic
    B. Clearance time
        1. Plasma clearance
        2. Target uptake
        3. Target clearance
        4. Biological half-life
    C. Target-to-background ratio
    D. Ease of preparation
    E. Shelf life
        1. Routes of administration Inhalation
        2. Intracavitary injection
        3. Intrathecal injection
        4. Intravenous injection Oral
        5. Subcutaneous injection
        6. Urethral infusion

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. Reactivity
        1. Valence state
        2. Free radicals
        3. Oxidation numbers
        4. Oxidation/reduction reactions
    B. Chemical bonds

C. 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. Yield Calculations
    4. Elution Technique
    5. Useful life span
D. Record Keeping

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

VII. 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. Sr82 and Sr85 in Rb82
            c. 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 (e.g., 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

VIII. 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

IX. 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

X. 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

XI. 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

XII. 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

XIII. 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. Chemotaxis
   6. Compartment localization
   7. Electrostatic binding
   8. Phagocytosis
   9. Antibody and antibody fragment localization
   10. Receptor localization
   11. Cellular sequestration
   12. Metabolism
   13. Other

XIV. Individual Radiopharmaceuticals

A. For each radiopharmaceutical, 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

XV. Pharmaceuticals

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

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. Regadenoson
    2. Dipyridamole
    3. Adenosine
    4. Dobutamine
    5. Aminophylline
    6. Captopril
    7. Enalaprilat
    8. Furosemide
    9. Insulin
    10. Acetazolamide

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

XVI. 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. Air
8. Other

Section 4: Diagnostic and Therapeutic Procedures

General Definition:

Diagnostic nuclear medicine and molecular imaging procedures are performed to identify normal and abnormal physiological, biological, cellular and molecular processes within the body. Therapeutic nuclear medicine procedures are performed using radioactive materials for the purpose of treating disease or providing palliative care.

Entry level nuclear medicine technology graduates are expected to:

4.1 Perform diagnostic and therapeutic nuclear medicine and molecular imaging procedures.
4.2 Determine appropriateness of each procedure.
4.3 Evaluate patient health status.
4.4 Ensure compliance with patient preparation requirements for each procedure.
4.5 Provide patient education appropriate to each procedure.
4.6 Facilitate or obtain informed consent, as appropriate.
4.7 Comply with current federal, regional, and institutional regulations regarding ionizing radiation.
4.8 Prepare all equipment according to the guidelines for each procedure.
4.9 Administer radiopharmaceuticals according to the guidelines for each procedure.
4.10 Administer adjunctive medications according to the guidelines for each procedure.
4.11 Evaluate image quality and other acquired data.
4.12 Describe the importance of adhering to a research protocol in imaging and non-imaging procedures.
4.13 Utilize up-to-date scientific evidence, clinical judgment, and patient information to make informed decision in performing diagnostic and therapeutic procedures.

I. Diagnostic Procedures
    A. Anatomy and Physiology
    B. Pathology
    C. Procedures/Scans
        1. Indications
        2. Contraindications
            a. Physical and pathologic conditions
            b. Interfering studies/appropriate sequencing
            c. Possible interfering drugs
        3. Radiopharmaceuticals and adjunctive medications
            a. Route of administration
            b. Dose
            c. Biodistribution
                i. Normal
                ii. Abnormal
            d. Dosimetry
        4. Adverse reactions
        5. Patient Preparation
        6. Instrumentation
        7. Acquisition Protocol
            a. Dose administration technique
            b. Imaging parameters
            c. Positioning and views
            d. Data processing
            e. Imaging display/format
            f. Sources of error
    D. Evaluation/Critique of Images and Data
        1. Normal
        2. Normal variants
        3. Abnormal
        4. Artifacts
        5. Diagnostic/prognostic value
        6. Evaluation of technical quality
        7. Correlative tests
    E. Pediatric Technical Considerations
        1. Instrumentation
        2. Patient safety and care
        3. Immobilization techniques
        4. Patient-parent interaction
        5. Injection technique
        6. Radiopharmaceutical administered dose
        7. Positioning
        8. Sources of Error

II. Diagnostic Protocols
    A. Skeletal
        1. Whole-Body Bone Scan
        2. Multiphase Bone Imaging
        3. Single-Photon Emission Computed Tomography (SPECT) and SPECT/Computed Tomography (CT) Bone Scan
        4. Positron Emission Tomography (PET) and PET/CT
        5. Bone Density/Absorptiometry
    B. Cardiovascular
        1. Cardiac Stress Testing Methods
        2. Myocardial Perfusion/Viability
        3. Planar
        4. SPECT and SPECT/CT
        5. PET and PET/CT
        6. Equilibrium Radionuclide Angiocardiography, Also Known as Multigated Blood Pool Acquisition (MUGA), Gated Blood Pool Scan, or Radionuclide Ventriculography
            a. Rest
            b. Stress
            c. SPECT
        7. First-Pass Radionuclide Angiography
        8. Right to left cardiac shunt
    C. Central Nervous System
        1. Brain Death/Cerebral Vascular Flow
        2. Dopamine Receptor Imaging
        3. Beta Amyloid Imaging
        4. Functional Brain SPECT
        5. PET and PET/CT Imaging of the Brain
        6. Brain Tumor Imaging
        7. CSF Studies
            a. Cysternogram
            b. Leak Study
            c. Shunt Patency
    D. Digestive System
        1. Salivary Gland Imaging
        2. Esophageal Motility/Transit and Reflux
        3. Gastric Emptying
        4. *Helicobacter pylori* Detection
        5. Liver/Spleen
        6. Hemangioma Detection
        7. Hepatobiliary

9. Imaging
10. Gastrointestinal Bleed
11. Meckel's Diverticulum
12. Periteoneo-Venous Shunt (i.e. LeVeen)
13. Intrahepatic Pump Study

E. Endocrine/Exocrine System
    1. Thyroid Uptake Study
    2. Thyroid Scan
    3. Parathyroid Imaging
    4. Adrenal Imaging
    5. Lacrimal Duct Imaging (Dacryoscintigraphy)

F. Genitourinary System
    1. Renal Perfusion (Functional Imaging)
        a. ACE Inhibitor
        b. Furosemide
    2. Glomerular filtration rate and effective renal plasma flow
    3. Morphological Imaging
    4. Cystogram
    5. Testicular Imaging

G. Hematology and In Vitro
    1. Total Blood Volume
        a. Red cell mass
        b. Plasma Volume
    2. Red Cell Survival and Sequestration
    3. Bone Marrow
    4. Splenic Imaging with heat-denatured RBC's

H. Respiratory System
    1. Perfusion
    2. Gas Ventilation
    3. Aerosol Ventilation
    4. Combined Ventilation/Perfusion Study
    5. Quantitative Lung Study

I. Infection and Inflammation
    1. Radiolabeled White Blood Cell Studies
    2. Gallium-67 Imaging for Infection

J. Oncology
    1. Gallium-67 Imaging for tumors
    2. Antibody Imaging
    3. Receptor Imaging
    4. Breast Imaging (Scintimammography and Breast-Specific Gamma Imaging)
    5. Sentinel Node Localization
    6. Lymphoscintigraphy
    7. Lymphangiogram

8. PET/CT
9. Thyroid Metastatic Survey (Whole Body Imaging)

K. CT imaging protocols
1. Head
2. Neck
3. Chest
4. Abdomen
5. Pelvis
6. Musculoskeletal

III. Cross Sectional Anatomy
A. Introduction to sectional anatomy
B. Body planes
1. Median
2. Sagittal
3. Coronal, frontal
4. Transverse, cross-horizontal
C. Anatomical directions and positions
1. Cranial, superior
2. Caudal, inferior
3. Anterior, ventral
4. Posterior, dorsal
5. Medial
6. Lateral
7. Proximal
8. Distal
D. Body cavities
1. Ventral
a. Thoracic
b. Abdominopelvic
2. Dorsal
a. Cranial
b. Vertebra
E. Anatomy and common pathologies recorded on multiplanar images of the head
1. Cranial bones
a. Frontal
b. Ethmoid
c. Parietal
d. Sphenoid
e. Occipital
f. Temporal
2. Facial bones
a. Nasal
b. Zygomas

        c. Maxilla
        d. Mandible
        e. Lacrimal
    3. Temporomandibular joint
    4. Sinuses
        a. Frontal
        b. Maxillary
        c. Ethmoid
        d. Sphenoid
    5. Orbit and eye
    6. Muscles
    7. Vascular structures
F. Anatomy and common pathologies recorded on multiplanar images of the brain
    1. Frontal lobe
    2. Parietal lobe
    3. Temporal lobe
    4. Occipital lobe
    5. Cerebellum
    6. Midbrain
    7. Pons
    8. Medulla oblongata
    9. Thalamus
    10. Hypothalamus
    11. Limbic system fissures (sulci)
    12. Convolutions (gyri)
    13. Meninges
    14. Ventricles
    15. Vascular structures
G. Anatomy and common pathologies recorded on multiplanar images of the neck
    1. Organs
        a. Pharynx
        b. Larynx
        c. Esophagus
        d. Trachea
        e. Thyroid
        f. Parathyroid
        g. Salivary
    2. Cervical spine
    3. Muscles
    4. Vascular structures
    5. Lymphatics

H. Anatomy and common pathologies recorded on multiplanar images of the thorax
    1. Organs
        a. Lungs
        b. Diaphragm
        c. Heart
        d. Breasts
        e. Thymus
    2. Thoracic spine
    3. Sternum
    4. Ribs
    5. Scapulae
    6. Clavicles
    7. Muscles
    8. Vasculature structures
    9. Lymphatics
I. Anatomy and common pathologies recorded on multiplanar images of the abdomen
    1. Organs
        a. Liver
        b. Gallbladder and biliary system
        c. Spleen
        d. Pancreas
        e. Stomach
        f. Kidneys and ureters
        g. Adrenals
        h. Intestines
    2. Lumbar spine
    3. Muscles
    4. Vasculature structures
    5. Lymphatics
J. Anatomy and Common Pathologies Recorded on Multiplanar Images of the Pelvis
    1. Organs
        a. Bladder/ureters
        b. Colon
        c. Rectum
    2. Male organs
        a. Penis
        b. Testes/scrotum
        c. Prostate
    3. Female organs
        a. Vagina
        b. Uterus
        c. Cervix

d. Ovaries
4. Pelvic bones
    a. Ilium
    b. Ischium
    c. Pubis
    d. Sacrum
    e. Coccyx
5. Muscles
6. Vasculature structures
7. Lymphatics

K. Anatomy and common pathologies recorded on multiplanar images of the spine
    1. Vertebral column
    2. Spinal cord
    3. Ligaments
    4. Muscles
    5. Vascular structures

L. Anatomy and common pathologies recorded on multiplanar images of the upper extremities
    1. Clavicle
    2. Scapula
    3. Humerus
    4. Ulna
    5. Radius
    6. Wrist
    7. Hand
    8. Muscles
    9. Vasculature structures
    10. Lymphatics

M. Anatomy and common pathologies recorded on multiplanar images of the lower extremities
    1. Hip
    2. Femur
    3. Patella
    4. Tibia
    5. Fibula
    6. Ankle
    7. Foot
    8. Muscles
    9. Vasculature structures
    10. Lymphatics

IV. Radionuclide Therapy
    A. Anatomy and physiology

B. Pathology
C. Procedures
    1. Indications
    2. Contraindications
        a. Physical and pathologic conditions
        b. Interfering studies/appropriate sequencing
        c. Possible interfering drugs
    3. Radiopharmaceuticals and adjunctive medications
        a. Route of administration
        b. Dose
        c. Biodistribution
            i. Normal
            ii. Abnormal
        d. Dosimetry
    4. Adverse reactions
    5. Radiation safety considerations and regulations
    6. Patient preparation including consent
    7. Instrumentation
    8. Basic Procedure/Protocol
        a. Dose and administration technique
        b. Sources of error
D. Prognostic value
    1. Outcomes
    2. Treatment Decisions
    3. Prognostic risk factors based on diagnosis
E. Pediatric considerations

V. Radionuclide Therapy Procedures
    1. Ablation for hyperthyroidism
    2. Thyroid carcinoma ablation
    3. Metastatic bone therapies
    4. Radiolabeled monoclonal antibody therapy
    5. Y-90 Microspheres
    6. Neuroendocrine tumor therapy
    7. P-32 therapy

VI. Emerging Technologies
    A. PET/MR
    B. PEM
    C. Other molecular imaging

Section 5: Patient Care

General Definition:

Patient care includes age-appropriate assessment, evaluation and management. Nuclear medicine technologists must demonstrate care that is effective, patient-centered, timely, efficient and equitable for the treatment of health and the promotion of wellness while the patient is in the process of having a procedure.

Entry level nuclear medicine technology graduates are expected to:

5.1 Ensure informed consent has been obtained as appropriate. Facilitate or obtain informed consent as appropriate.
5.2 Employ proper infection control techniques.
5.3 Employ proper patient and personal safety techniques.
5.4 Differentiate and perform various routes of radiopharmaceutical and adjunctive medication administration.
5.5 Monitor patients for adverse reactions to administered radiopharmaceuticals and adjunctive medications.
5.6 Respond appropriately in the event of a patient emergency.

I. Patient Care and 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. Patient communications and interactions
        1. Explanation of procedures
        2. Age/group-specific competencies
        3. Situation specific
    F. Patient assessment
        1. Patient history
            a. Medications
            b. Clinical laboratory values
            c. Pertinent physical history
        2. Preprocedural preparation
        3. Identification of possible contraindications
    G. Infection control
    H. Contamination control
    I. 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
    J. Adverse reactions
        1. Identification
        2. Response
        3. Report
    K. Patient Transport and Safety
        1. Transportation
            a. Body mechanics
            b. Lifting techniques

c. Transfer techniques
d. Special considerations
i. Casts
ii. Traction devices
iii. Intravenous lines and poles
iv. Catheters
v. Oxygen cylinders and tubing
vi. Chest tubes
vii. Other

2. Safety
a. Safety devices for stretchers, scanning tables, wheelchairs
b. Immobilization techniques
c. Equipment safety

II. 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

III. 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
7. Basic needs

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. Treadmill
10. Pulse oximeter
11. ECG monitor

12. Defibrillator
13. Sphygmomanometer
14. Removable and non-removable braces
15. Catheters
    a. Peripheral inserted central catheter lines recognition
    b. Central line catheter recognition

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

VI. 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
6. Automatic techniques
    a. Syringe infusion pumps
    b. Contrast media injectors
7. Intravenous flow rates
8. Complications
    a. Air embolism
    b. Extravasation
    c. Adverse reaction
    d. Thrombosis
    e. Tissue inflammation, damage, and necrosis
    f. Loss of sensation
9. 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

IV. Phlebotomy

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

Section 6: Professionalism and Interpersonal Communication

General Definition:

Professionalism is the expression of positive values and ideals as care is delivered. Interpersonal and communication skills encompass verbal, nonverbal and written exchange of information. Nuclear medicine technologists must demonstrate a high level of responsibility, ethical practice, sensitivity to a diverse patient population and adherence to legal and regulatory requirements. Nuclear medicine technologists must also demonstrate interpersonal and communication skills that result in effective information exchange with patients, their families, and health care professionals.

Entry level nuclear medicine technology graduates are expected to:

6.1 Exemplify excellence in professional practice by demonstrating a calm, compassionate and helpful demeanor when interacting with others.
6.2 Treat others with a high level of dignity and respect.
6.3 Collaborate with healthcare team members.
6.4 Advocate for the nuclear medicine technology profession by participating in professional organizations, keeping professional confidences, maintaining competency, and exhibiting a professional image.
6.5 Adhere to the scope of practice and performance standards.
6.6 Demonstrate an on-going commitment to medico-legal and ethical principles.
6.7 Communicate effectively with patients, their families and health care professionals.
6.8 Demonstrate caring, respectful and ethical behaviors when interacting with patients, their families, and health care professionals.
6.9 Provide culturally competent care.
6.10 Demonstrate effective oral communication skills.
6.11 Demonstrate effective written communication skills.
6.12 Exhibit effective communication skills with respect for social diversity.
6.13 Demonstrate team oriented communication skills to work effectively with health care professionals.
6.14 Protect and preserve personal and confidential patient information.
6.15 Demonstrate intrapersonal and interpersonal awareness of personality differences.
6.16 Employ effective conflict resolution techniques.

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

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. Injury
        2. Duty/standard of care
        3. Breach of duty
        4. Causation
    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 and criminal procedure
    1. Complaint
    2. Summons
    3. Discovery
    4. Motions
    5. Trial
    6. Evidence
    7. Verdict
    8. Appeals
G. Legal doctrine
    1. Individual liability
    2. Reasonably prudent person
    3. Res Ipsa Loquitur
    4. Respondeat Superior
H. Informed consent
    1. Implied
    2. Verbal
    3. Written
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
    4. Conditions of employment
K. Liability coverage
    1. Employer
    2. Personal
    3. Institutional (students)
L. Equipment safety regulations
M. Facility safety/training
N. Risk management
O. 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 law
H. Patient consent

VIII. Interpersonal Communication
A. Affective domain
1. Professional relationships
a. Cooperation and teamwork
b. Professional etiquette
c. Conflict management
2. Professional skills and behaviors
a. Dependability
b. Critical thinking
c. Integrity
d. Communication
e. Adaptability
f. Cooperation
g. Interpersonal skills
h. Self-confidence
i. Initiative
j. Efficiency
k. Cultural competency
l. Professional appearance
B. Patient communication and interaction
1. Components of communication
a. Verbal
b. Nonverbal
c. Written
2. Problems in communication
a. Effects of positive and negative methods of communication
b. Barriers to effective communication
c. Confrontational versus non-confrontational communication
d. 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
11. Age-specific competency
    a. Developmental changes
    b. Impact of illness
    c. Adaptation to patient's age-specific needs
    d. Cognitive domain
    e. Affective domain
    f. Psychomotor domain

Section 7: Organizational Systems-Based Practice

General Definition:

Systems-based practice is an awareness and understanding of the impact of societal and organizational environments on the profession. Nuclear medicine technologists must understand the fundamentals of current healthcare policy and the regulations of delivery systems to blend the complex layers of healthcare to maximize the value of patient care.

Entry level nuclear medicine technology graduates are expected to:

7.1 Describe the structure, governance, and operation of the health care system.
7.2 Explain the funding sources and payment systems.
7.3 Input relevant medical data in health information systems.
7.4 Confirm the accuracy of relevant medical data in health information systems.
7.5 Comply with current federal, state, and institutional regulations.
7.6 Describe factors shaping the future of health care.
7.7 Demonstrate responsibility for promoting a safe environment for patient care by recognizing systems-based factors that negatively impact patient care.
7.8 Contribute to inter-professional team discussions.

I. Digital Data Systems and Regulations
    A. Hospital Information Systems (HIS)
    B. Electronic Medical Records (EMR)
        1. Purpose
        2. Contents and organization
        3. Technologist's responsibilities
        4. Documentation of procedure
        5. Confidentiality
        6. Ethical and legal
            a. HIPAA
            b. Practice standards
    C. Radiology Information Systems (RIS)
    D. PACS
        1. Acquisition device
        2. Types of system interfaces
        3. Digital Imaging and Communications in Medicine (DICOM) compatible
        4. Networking and servers
            a. Centralized servers
            b. Distribution servers
            c. Hybrids
            d. Virtual private network
        5. Imaging display
        6. Archiving
        7. Internet
        8. Integration with other systems

II. 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

III. 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 (TJC)
   2. Intersocietal Commission on the Accreditation of Nuclear Laboratories (ICANL)
   3. American College of Radiology (ACR)

F. Budgetary management/stakeholder association
   1. Fiscal management
   2. Operations management
   3. Asset management

IV. 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 (HIPAA)
   3. Reimbursement
      a. Third-party payors
      b. Private commercial insurance
      c. Government-controlled reimbursement
      d. Patient Protection and Affordable Care Act (PPACA)
      e. Diagnostic Related Group (DRG)
      f. Common Procedural Terminology (CPT)
      g. Ambulatory Payment Codes (APC)
      h. Healthcare Common Procedure Coding System (HCPCS)
      i. 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

V. 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 multi-credentialing 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

VI. The Joint Commission Standards (TJC)

A. Accountability for protecting patient information
B. Consents
C. Education regarding policies, rights, and responsibilities
D. Personnel credentials

VII. 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

VIII. 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
a. Elements of proper charting and documentation
b. Legal ramifications of improper charting and documentation
C. Ownership and release of the medical record

Section 8: Research Methodology

General Definition:

Research methodology encompasses the theoretical and systematic analysis of scientific research and development. The nuclear medicine technologist needs to understand and utilize resources to promote best practices in the profession.

Entry level nuclear medicine technology graduates are expected to:

8.1 Demonstrate basic concepts of research methods.
8.2 Analyze literature to determine applicability to the profession.
8.3 Apply problem solving and critical thinking skills through research activities.
8.4 Apply the values and ethical principles in relation to research activities.
8.5 Demonstrate a working knowledge of regulatory compliance associated with research studies.
8.6 Demonstrate technical writing skills.
8.7 Orally present professional information.

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. Online 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. 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. Standardized tests, scales, and inventories
    7. Validity and reliability of survey and testing instruments
E. Research design and data analysis
    1. Qualitative
        a. Patterns, categories, and descriptive units
        b. Theoretical frameworks
    2. Quantitative
        a. Parametric data
        b. Interval data
        c. Ratio data
        d. Nonparametric data
        e. Nominal data
        f. Ordinal data
        g. Theoretical frameworks
    3. Descriptive statistics
        a. Measures of central tendency
        b. Measures of dispersion
    4. Inferential statistics
        a. Significance testing
        b. Correlation
        c. Linear Regression
    5. Biostatistics
        a. Sensitivity
        b. Specificity
        c. Positive predictive value
        d. Negative predictive value
        e. Accuracy
    6. Electronic statistical analysis packages