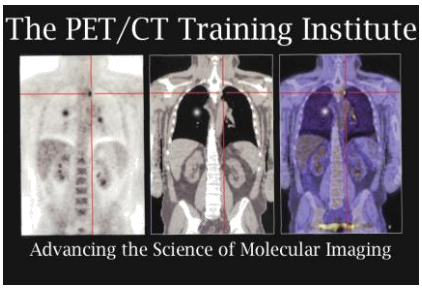

"<u>NUCLEAR CARDIOLOGY COURSE</u>"

Course Control Document

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Contents

➢ Module I: Radiopharmacy

Lecture 1: Basic Match Skills for Nuclear Medicine Technologists I (60 minutes)

Keywords: Radioactive Decay, Post Calibration, Methods for Calculating, Decay Equation, Decay Charts, Universal Decay Table, Pre-Calibration Mathematics, Pre-calibration factor (PCF), Decay Factor (DF), Specific Activity (CA), Specific Concentration Mathematics

Objectives:

- Define Post Calibration or Decay Equations
- Review how to enter into the calculator
- Provide examples of decay equations
- Discuss the Decay Chart Method
- Provide examples to solve using the Decay Chart
- Review the Universal Decay Table Method
- Provide examples to solve using the Universal Decay Method

Upon completion of this section, the student should be able:

- Solve simple mathematical problems using the Texas Instruments TI 30 X IIS calculator
- Perform simple radioactive decay equations using the decay equation, decay chart method, and universal decay table method
- Choose the correct pre-calibration factor from a chart
- Determine specific concentration and activity of a sample

Content:

I. Radioactive Decay Mathematics

1. Principles of Radioactive Decay
2. Post Calibration (Decay)
3. Why is the Radionuclide Decaying
4. Three methods for calculating for Radioactive Decay
   a. Method I: Decay Equation
   b. Method II: Decay Charts
   c. Method III: Universal Decay Table
5. Questions
6. Conclusion

II. Pre-Calibration Mathematics

1. Principles of Pre-Calibration
2. Calculation Activity Using a Pre-calibration factor (PCF) or Decay Factor (DF)
   a. Technetium 99m Half-life Chart
   b. Question №1: Pre-calibration Method (PCF)
   c. Question №2: Post Calibration Method (DF)
   d. Question №3
3. Conclusion

III. Specific Activity and Specific Concentration Mathematics

1. Principles of Specific Activity and Specific Concentrations
2. Calculation Specific Activity
   a. Definition of Specific Activity (SA)

b. Units of Specific Activity
c. Sample problem
d. Sample problem 2

3. Calculation Specific Concentration
   a. Definition of Concentration
   b. Units of Concentration
   c. Sample problem
   d. Sample problem 2
4. Conclusion

IV. For more information

Lecture 2: Basic Match Skills for Nuclear Medicine Technologists II (60 minutes)

Keywords: Calculator TI30XIIS, Dose volume, Effective half-life, Radiation dose, Time mathematics, the total radiation dose, Distance mathematics, Inverse Square Law, Shielding mathematics, Conversion mathematics, Curies, Becquerels, Rad, Grays, Rem, Sieverts

Objectives:

- Define the principles of Dose volume determination, Effective half-life, Radiation dose versus time, the Inverse Square Law, Radiation Dose Versus Shielding Materials
- Discuss how to calculate dose volumes
- Review the methods for calculating effective half-life
- Discuss how to calculate the total radiation dose based on time of exposure
- Discuss how to calculate the radiation dose based on distance
- Review how to solve mathematical problems using the half-value layer formula
- Review how to convert between curie and becquerels, between rads and grays, between rems and sieverts
- Provide examples of math problems

Upon completion of this section, the student should be able:

- Solve these simple mathematical problems
- Perform simple dose volume calculations
- Calculate effective half-life
- Determine the amount of radiation dose received versus time
- Calculate the amount of radiation dose received with distance
- Solve for radiation dose versus shielding
- Convert unit of radiation exposure, absorption and activity

Content:

I. Calculator Overview

II. Dose Volume Determination Mathematics

1. Principles
2. Calculation of Dose Volumes
   a. Formula
   b. Question №1
   c. Question №2
   d. Question №3

III. Effective Half-Life Mathematics

1. Principles
2. Calculation of Effective Half-Life
   a. Formula

Lecture 3: Production of Radionuclides: Atomic Structure and Nuclear Stability (60 minutes)

Keywords: Matter, Energy, Atom, Atomic model dilemma, Extra neutrons, Alpha, Beta and Gamma Rays, Atomic Structure, Energy of Electrons, Nucleons, Nuclear Cement, Strong force, Electromagnetic force, Unstable nuclides, Radioactive Decay, Atomic Model, Conservation of Matter and Energy

Objectives:

- Describe the structure of the atom, its components and properties
- Describe the properties of electromagnetic and particulate radiations

Content:

I. Matter and Energy

1. Matter
2. Atom
    a. Sub-atomic Particles
    b. Alpha, Beta and Gamma Rays
    c. New model of Atom
    d. Solutions to Atomic model Dilemma
3. Isotopes have Extra Neutrons
4. The Elements of the Periodic Table
5. The Difference between X-rays Used in Radiology and Gamma Rays used in Nuclear Medicine
6. The “unified field theory”
7. Binding Energy of Electrons
8. The “photo-electric effect”
9. Atomic Structure

II. Nucleons

1. Excited State Nuclides
2. Meta-stable State
3. MeV Binding Energy
4. KeV Binding Energy
5. Tc99m
6. Nuclear Cement
    a. Strong force
    b. Electromagnetic force
7. Radioactive nuclides
8. Unstable nuclides
9. Radioactive Decay
10. Atomic Model
    a. Radium purified by the Curies
    b. Refined Atomic Model

III. Laws of Conservation of Matter and Energy and electric charge

1. Conservation of energy
2. Radioactive Decay
3. Types of Radioactive Decay
4. Alpha Ion
5. Beta Decay
6. Isobaric Transition
7. Law of Conservation of Mass
8. Carbon Dating
9. Physical half-life

10. Beta positive decay
11. Electron Capture
12. Practice Decay identification
13. Isomeric Transition
14. Electromagnetic spectru
15. Gamma rays released by Isomers
16. Internal Conversion
17. Decay schemes

IV. Review Terminology

Lecture 4: PET Radiopharmaceuticals (60 minutes)

Keywords: Advantages of PET, Value of PET, Radiopharmaceuticals, 18F-FDG, C11, N13, O15, F18, Reimbursement Issues, Clinical Utility, Cyclotron Manufacturing Process, Sinthesis, Automated Synthesis Device, Black box, Quality Control, Physicochemical Test, Biological Test, USP Specifications

Objectives:

- Discuss the application of PET Imaging
- Describe the value of PET in clinical imaging
- Review the basic preparation of PET Radiopharmaceuticals
- Review the molecular structure of FDG
- Discuss the various PET Radiopharmaceuticals used for clinical applications.
- Define the cyclotron process of manufacturing various PET Radiopharmaceuticals
- Review C-11, N-13, O15, F-18
- Discuss the synthesis process for manufacturing PET Radiopharmaceuticals

Content:

I. PET (Positron Emission Tomography)

1. Definition
2. Advantages of PET as compared to X-rays and CT
3. Value of PET

II. PET Radiopharmaceuticals

1. Underlying Principle
2. 18F-FDG
    a. Preparation of 18F-FDG
    b. Comparison: Structures of FDG and Glucose
    c. Mechanism of Uptake
3. 11C Compounds
4. 13N, 15O Compounds
5. 18F Compounds
6. Other Compounds
7. PET Reimbursement Issues
8. Clinical Utility
    a. General Tumor Imaging with FDG
    b. Indications for whole-body 18F-FDG PET scans
    c. Approved indications for cardiac 18F-FDG PET scans
    d. PET in Cardiology
    e. Approved indications for cerebral 18F-FDG PET scans
    f. PET in Neurology

III. The Cyclotron Manufacturing Process

1. Hot Cells
2. Synthesis modules
3. PET radionuclides
4. PET Radiopharmaceuticals
5. Preparation of Radiopharmaceuticals
    a. 13N and 15O radiochemical syntheses
    b. 11C and 18F radiochemical syntheses
6. Radiochemistry with 18F
    a. FDG – nucleophilic substitution
    b. DOPA – electrophilic substitution
7. Radiochemistry with 11C

a. C-11 methylation

IV. Sinthesis of PET Radiopharmaceuticals

1. PET Radiopharmaceuticals
2. Commonly used PET Radiopharmaceuticals
    a. F18-sodium fluoride
    b. F18-flourodeoxyglucose (FDG)
    c. 6-F18-L-Fluorodopa
    d. F18-fluorothymidine (FLT)
    e. O15-water
    f. N-O15-butanol
    g. N13-ammonia
    h. C11-sodium acetate
    i. C11-flumazenil
    j. C11-methylspiperone (MSP)
    k. C11-L-methionine
    l. C11-aclopride
    m. RB82-rubidium chloride
3. Automated Synthesis Device
4. Quality Control of PET Radiopharmaceuticals
    a. Physicochemical Test
    b. Biological Test

V. USP Specifications for Routine PET Radiopharmaceuticals

Lecture 5: Radiopharmaceutical Quality Control (60 minutes)

Keywords: Quality Control, Equipment, Solvents, Storage and Handling, Media, Strip Preparation, Developing Procedure, In-111 Satumomab (Oncoscint), In-111 Pentetreotide (Octreoscan)

Objectives:

- Discuss the purpose of quality control
- Describe the equipments
- Review the solvents and explain solvent storage and handling
- Review the media and explain media storage and handling
- Define of strip preparation
- Discuss developing procedure
- Illustrate examples of procedures

Content:

I. Purpose

II. Equipment

9. Scissors
10. Tweezers
11. Pencil/Pen
12. Counting tubes
13. Vials
14. MCA or SCA or Scaler with scintillation well
15. Developing Media
16. Developing Solvents

III. Solvents

1. The more commonly used solvents in Tc-99m chromatography
    a. Acetone
    b. Ethanol
    c. Ethyl Acetate
    d. Distilled Water
    e. Acenitrile
    f. n-Butanol
    g. HCl
    h. Tetrohydrofuran
    i. Chloroform
2. Storage and Handling

IV. Media

1. The more commonly used stationary phases in Tc-99m chromatography
    a. ITLC-SG
    b. ITLC-SA
    c. Whatman 31
    d. Whatman 17
    e. Whatman 3MM
    f. Aluminum Oxide Plates
    g. Sep-Pak Cartridges
    h. Solvent Saturation Pads
2. Storage and Handling

V. Strip Preparation

VI. Developing Procedure

VII. Tips

VIII. Procedure II

1. The list of drugs
2. Materials needed
3. Procedure
4. Counts
5. USP Minimum Acceptable Purities

IX. Procedure III

1. The list of drugs
2. Materials needed
3. Procedure
4. Counts
5. USP Minimum Acceptable Purities

X. Procedure IV

1. The list of drugs

2. Materials needed
3. Procedure
4. Counts
5. USP Minimum Acceptable Purities

XI. In-111 Satumomab (Oncoscint) Quality Control Procedure

1. Materials needed
2. Procedure
3. Counts
4. USP Minimum Acceptable Purities

XII. In-111 Pentetreotide (Octreoscan) Quality Control Procedure

1. Materials needed
2. Procedure
3. Counts
4. USP Minimum Acceptable Purities

Lecture 6: The Nuclear Pharmacy (60 minutes)

Keywords: Nuclear Pharmacy, Equipment, Dose Calibrator, Quality Control, Survey Meter, Unit Dose Manager, Safety Equipment, Constancy Test, Linearity Test, Geometry Dependence, Accuracy, Area Survey Records, Ancillary Equipment, Safety equipment, Nuclear Medicine Facility, Waste Disposal Log, Radioactive Materials Receipt, Patient Dose Records

Objectives:

- Discuss Equipment found in the Nuclear Pharmacy
- Review the Dose Calibrator Quality Control procedures
- Review the Survey Meter Quality Control procedures
- Discuss Area Surveys
- Review Ancillary Equipment in the Hot Lab
- Review the Unit Dose Manager
- Discuss Radioactive Receipts
- Review Waste Logs
- Review Hot Lab Record Keeping

Content:

I. Typical Equipment found in the Nuclear Medicine Radiopharmacy

4. Dose calibrator
5. Survey Meter
6. Unit Dose Manager
7. Safety Equipment

II. Dose Calibrators or Activity Calibrators

III. Quality Control Procedures for a Dose Calibrator

1. Quality Control
2. Constancy Test
3. Linearity Test
   a. Decay Method
   b. Shield Method
   c. Calibration of the Sleeves
   d. Calibration of the Dose Calibrator
4. Geometry Dependence

5. Accuracy

IV. Quality Control Procedures for a Survey Meter

1. Survey Instruments
2. Survey Meters
   a. The cutie-pie
   b. The Geiger-Mueller counter
3. Quality Control
4. Accuracy
5. Constancy
6. Steps to take when using a Survey Meter
7. Interpreting Survey Meter Readings
8. Survey Meter Records
9. Sample Survey Meter Form
10. Area Survey Records

V. Ancillary Equipment

1. Safety equipment
   a. L- blocks
   b. Syringe shields
   c. Container shields
   d. Sharps containers
   e. Latex gloves
   f. Transportation Cases ("suitcases" or “ammo boxes”)

VI. Nuclear Medicine Facility

1. Hot Lab
2. Gamma camera
3. Treadmill
4. Posting
   a. Caution Radioactive Materials
   b. Emergency Notification Information
   c. Notice to Employees

VII. The Unit Dose Manager

1. Waste Disposal Log
2. Radioactive Materials Receipt
   a. Transportation Labels for Packaging Containing Radiation Area
   b. Procedures for receiving and opening packages
3. Patient Dose Records
4. Mo99/Tc99m Records
5. Decay-in-Storage Form
6. Dose Log Sheet

Lecture 7: Radioactive Receipt (60 minutes)

Keywords: Receiving Radioactive Materials (RAM), DOT 49 CFR, IATA, USPS Restrictions, Training Requirements, Classification, Packaging, Labeling, Radiation, Limits, Marking, Shipping, Papers, Placarding, Conveyance, Emergency Response Information

Objectives:

- Discuss the regulations of DOT 49 CFR and IATA

- Describe the classification of receiving radioactive materials (RAM)
- Review the general requirements for shipping and receiving
- Review packaging, marking and labeling
- Define documentation requirements
- Discuss emergency response information
- Illustrate the examples

Content:

I. Regulations

8. DOT 49 CFR
9. IATA
10. USPS Restrictions
11. Who Must be Trained?
12. Initial and Recurrent Training
13. DOT Training Requirements
14. Employing Unit Responsibilities

II. Classification

1. Classification of receiving radioactive materials (RAM)
2. Radioactive Material Defined
3. DOT / IATA Exemptions
4. Special or Normal Form
    a. Special Form
    b. Normal Form
5. A1 and A2 Values
6. Type B / Highway Route Controlled Quantity
7. Special Classifications
    a. Excepted Package
    b. Empty
    c. LSA (Low Specific Activity)
    d. SCO (Surface Contaminated Object)
8. Review of Classifications
9. Transportation Activity Spectrum

III. General Requirements

1. Exclusive Use Vehicle
2. Radiation Level Limitations
3. Contamination
4. Quality Control Requirements

IV. Packages

1. Type A Packages
    a. Specifications
    b. Categories
2. General Design Requirements
3. Type A Package Tests
    a. Water Spray Test
    b. Free Drop Test
    c. Corners / Rim Drops
    d. Stacking Test
    e. Penetration Test
4. Excepted Packaging
    a. Suggestions
5. Packaging LSA/SCO

V. Marking

1. Outer Package Information
2. Excepted Package Marking & Labeling
    a. Air Shipping
    b. Ground Shipping
3. Type A Package Markings

VI. Labeling

1. Transport Index
2. Labeling – Information
3. Non –Excepted Type A Shipping Labels
4. IATA Excepted Package – Limited Quantity
5. Cargo Aircraft Only
6. Package Orientation Labels

VII. Documentation

1. Documentation
2. Shipping Paper / DGD Requirements
3. Other Possible Designations
4. Passenger Aircraft Limitations
5. Additional DGD Requirements
6. Air Waybill
7. Record Keeping

VIII. Emergency Response Information

1. Form of information
2. Maintenance of Information
    a. Carriers
    b. Facility Operators

IX. Receiving Radioactive Material Shipments

1. Receiving RAM Shipments
2. Required Surveys
    a. Contamination surveys
    b. Dose rate surveys
3. Surveying Inner Contents
4. Required RSO Notification
5. Other RAM Receipt Requirements

X. Shipping Radioactive Materials

XI. Examples

1. Example 1
    a. The conditions of the problem
    b. Determine if the shipment meets the definition of radioactive material
    c. Determine if the shipment is a Reportable Quantity
    d. Determine whether the shipment is Normal Form or Special Form
    e. Determine if the shipment is a limited quantit
    f. Determine the packaging required
    g. Determine the proper shipping name
    h. Documentation
2. Example 2
    a. The conditions of the problem
    b. Determine if the shipment meets the definition of radioactive material
    c. Determine if the shipment is a Reportable Quantity
    d. Determine whether the shipment is Normal Form or Special Form
    e. Determine if the shipment is a limited quantit
    f. Determine the packaging required

g. Determine the labels required
h. Determine the proper shipping name
i. Example of Dangerous Goods Declaration

XII. Transporting RAM

1. Transporting Shipments
2. Vehicle Placards
3. Driver's Training Requirement
4. Missing/Lost RAM Reporting

XIII. For Assistance

Lecture 8: Radioactive Waste Disposal (60 minutes)

Keywords: Waste Disposal, Waste Types, Waste Containers, Ordinary waste, Laboratory waste, Infectious waste, Plastic serological pipettes, Sharps, Broken glass/bottles, Chemical waste, Chemotherapy waste, Mixed waste, Radioactive waste, Radiation Protection, Radioactive Spill, Contamination, Decontamination, Decay-in-Storage Form, Sample Survey Meter Forms, Sink Disposal of Liquids, Disposal of Large Quantities of Liquid Waste, Animals, Storage

Objectives:

- Identify various forms of waste
- Review different waste receptacles
- Review proper waste disposal practices
- Discuss sharps disposal techniques
- Discuss chemical waste disposal techniques
- Review radioactive waste requirements
- Discuss sink disposal limits
- Review storage of radioactive waste
- Discuss proper caution signs for storage areas
- Review the restricted and unrestricted areas
- Discuss the Do's of hot lab etiquette
- Review long term radiation decay storage
- Discuss sewage disposal limitations
- Review a basic decontamination kit
- Discuss simple decontamination principles
- Discuss decay storage forms

Content:

I. Introduction

1. Identifying waste
2. Minimizing waste generation

II. Waste Types

1. Waste Types found in the NM Lab
   a. Ordinary waste
   b. Laboratory waste
   c. Infectious waste
   d. Plastic serological pipettes
   e. Sharps
   f. Broken glass/bottles
   g. Chemical waste

h. Chemotherapy waste
i. Mixed waste
j. Radioactive waste

2. Waste Containers

III. Proper Waste Disposal

1. Ordinary waste
   a. Ordinary Trash
2. Laboratory waste (noninfectious)
3. Infectious waste
   a. Autoclave Infectious Waste
   b. Chemical Disinfectant
4. Sharps Disposal
5. Plastic Serological Pipettes
6. Broken glass/bottles
7. Chemical waste Pick up
8. Hazardous Waste label
   a. Disposal of Empty Bottles
   b. Chemical Consolidation
   c. Some examples of hazardous chemicals to be discarded
   d. Gel Containers
9. Chemotherapy waste
10. Mixed waste
11. Silver Recovery Unit

IV. Radioactive Waste

1. Radioactive Waste Disposal
   a. Requirements
   b. Short Lived Waste
   c. Long Lived Waste
   d. Liquid Scintillation Vials
2. Sink Disposal of Liquids
3. Disposal of Large Quantities of Liquid Waste
4. Animals
5. Storage of Radioactive Waste
   a. Requirements
   b. Waste Containers
6. Legal Methods of Disposing of Radioactive Waste
   a. Hold for Decay
   b. Dump to Sanitary Sewer
   c. Incineration
   d. Ship to Disposal Site
   e. Dispose of as if not radioactive
7. Waste Disposal Tag
   a. Caution Signs and Labels
   b. Unrestricted Area
   c. Radiation Area
   d. High Radiation Area
   e. Very High-Radiation Area
   f. Radioactive Material

V. Do's and Don'ts in Radiation Protection

VI. Radioactive Waste Disposal

1. Decay in storage
2. Release into sewerage system

3. Transfer to authorized recipient
4. Other disposal methods approved by the NRC

VII. Cleaning up a Radioactive Spill

VIII. Contamination and Decontamination

1. Decontamination Kit
2. Contamination
3. Exposure vs. Contamination
   a. Exposure to Radiation
   b. Exposure with Contamination
4. How to Decontaminate a Patient
5. External Contamination
6. Contamination Control 49 CFR 173.443(a)
7. Examples of Radiation Skin Burns
8. Decontamination of Skin
9. Cease Patient Decontamination
10. Decontamination of Wounds

IX. Radioactive Waste Disposal Forms

1. Decay-in-Storage Form
2. Sample Survey Meter Forms

X. Summary

➢ Module II: Radiation Safety

Lecture 1: Cellular Effects of Radiation Exposure (60 minutes)

Keywords: Effects of Radiation, Radiolysis of Water, Free Radicals, Biochemical Damage, DNA Damage, Chromosome Damage, Membrane Damage, Cell Cycle, Bergonié-Tribondeau Law, Response Curves, Dose Response Relationship, Linear Nonthreshold Dose Response, Target Theory and Cell Survival Curves, Cell Death

Objectives:

- Review direct and indirect effect of radiation exposure
- Discuss biochemical damage from ionizing radiation
- Review the cellular cycle
- Discuss the Laws of Bergonie and Tribondeau
- Discuss Target Theory
- Evaluate the radiolysis of water
- Review Cell death
- Analyze the types of dose response curves

Content:

I. The Effects of Radiation on the Cell at the Molecular Level

1. Direct Effects
2. Indirect Action
   a. Radiolysis of Water

b. The Lifetimes of Free Radicals
c. Free Radicals

II. Biochemical Reaction with Ionizing Radiation

1. DNA Demage
2. Chromosome Damage
3. Membrane Damage

III. Cell Cycle

IV. Bergonié-Tribondeau Law

1. Radiosensitivity
2. Direct Effects
   a. Chromosomal Damage
3. Indirect Action
   a. Radiolysis of Water

V. Linear Nonthreshold Dose Response

1. Dose Response Curves
2. Dose Response Relationship
   a. Linear
   b. Nonlinear
   c. Threshold
   d. Nonthreshold
3. Linear Nonthreshold Dose Response
4. Factors Effecting the Dose Models and Theories

VI. Target Theory and Cell Survival Curves

1. Target Theory
   a. Foundation of the Target Theory
2. Cell Survival Curve
   a. Factors Contributing to the Probability of Cell Death
   b. Different Cell Survival Curves
   c. Cell Death
   d. Cell Death Factors
   e. Factors that make Cells Less Radiosensitive

VII. Summary

Lecture 2: Effects of Initial Exposure to Radiation (60 minutes)

Keywords: Biological Effects of Radiation, Relative Biological Effectiveness (RBE), Action of Radiation, Radiation Sickness, Cancer, Genetic Effects, Tissue and Organ Radiosensitivity, Skin Effects, Tissue Types, Acutely Responding and Late-responding Organs, Hematologic and Cytogenetic Effects, Acute Radiation Syndromes, Phases of Acute Radiation Syndromes (Response Stage), Dose Response Curve, Cell Sensitivity, Response Stage, Radiation Syndrome

Objectives:

- Describe the effects of radiation at the cellular and molecular level
- Review the cell cycle
- Discuss the relative tissue and organ radiosensitivities
- Review the effects of radiation on specific tissue and organs
- Review hematological effects of radiation

- Review the cytogenetic effects of radiation
- Discuss the dose response curves
- Review the Acute Radiation Syndromes
- Discuss the Response Stages

Content:

I. Justification

1. Conditions of Potential Biological Effects and Damages caused by Radiation
   a. Quality of Radiation
   b. Quantity of Radiation
   c. Received Dose of Radiation
   d. Exposure Conditions (Spatial Distribution)
2. Relative Biological Effectiveness (RBE)
3. Radiation damage to body organs, tissue and cells
4. Biological Effects of Radiation
   a. Direct and Indirect Action
   b. Short and Long Term Effects
   c. High Dose
   d. Data on Radiation Exposure to Humans
   e. Risk Assessment of Cancer

II. Relative Tissue and Organ Radiosensitivity

1. Skin Effects
2. Tissue Types
   a. Vegitative intermitotic tissue cells (VIMs)
   b. Differentiating intermitotic cells (DIMs)
   c. Multiple connective tissue cells (MCTs)
   d. Reverting postmitotic cells (RPMs)
   e. Fixed post mitotic cells (FPMs)
3. Organs Types
   a. Acutely Responding Organs
   b. Late-responding Organs

III. Effects of Radiation on Specific Tissues and Organs

1. Early and Late Effects
2. Skin
   a. Atrophy
   b. Fibrosis
   c. Scarring
   d. Telangiectasia
3. Oral Mucosa
   a. Marked Erythema
   b. Patch Mucositis
4. Salivary Glands
5. Submandibular Glands
6. Gastrointestinal Tract
7. Central Nervous and Peripheral Nervous System
   a. Brain
   b. Spinal Cord
   c. Peripheral Nerves
8. Lung
9. Kidney
10. Heart
11. Liver
12. Bladder

IV. Hematologic and Cytogenetic Effects

1. Hemopoietic System
   a. Bone marrow
   b. Circulating blood
   c. Lymph nodes
   d. Spleen
   e. Liver
   f. Thymus
2. Types of Marrow
   a. Red
   b. Yellow
3. Stem cell
   a. Radiation Dose
   b. Stem cell sensitivity
4. Lymphocyte
   a. Spleen
5. Cytogenetic
6. Structural changes
7. Chromosomal aberration
   a. Types of Chromosomal Aberrations
   b. Factors that Influence the Repair of Chromosomal Aberrations
   c. The magnitude of total genetic damage
   d. Karyotype

V. Acute Radiation Syndromes

1. Conditions of Radiation Exposure
2. Phases of Acute Radiation Syndromes (Response Stage)
   a. Prodromal
   b. Latent period
   c. Manifest illness
   d. Recovery or Death
3. Consequences of Acute Radiation
4. Acute Exposure
5. Dose Response Curve
   a. Hematologic, hematopoetic or bone marrow syndrome
   b. GI syndrome
   c. Central nervous system syndrome
6. Radiation Doses and Expected Effects
7. Commonly Encountered Radiation Doses
8. Radiation Effects on Embryo/Fetus
9. Cell Sensitivity
   a. Lethal Dose 50/30 and Lethal Dose 50/60
10. Response Stage
    a. The prodromal stage
    b. The latent stage
    c. The manifest illness stage
    d. The recovery or death stage
11. Bone Marrow Syndrome
    a. Signs and Symptoms of Bone Marrow
12. Gastrointestinal Syndrome
    a. Signs and Symptoms of Gastrointestinal
13. Central Nervous System Syndrome
    Signs and Symptoms of Central Nervous System
14. Elements of acute radiation syndrome
    a. Gastrointestinal
    b. Hematopoietic

c. Vascular

Lecture 3: Effects of Long Terms Exposure to Radiation (60 minutes)

Keywords: Epidemiology, Limitations on Epidemiologic Studies, Types of Epidemiologic Studies, Hiroshima-Nagasaki, Atomic Bombings, Low Levels of Irradiation, Effects of Radiation, Estimation of Risk, Risk Models, Cancer, Radiation Sensitivity, Latent Effects, Dose Rate Effects, Thyroid and Breast Cancers, Age Dependency, Somatic Effects, Genetic Effects, Effects on the Embryo, Fetal Irradiation, Linear No-Threshold Hypothesis, Life Span Shortening, Stochastic and Non-stochastic Effects, Hormesis

Objectives:

- Discuss epidemiology, limitations on epidemiologic studies and population used as sources
- Describe Hiroshima-Nagasaki atomic bombings and radiation induced malignancies
- Explain different risk models
- Define the dose rate effects
- Review the genetic effects of radiation
- Discuss the effects of radiation to the fetus and life span shortening
- Review stochastic and non-stochastic effects and radiation hormesis

Content:

I. Epidemiology

1. The Science of Epidemiology
2. Population Used as Sources
   a. Atomic bomb survivors
   b. Medically exposed patients
   c. Occupationally exposed personnel
   d. Populations who receive high natural background exposure
3. Limitations on Epidemiologic Studies
4. Types of Epidemiologic Studies
   a. Retrospective studies
   b. Prospective studies
5. Hiroshima-Nagasaki atomic bombings and radiation induced malignancies
6. Populations Exposed to Very Low Levels of Irradiation
   a. DOE's hanford facility
   b. Portsmouth naval nuclear shipyard
   c. Tri-state study of leukemia deaths
   d. Utah residents exposed to fallout
   e. Project "Smoky"
   f. Three-Mile Island
7. Effects for Which No Relationship with A-Bomb
   a. Increased birth defects in the F1 generation
   b. Increased F1 mortality
   c. Infertility
   d. Accelerated aging
   e. Altered immune function
   f. Diseases other than neoplasm

II. Estimation of Risk

1. "Low level" Radiation Exposure
2. Risk Models
   a. The relative or multiplicative risk model

   b. The absolute or additive risk model
   c. Excess risk
3. Cancer
   a. Cancer risk estimates
   b. Stochastic and non-stochastic effects
4. Risks of Low-Level Radiation
   a. General conception
   b. Variable radiation sensitivity
   c. Latent effects
   d. Radiation-Induced cancers
   e. High background of “spontaneous” cancers

III. Dose Rate Effects

1. Thyroid and Breast Cancers
   a. Linear-, Non-threshold estimation of risks at low doses
   b. Linear extrapolation of risk estimation
2. Age Dependency
3. Treatment of Hyperthyroid Disease in Humans with 131I Radioiodine (Na131I)
4. Expression of Radiosensitivity
   a. Absolute risk
   b. Relative risk
5. Somatic Effects

IV. Genetic Effects of Radiation

1. Radiation damage to chromosomes
   a. Indirect damage
   b. Direct damage
   c. Chromosome Damage
2. Estimation of Genetic Effects

V. Effects on the Embryo

1. Justification
2. Radiation Effects on the Embryo
   a. Radiation dose
   b. Dose-rate
   c. Stage of gestation
3. Triad of effects of radiation on the embryo
   a. Growth retardation
   b. Embryonic, fetal or neonatal death
   c. Congenital malformation
4. Embryo is Radiosensitive
5. 10 Day Rule
6. Fetal Irradiation

VI. Linear No-Threshold Hypothesis (LNT)

VII. Life Span Shortening

VIII. Stochastic (random) and Non-stochastic (not random) Effects

IX. Hormesis

Lecture 4: Radiation Protection of Personnel (60 minutes)

Keywords: Radiation and Radioactivity, Ionizing and Non-Ionizing Radiation, Radiation Protection Programs, Radiation protection procedures, Dose Limiting, A-L-A-R-A , Protective Clothing, The Work Place, Manipulations of Radioactive Materials, External Radiation Protection, Shielding, Inverse Square Law, Internal Radiation Protection, Radioactive Waste Disposal, Radioactive Spills, Survey Procedures or Monitoring, Dosimetry, Radiation Badges, Dosimetry Reports, PET Nuclear Medicine Technology, Hot Lab Technique, F-18 FDG PET; Minimization of Radiation Exposure, Fetus, Staff, Patients, Families and the General Public

Objectives:

- Discuss the rationale for radiation protection and radiation protection programs
- Explain personnel dosimeters, dosimetry reports, and duties of the Radiation Safety Officer (RSO)
- Describe how the PET/CT Technologist can decrease their radiation exposure during the patient preparation and scanning sequences
- Define and calculate the dose limiting recommendations for PET/CT personnel
- Review the basic structural shielding construction and list the items that influence this construction
- Illustrate the Inverse Square Law and how using distance can decrease radiation exposure

Content:

I. The Rationale for Radiation Protection

1. Radiation and Radioactivity
2. Ionizing and Non-Ionizing Radiation
   a. Sources of ionizing radiation

II. Radiation Protection Programs

1. Regulators
   a. International Commission on Radiological Protection (ICRP)
   b. National Council on Radiation Protection and Measurements (NCRP)
   c. Nuclear Regulatory Commission (NRC)
   d. “Agreement State” Radiation Protection Agencies
2. Regulatory Authority
   a. Nuclear Regulatory Commission (NRC)
   b. Agreement State
   c. Radiation Safety Program

III. Radiation protection procedures

1. Units of Radiation Exposure
   a. Roentgen (R)
   b. Rad (radiation absorbed dose)
   c. Rem (roentgen equivalent man)
2. Radiation protection standards
   a. Radiation dose limit
   b. Principle of “ALARA”
3. General Handling Precautions
   a. Protective Clothing
   b. The Work Place
   c. Manipulations of Radioactive Materials
4. External Radiation Protection
   a. Time
   b. Distance
   c. Shielding
5. Internal Radiation Protection
   a. Mode of Entry into Body
   b. Routes of Intake, Transfers and Excretion
   c. Tissue Damage and Health Effects

6. Radioactive Waste Disposal
    a. Disposal
    b. Precautions on Waste Disposal
7. Precautions for Radioactive Spills
    a. Major Spills
    b. Minor Spills
    c. Key to Success
8. Survey Procedures or Monitoring
    a. Precautions on Dosimetry
    b. Radiation Badges
    c. Individuals Requiring Radiation Safety Training
    d. Annual Radiation Dose Limits
    e. Radiation Warning Signs
    f. Record Retention
    g. Criteria for Personnel Monitoring
    h. Survey Meter Quality Assurance
    i. Medical Events: Administrative Criteria
    j. Medical Events: Dose Criteria
    k. Reporting Medical
9. PET
    a. Higher Exposure Rate Constants
    b. Higher Dose Rate From Patients
    c. PET Shielding: Tenth Value Layers
    d. Shorter Physical Half-Life
    e. Shorter Half-Life: Lower Dose

IV. Minimization of Radiation Exposure to Staff

1. Sources of exposure for staff
2. Measures to Reduce Personnel Dose
    a. Time, distance and shielding
    b. Laboratory technique
    c. Administrative and procedural controles
3. Laboratory technique
    a. Good Hot Lab Technique
    b. NOT To Do in the Hot Lab
4. Minimize Time and Maximize Distance
    a. Inverse Square Law (1/r2)
5. Utilize Shielding
    a. PET Barrier Materials
    b. Typical Hot Lab L-Block Shield
    c. Other Shielding Methods
    d. X-Ray Protective Equipment
    e. Mobile Shields
    f. Tongs to Maximize Distance
    g. Syringe Shields
6. Procedural Controls
    a. Automated dose dispensing and Calibration
    b. Elimination or automation of “flush” during patient administration
    c. Rotation of personne

V. Minimization of Radiation Exposure to Patients

1. Reducing PET/CT Patient Does
    a. Optimize administered radioactivity
    b. Reduce CT mAs
    c. Increase “pitch”
    d. Technique charts to minimize CT exposure to pediatric patients and small adults
2. Corrective Actions

a. Increasing staff awareness and retraining
b. Addition of policies or procedures
c. Modification of existing policies and procedures
d. Addition of engineering controls
e. Termination of staff

VI. Minimization of Radiation Exposure to Families and the General Public

1. Regulatory Requirements
2. "Patient Release" Guidelines
3. Annual Dose Limit to Non-Radiation Workers

VII. Principles of PET/CT Shielding Calculations

1. Occupational Exposure Protection of the Worker
2. F-18 FDG PET Studies
   a. Exposure factors
   b. Dose Factors
3. Other PET Isotope Data
4. Exposure
5. Shielding
   a. Bench top shield
   b. Vial shields
   c. Syringe shields
   d. Structural shielding
6. Shielding of Sources
   a. Factors affecting the design of shield
7. Shielding Material and Transmission
   a. Transmission in Concrete
   b. Transmission in Steel
8. PET Clinic Layout
   a. Typical PET room
   b. Distances to be used in shielding calculations
   c. Calculation for Room Above an Uptake Room
   d. PET Clinic Shielding
   e. Wall Shielding

VIII. Radiation Exposure to the Fetus

1. Prevention of Unintentional Fetal Exposure
2. Fetal Doses

IX. The Pregnant or Potentially Pregnant Radiation Worker

1. Federal regulations
2. Important Mutual Responsibilities
3. Methods to Reduce Occupational Exposure for the Pregnant Worker
4. Radiation Safety Officer (RSO)

X. Internet Resources

Lecture 5: Radiation Safety in PET Imaging (60 minutes)

Keywords: Safety Definitions and Symbols Used, General Safety Guidelines, Electrical Shock Hazard, Electrical Fire, Explosion Hazard, Implosion Hazard, Overheating, X-ray Radiation, CT Scan Types, Weighted CT Dose Index (CTDIw), Emergency Stop Buttons, Warning Signs and Labels, Safety Labels and Rating Plates, Laser Safety, Gamma Radiation Safety, Emergency devices, Radiation and laser indications, Prevention of harmful cumulative dose, Data Safety, Safe

Operation Guidelines, Compliance and Regulatory Information, Operator's Safety, Safe Patient Handling

Objectives:

- Discuss about the safety precautions and procedures
- Describe the compliance information for the operation of the PET/CT systems
- Review the location and the uses of the emergency stops and information regarding laser light safety

Content:

I. Safety Definitions and Symbols Used

1. Labels
    a. Danger
    b. Warning
    c. Caution
2. Symbols
    a. IEC standards

II. General Safety Guidelines

1. Guidelines
2. Electrical Shock Hazard
3. Electrical Fire
4. Explosion Hazard
5. Implosion Hazard
6. Overheating
7. X-ray Radiation

III. X-ray Radiation Safety Potential Radiation Hazards

1. Warning
2. Caution
3. Using a non manufacturers X -ray tube and two dangers
4. Radiation Safety Control Mechanisms

IV. CT Scan Acquired at the Same Tomographic Plane

1. Scan Types
    a. Smart View
    b. Smart Prep Baseline and Monitor Scans
    c. Cine Scans
    d. Axial Scans with zero table increment

V. Weighted CT Dose Index (CTDIw)

1. Dose Length Product
2. Accumulated Exam DLP

VI. Emergency Stop Buttons

VII. Warning Signs and Labels

1. Caution, High Voltage
2. Electric Shock Hazard
3. LS Table Assembly Label

VIII. Safety Labels and Rating Plates

1. Radiation Emission Warning
2. Pinch Hazard Label
3. Shock Hazard

4. Do Not Touch

IX. Laser Safety
1. Warning

X. Gamma Radiation

XI. Prevention of Harmful Cumulative Dose

XII. Data Safety

XIII. Safe Operation Guidelines

XIV. Compliance and Regulatory Information

XV. Operator's Safety

XVI. Safe Patient Handling
1. Before starting the scan procedure

➢ Module III: Instrumentation

Lecture 1: SPECT Terminology (180 minutes)

Keywords: Glossary, Molecular Imaging Terms, Nuclear Terms

Objectives:
- Discuss Glossary of Molecular Imaging Terms
- Discuss Glossary of Nuclear Terms
- Define Terms from "A" to "Z"

Part I Glossary of Nuclear Terms

Content:

I. "A"
1. Absorbed dose
2. Absorbed dose rate
3. Absorber
4. Absorber rod
5. Accelerator
6. Accident
7. Accounting
8. Activation
9. Activation analysis
10. Activation cross section
11. Active beam
12. Activity
13. Activity concentration
14. Activity intake
15. Activity, specific
16. After-heat

17. AGR (Advanced Gas-Cooled Reactor)
18. Air lift
19. ALARA
20. ALI
21. Alpha decay
22. Alpha particle
23. Ambient dose equivalent
24. Amplitude analysis
25. Amplitude analyzer
26. Annihilation radiation
27. Annual limit on intake (ALI)
28. Annular gap
29. Anticoincidence circuit
30. Antimatter
31. Antiparticles
32. Argonaut
33. ASME (American Society of Mechanical Engineers)
34. Asse
35. Atom
36. Atomic bomb
37. Atomic clock
38. Atomic number
39. Atomic weight
40. ATWS (Anticipated Transients Without Scram)
41. Autoradiolysis
42. Autoradiogram
43. Availability factor
44. AVM procedure
45. AVR

II. "B"

1. Barn
2. Barrier
3. Baryon
4. Base load power plants
5. Becquerel
6. BEIR
7. BER II
8. Beta decay
9. Beta-minus decay
10. Beta particle
11. Beta-plus decay
12. Beta radiation
13. Betatron
14. BfS
15. Biblis A
16. Biblis B
17. Binding energy
18. Biosphere
19. Blanket
20. BMBF
21. BMU
22. Body burden
23. Body counter
24. Body dose
25. Boiling water reactor
26. Bone seeker

27. Boron counter
28. Borosilicate glass
29. Bq
30. Breeding
31. Breeding factor
32. Breeding gain
33. Breeding process
34. Breeding ratio
35. Breeding reactor
36. Bremsstrahlung
37. Bubble chamber
38. Build-up factor
39. Burnup
40. BWR

III. "C"

1. C-14
2. Calder Hall
3. CANDU
4. Canister
5. Capacity factor
6. Capacity operating hours
7. Carbon-14
8. Castor
9. CEA
10. Centrifuge
11. Cerenkov radiation
12. Chain reaction
13. Chernobyl
14. Chop and Ieach
15. Chromatography
16. Ci
17. Cladding
18. Classification of elements
19. Closed-circuit cooling systems
20. Closed-circuit ventilation
21. Cloud chamber
22. Coal equivalent
23. Coated particles
24. Cogeneration
25. Coincidence
26. Collective dose
27. Commission on Radiological Protection
28. Committed dose
29. Compact storage basins
30. Company for Industrial Plants and Nuclear Safety
31. Compton effect
32. Condensing basin
33. Containment
34. Contamination
35. Control rod
36. Controlled area
37. Convention on Third Party Liability in the Field of Nuclear Energy
38. Conversion coefficient, internal
39. Conversion electron
40. Conversion

41. Conversion, radioactive
42. Converter reactor
43. Coolant
44. Cooling pond
45. Cooling tower
46. Core
47. Core catcher
48. Core meltdown
49. Core meltdown retention basin
50. Cosmic radiation
51. CP-1
52. Critical
53. Critical experiment
54. Criticality
55. Criticality accident
56. Criticality, prompt
57. Criticality safety
58. Critical mass
59. Critical size
60. Crud
61. Curie
62. Cyclotron

IV. "D"

1. DAtF
2. Dating, radioactive
3. Daughter and grandchild nuclides
4. DBE
5. Decay
6. Decay basin
7. Decay chains, natural
8. Decay constant
9. Decay time
10. Decommissioning of nuclear power plants
11. Decontamination
12. Decontamination factor
13. Degree of enrichment
14. Delayed critical
15. Demineralised water
16. Depleted uranium
17. Depletion
18. Depth dose
19. Depth dose, relative
20. Design basis accident
21. Detection limit
22. Deterministic radiation effect
23. Deuterium
24. Deuteron
25. Deutsches Atomforum (German Atomic Forum)
26. DIDO
27. Diffusion separation process
28. Direct cooling
29. Directional dose equivalent
30. Direct radiation
31. Disaster control plans
32. Discussion date
33. Dispersion calculations

34. Disposal precaution
35. Dissolution device
36. Dissolver
37. District heating power plant
38. Diversity
39. Dodecane
40. Dollar
41. Doppler effect
42. Dose
    a. Dose equivalent
    b. Effective dose
    c. Absorbed dose
    d. Committed dose
    e. Skin dose
    f. Equivalent dose
    g. Local dose
    h. Personal dose
    i. Directional dose equivalent
    j. Personal dose equivalent
    k. Ambient dose equivalent
43. Dose build-up factor
44. Dose coefficient
45. Dose effect curve
46. Dose-effect relation
47. Dose equivalent
48. Dose equivalent rate
49. Dose limit value
50. Dose rate
51. Dosimeter
52. Dosimetry
53. Doubling time
54. Dry cooling tower
55. Dry storage
56. DTPA

V. "E"

1. ECCS
2. Ecology
3. Ecosystem
4. Efficiency
5. Electromagnetic isotope separation
6. Electromagnetic radiation
7. Electron
8. Electron capture
9. Electron equilibrium
10. Electron volt
11. Element
12. Element, artificial
13. Elementary charge
14. Elementary particles
15. Emergency core cooling system
16. Emission
17. Emission height
18. Enclosed radioactive substances
19. Energy
20. Energy balance record

21. Energy carrier
22. Energy conversion
23. Energy requirement
24. Energy reserves
25. Energy units
26. Engineered storage
27. Enriched uranium
28. Enrichment
29. Enrichment chains
30. Enrichment factor
31. Enrichment method
32. ENS
33. Environmental load
34. Environmental monitoring
35. EPR
36. Equilibrium, radioactive
37. Equipment availability factor
38. ERAM
39. Euratom basic safety standards
40. Eurochemic
41. European Pressurized Water Reactor
42. eV
43. EVA
44. Evacuation plans
45. Examination threshold
46. Excess reactivity
47. Excitation energy for nuclear fission
48. Excited state
49. Exclusion area
50. Excursion
51. Exhaust air path
52. Experimental reactor
53. Experimentation channel
54. Exposure path
55. Extraction
56. Extractor

VI. "F"

1. Fail safe
2. Fallout
3. Fast breeder reactor
4. Fast fission factor
5. Fast reactor
6. FBR
7. FE
8. Federal Office for Radiation Protection
9. Fertile material
10. Film dosimeter
11. Final energy
12. Financial security
13. Fissile material
14. Fissile material flow control
15. Fissility
16. Fission
17. Fission chamber
18. Fission gas
19. Fission gas plenum

20. Fission neutron
21. Fission neutron yield
22. Fission product poison
23. Fission products
24. Fission yield
25. Fission, spontaneous
26. Fission, thermal
27. Fissium, simulated
28. FMRB
29. FORATOM
30. FR 2
31. FRG-1
32. FRG-2
33. FRH (Forschungsreaktor Hannover)
34. FRJ-1
35. FRJ-2
36. FRM
37. FRM II
38. FRMZ (Forschungsreaktor Mainz)
39. Fuel
40. Fuel comparison
41. Fuel cycle
42. Fuel element
43. Fuel element, irradiated
44. Fuel element, spent
45. Fuel reprocessing
46. Fuel rod
47. Fuel, ceramic
48. Fusion

VII. "G"

1. Gamma quantum
2. Gamma radiation
3. Gas amplification
4. Gas centrifuge process
5. Gas-cooled reactor
6. Gaseous diffusion process
7. Gas flow counter
8. Geiger-Müller counter
9. Geometrically safe
10. GeV
11. GKN-1
12. GKN-2
13. Glass dosimeter
14. Glove Box
15. Gonad dose
16. Gorleben
17. Gray
18. Ground radiation
19. GRS
20. GW
21. Gwe
22. Gy

VIII. "H"

1. Hafnium
2. Half-life

3. Half-life, biological
4. Half-life, effective
5. Half-value thickness
6. Halogen-quench Geiger tube
7. Handling of radioactive substances
8. Harrisburg
9. HAW
10. HDR
11. Head-end
12. Heavy hydrogen
13. Heavy water
14. Heavy-water reactor
15. HEPA filter
16. Heterogeneous reactor
17. HFR
18. High-temperature reactor
19. Homogeneous reactor
20. Hot
21. Hot cell
22. Hot laboratory
23. Hot workshop
24. HTR
25. Hydrogen bomb
26. Hydrogen sulphide process
27. Hyperons

IX. "I"

1. IAEA
2. ICRP
3. ICRU
4. IK
5. ILL
6. Imission
7. Incident
8. Incident/accident levels
    a. Level S
    b. Level E
    c. Level N
    d. Level V
9. Incident precautions
10. Incident probability analysis
11. Incident sequence analysis
12. Incorporation
13. Indicator
14. Inert gas
15. INES
16. Informationskreis KernEnergie
17. Ingestion
18. Inhalation
19. Inherently safe
20. INIS
21. In-pile
22. Intake
23. Integrity under aircraft crash
24. Interaction
25. Interaction, strong
26. Interaction, weak

27. Interim storage facilities for fuel elements
28. Interim storage of spent fuel elements
29. Intermediate load power plant
30. International Commission on Radiological Protection
31. Intervention threshold
32. Intervention
33. Iodine filter
34. Ion
35. Ion dose
36. Ion exchanger
37. Ionization chamber
38. Ionization
39. Ionizing radiation
40. IRPA
41. Isobars
42. Isodose curve
43. Isomers
44. Isotones
45. Isotope
46. Isotope enrichment
47. Isotope exchange
48. Isotope laboratory
49. Isotope separation
50. Isotopic abundance
51. Isotopic abundance, natural
52. Isotopic dilution analysis
53. ITER

X. "J"

1. JET (Joint European Torus)

XI. "K"

1. KBR
2. K-capture
3. KERMA
4. Kerntechnischer Hilfsdienst
5. Kerosene
6. keV
7. Key measurement point
8. KFÜ
9. KGR
10. KHG
11. Kilogram, effective
12. KKB
13. KKE
14. KKG
15. KKI-1
16. KKI-2
17. KKK
18. KKN
19. KKP-1
20. KKP-2
21. KKR
22. KKS
23. KKU
24. KKW-Nord

25. K-meson
26. KMK
27. KNK-II
28. Konrad
29. K-radiation
30. KRB-A
31. KRB-B
32. KRB-C
33. KTA
34. KTG
35. KWG
36. KWL
37. KWO
38. KWW

XII. "L"

1. Large-scale research facilities
2. LAW
3. LD50
4. Leach rate
5. Lepton
6. LET
7. Lethal dose
8. Liability convention
9. Liability for nuclear facilities
10. Licensing procedure
11. Life time, mean
12. Light water reactor
13. Linac
14. Line losses
15. Linear accelerator
16. Linear amplifier
17. Linear energy transfer
18. Linear heat generation rate
19. Liquid scintillation counter
20. LMFBR
21. Load ranges of power plants
22. LOCA
23. Local dose
24. Long-lived radionuclides
25. Long-time dispersion factor
26. Loop
27. Lost concrete shielding
28. Lost energy
29. Low-temperature rectification
30. LSC
31. LWR

XIII. "M"

1. Magnetic lens
2. Magnox
3. Magnox reactor
4. Maintenance
5. MAK
6. Manipulator
7. Marking
8. Mass, critical

9. Mass defect
10. Mass number
11. Mass spectrograph, mass spectrometer
12. Material balance area
13. Material, depleted
14. Material, enriched
15. Material, unaccounted for
16. MAW
17. Max Planck Institute for Plasma Physics
18. Maximum capacity
19. Maximum credible accident
20. MBA
21. MCA
22. µCi
23. MCI
24. Mechanical-draft cooling tower
25. Megawatt
26. Meson
27. MeV
28. Microcurie
29. Millicurie
30. Millirem
31. 30-millirem concept
32. Mixed oxide
33. Mixer settler
34. Moderation
35. Moderator
36. Molecule
37. Monazite
38. Monitor
39. Monitoring area
40. Monte-Carlo Method
41. MOX
42. mrem
43. MTR
44. MUF
45. Mülheim-Kärlich
46. Multiple disaggregation
47. Multiple-channel analyser
48. Multiplication factor
49. MW
50. MWd
51. MWd/t
52. MWe
53. MWth
54. Myon
55. MZFR

XIV. "N"

1. Natural draught cooling tower
2. Natural uranium
3. nCi
4. NEA
5. Neutrino
6. Neutron
7. Neutron activation analysis

8. Neutron density
9. Neutron, fast
10. Neutron flux density
11. Neutron, intermediate
12. Neutron, slow
13. Neutron source
14. Neutrons, delayed
15. Neutrons, epithermal
16. Neutrons, prompt
17. Neutrons, thermal
18. Non-destructive testing
19. Non-energetic consumption
20. Non-proliferation Treaty
21. Normal operation and anticipated operational occurrences
22. NPP
23. NPT
24. NRC
25. NSSS
26. Nuclear chemistry
27. Nuclear energy
28. Nuclear event
29. Nuclear facility
30. Nuclear fission
31. Nuclear fuel
32. Nuclear fuel cycle
33. Nuclear fusion
34. Nuclear materials
35. Nuclear material monitoring
36. Nuclear medicine
37. Nuclear parent
38. Nuclear poison
39. Nuclear power plant
40. Nuclear power plants in Europe
41. Nuclear power plants in Germany
42. Nuclear power plants, world-wide
43. Nuclear power plants, world-wide, reactor types
44. Nuclear reactor
45. Nuclear reactor telemonitoring system
46. Nucleon
47. Nucleus
48. Nuclide chart
49. Nuclide

XV. "O"

1. Off-gas treatment
2. Oklo
3. Open radioactive substances
4. Operating experience with nuclear power plants
5. Operating hours
6. Operating manual
7. Organ committed dose
8. Organ dose
9. „Otto Hahn"
10. Output, specific
11. Overheating

XVI. "P"

1. Pair generation
2. Paris Convention
3. Partial body dose
4. Particle accelerator
5. Partition wall process
6. Party responsible for radiation protection
7. Peak load power plants
8. Pebble bed reactor
9. Pellet
10. Pen dosimeter
11. Period
12. Personal dose
13. Persons exposed to radiation in their work
14. Phosphate glass dosimeter
15. Photo-cathode
16. Photo-effect
17. Photon
18. PHWR
19. 2 pi-counter
20. 4 pi-counter
21. Pi meson
22. Pinch effect
23. Pion
24. Plasma
25. Plateau
26. Plutonium
27. Poison
28. Poisoning
29. Pollux
30. Pool reactor
31. Positron
32. Power generation from nuclear plants in Europe
33. Power generation, Germany
34. Power generation, nuclear power plants in Germany
35. Power generation, nuclear power plants world-wide
36. Power reactor
37. ppb
38. ppm
39. Pressure tube reactor
40. Pressure vessel
41. Pressurized water reactor
42. Primary energy
43. Primary energy consumption, Germany
44. Primary energy reserves
45. Proliferation
46. Proportional counter
47. Proton
48. Pulsed column
49. Pulsed reactor
50. Pure element
51. PUREX
52. PUREX process
53. PWR

XVII. "Q"

1. Quality assurance

2. Quality factor

XVIII. "R"

1. R
2. Rad
3. Radiation
4. Radiation biology
5. Radiation, characteristic
6. Radiation chemistry
7. Radiation damage in human beings
8. Radiation damage, biological
9. Radiation damage, early symptoms
10. Radiation damage, physical-chemical
11. Radiation detector
12. Radiation effect, stochastic
13. Radiation-exposed persons
14. Radiation exposure, average in Germany
15. Radiation exposure, building material, Germany
16. Radiation exposure, civilization-related, Germany
17. Radiation exposure, comparability, natural/civilization-related
18. Radiation exposure, cosmic
19. Radiation exposure, dose limits, Germany
20. Radiation exposure, medical, Germany
21. Radiation exposure, natural
22. Radiation exposure, nuclear power plants, Germany
23. Radiation exposure, occupational, Germany
24. Radiation exposure, power plants
25. Radiation exposure, terrestrial
26. Radiation hygiene
27. Radiation medicine
28. Radiation physics
29. Radiation protection
30. Radiation protection areas
31. Radiation protection officer
32. Radiation syndrome
33. Radiation weighting factors
34. Radio diagnostics
35. Radio iodine
36. Radioactive isotope
37. Radioactive substances
38. Radioactivity
39. Radioactivity, induced
40. Radioactivity, natural
41. Radiocarbon
42. Radiochemistry
43. Radioecology
44. Radio-element
45. Radiogram
46. Radiography
47. Radioisotope generator
48. Radiology
49. Radiolysis
50. Radionuclide
51. Radionuclides, cosmogenic
52. Radionuclides, primordial
53. Radio-photoluminescence
54. Radioscopy

55. Radiotherapy
56. Radiation effect in the case of very high whole-body irradiation
57. Radiotoxicity
58. Radium
59. Radon
60. Range, medium free
61. Rasmussen report
62. Ratemeter
63. RBMK
64. RBW
65. rd
66. RDB
67. Reactivity
68. Reactor
69. Reactor coolant
70. Reactor coolant circuit
71. Reactor control
72. Reactor, fast
73. Reactor, gas-cooled
74. Reactor pressure vessel
75. Reactor protection system
76. Reactor risk study
77. Reactor Safety Commission, Germany
78. Reactor time constant
79. Reactor types, world-wide
80. Reactor, thermal
81. Receiving point
82. Recording threshold
83. Redundancy
84. Reference nuclide
85. Reference threshold
86. Reflector
87. Relative biological effect
88. rem
89. Reprocessing Plant Karlsruhe
90. Reprocessing
91. Research reactor
92. Residual heat
93. Residual risk
94. Rest-energy
95. Rest mass
96. Risk
97. Risk study
98. roentgen
99. Rupture protection

XIX. "S"

1. Safeguard
2. Safety barriers
3. Safety report
4. Saturated steam
5. Scattering
6. Scattering, inelastic
7. Inelastic scattering of a neutron
8. Scintillation counter
9. Scintillator

10. Scram
11. Secondary coolant
12. Secondary cooling system
13. Secondary energy
14. Seismic qualification
15. Self-absorption
16. Self-heating
17. Sellafield
18. Semi-conductor counter
19. Separating plant
20. Separation factor
21. Separation nozzle process
22. Separative work
23. Shield, biological
24. Shielding
25. Shield, thermal
26. Shim rod
27. Shipper/receiver difference
28. Short-lived radionuclides
29. Short-time dispersion
30. Shutdown reactivity
31. Shutdown rod
32. Sievert
33. Single failure
34. Skin dose
35. Skyshine
36. SNR-300
37. Soft tissue
38. Solidification
39. Solvent extraction
40. Source material
41. Spallation
42. Spark chamber
43. Spin
44. SSK
45. State collecting facilities
46. Steam bubble coefficient
47. Stellarator
48. Stochastic radiation effect
49. Storage ring
50. Subcritical arrangement
51. Subcritical mass
52. Suitable for ultimate waste disposal
53. Supercritical arrangement
54. Supercritical reactor
55. SUR-100
56. Synchro-cyclotron
57. Synchrotron

XX. "T"

1. Tail-end
2. Tandem accelerator
3. Target
4. TBP
5. Temperature coefficient of reactivity
6. Terrestrial radiation
7. Thermal breeding reactor

8. Thermal column
9. Thermionic conversion
10. Thermoluminescence dosimeter
11. Thermonuclear reaction
12. THORP
13. Three Mile Island
14. Threshold detector
15. Threshold dose
16. THTR-300
17. Time-of-flight analyzer
18. Tissue equivalent
19. Tissue weighting factor
20. TLD
21. Tokamak
22. Traceability limit
23. Tracer
24. Transients
25. Transmutation
26. Transport of radioactive substances
27. Transuranium element
28. Tributyl phosphate
29. TRIGA
30. Trip
31. Tritium
32. Triton
33. TUSA

XXI. "U"

1. Ultimate waste disposal, Germany
2. Ultimate waste disposal, direct
3. UNSCEAR
4. Uranium
5. Uranium, depleted
6. Uranium, enriched
7. Uranium hexafluoride (UF6)
8. Uranium mining, global
9. Uranium resources
10. Uranium separative work
11. Uranyl nitrate
12. Useful energy
13. UTA (Uranium separative work)
14. Utilization ratio

XXII. "V"

1. VAK
2. Van de Graaff generator
3. Vitrification
4. Vitrification plant Karlsruhe
5. Void effect

XXIII. "W"

1. WAK
2. Waste heat
3. Waste management
4. Waste processing
5. Waste water path

6. Waste, radioactive
7. Waste, radioactive, classification
8. Waste, radioactive, from nuclear power plants
9. Waste, radioactive, volume
10. Waste, radioactive, volume reduction
11. Weighting factor
12. Wet cooling tower
13. Wet steam
14. Wet storage
15. Whole-body dose
16. Wigner effect
17. Wigner energy
18. Wipe test

XXIV. "X"

1. Xenon poisoning
2. X-radiation
3. X-ray treatment

XXV. "Y"

1. Yellow cake

XXVI. "Z"

1. Zero effect
2. Zero power reactor
3. Zircaloy

XXVII. Annex

Part II Glossary of Molecular Imaging Terms

Content:

3. Benign
4. Beta-amyloid plaque
5. Beta-minus
6. Beta-plus
7. Biological half-life
8. Biological pathway
9. Bioluminescent imaging
10. Biomarker
11. Biopsy
12. Blood-brain barrier
13. Bone marrow
14. Bone scan
15. Brachytherapy
16. Bradycardia
17. Breast-specific gamma imaging

III. "C"

1. C-11-PIB
2. Carcinoembryonic antigen (CEA)
3. Cardiac catheterization
4. Cardiac sarcoidosis
5. Cardiomyopathy
6. Cartilage
7. Cervix
8. Chemotherapy
9. Co-registration
10. Cold kit
11. Colorectal
12. Colorectal cancer
13. Computed tomography
14. Computerized tomography (CT)
15. Congenital
16. Congestive heart failure
    a. systolic
    b. diastolic
17. Contamination
18. Contrast agent (contrast media or contrast material)
19. Coronary artery disease
20. Cryosurgery
21. CT
22. Curie (Ci)
23. Curietherapy

IV. "D"

1. Decay
2. Degenerative
3. Dementia
4. Diagnostic imaging (diagnostic scan)
5. Diastolic
6. Differential diagnosis
7. Differentiated thyroid cancer
8. Diffuse
9. Dosimetry
10. Ductal carcinoma in situ (DCIS)
11. Ducts

V. "E"

1. ECG stress test
2. Echo stress test
3. Echocardiography
4. Effective dose
5. Effective half-life
6. Ejection fraction
7. Electrocardiography
8. Electrodessication and curettage
9. Electromagnetic radiation
10. Electron
11. Embolism
12. Endocrine
13. Enzyme
14. EMEA
15. Epilepsy
16. Equivalent dose or Dose equivalent
17. Esophageal
18. Estrogen receptor-positive breast cancer
19. Estrogen, estrogen receptor
20. Exercise treadmill testing
21. External radiotherapy

VI. "F"

1. FDA (Food and Drug Administration)
2. FDG (Fluorodeoxyglucose)
3. Fluorescence imaging (fluorescent molecular tomography [FMT])
4. Fluorine
5. Fluoroestradiol (FES)
6. Fluorothymidine (FLT)
7. Follicular thyroid cancer
8. Free radical
9. Frontotemporal dementia
10. Frontotemporal disorders
11. Fusion imaging

VII. "G"

1. Galenic
2. Gallbladder
3. Gamma(γ)
4. Gamma camera
5. Gastric
6. Gastrointestinal (GI) tract
7. Generator
8. Glial cell
9. GMP
10. Gray (gy)
11. Gynecology

VIII. "H"

1. Half-life
2. Heart attack
3. Heart failure
4. Hippocampus
5. Hodgkin's disease
6. Hurthle cell thyroid cancer
7. Hybrid imaging

8. Hypothyroidism

IX. "I"

1. I-123 MIBG scintigraphy
2. I-131 radiotherapy
3. Imaging agent (imaging probe, radiotracer)
4. Imaging biomarker (see biomarker)
5. Imaging device
6. Imaging probe (imaging agent)
7. Immunotherapy
8. Incidental cancers
9. IND (Investigational New Drug (dossier))
10. Indium-111-octreotide
11. Internal radiotherapy
12. Intracavity radiation
13. Intraoperative radiation
14. Intravenous (IV)
15. Ionizing radiation
16. Irradiation
17. Isotope

X. "L"

1. Label
2. Labeling
3. larynx
4. Lewy body dementia
5. Ligand
6. lobules
7. localize
8. lumpectomy
9. lymph
10. lymph node biopsy
11. lymph nodes
12. lymph vessels
13. lymphatic system
14. lymphocyte
15. lymphoma
16. lymphoscintigraphy

XI. "M"

1. Magnetic resonance imaging (MRI)
2. Magnetic resonance spectroscopy (MRS)
3. Malignant
4. Masectomy
5. Matrix metalloproteinase (MMP)
6. Mediastinoscopy
7. Melanin
8. Melanocytes
9. Melanoma
10. Metabolic
11. Metabolic radiotherapy
12. Metabolism
13. Metabolites
14. Metastasize
15. Micro- (PET, MR, CT, SPECT)
16. Microbubbles

17. Mild cognitive impairment (MCI)
18. Millisieverts (mSv)
19. Molecular imaging (MI)
20. Molecular markers
21. Molecular radiotherapy (MRT)
22. Molecular ultrasound
23. Monoclonal antibody
24. Monoclonal antibody imaging
25. MR spectroscopy
26. Myelin
27. Myocardial infarction (MI)
28. Myocardial perfusion imaging
29. Myocardial perfusion scan (MPI)
30. Myocarditis

XII. "N"

1. Nanometer
2. Nanoparticle
3. Nanotechnology
4. National Oncologic PET Registry (NOPR)
5. NDA (New Drug Application (dossier))
6. Nerve
7. Nervous system
8. Neurodegenerative diseases
9. Neuroendocrine
10. Neuroimaging
11. Neuroimaging probes
12. Neutron
13. Neutron therapy
14. Neurotransmission
15. Neurotransmitter
16. Non-Hodgkin lymphoma (NHL)
17. Non-invasively
18. Noninvasive
19. Nuclear cardiology
20. Nuclear functional study
21. Nuclear medicine/nuclear imaging
22. Nucleus
23. Nuclide

XIII. "O"

1. Obsessive-compulsive disorder
2. Oncology (or cancerology)
3. Opacity
4. Optical imaging
5. Orphan drug
6. Ovary

XIV. "P"

1. Pancreas
2. Papillary thyroid cancer
3. Parkinson's disease (PD)
4. Peripheral artery disease (PAD)
5. PET
6. PET/CT
7. Pharmacodynamics
8. Pharmacogenetics

9. Pharmacokinetics
10. Pharmacological stress test
11. Pharynx
12. Photodynamic therapy
13. Photon
14. Pick's disease
15. Plaque
16. Plaque, beta-amyloid
17. Positron
18. Positron emission mammography (PEM)
19. Positron emission tomography (PET)
20. Posology
21. Post-traumatic stress disorder (PTSD)
22. Prevalence
23. ProstaScint® scan (PSMA Study)
24. Prostate gland
25. Prostate-specific antigen (PSA)
26. Prostate-specific membrane antigen (PSMA) study
27. Prostatectomy
28. Proton
29. Proton therapy

XV. "R"

1. Rad
2. Radiation
3. Radiation therapy
4. Radioactive half-life (or period)
5. Radioactivity
6. Radiochemical
7. Radiochemist
8. Radiochemistry
9. Radioelement
10. Radioimmunoscintigraphy (RIS) (monoclonal antibody imaging)
11. Radioimmunotherapy (RIT)
12. Radioiodine
13. Radioisotope
14. Radiologist
15. Radionuclide (radioactive atomic nucleus)
16. Radiopharmaceutical
17. Radiopharmacist
18. Radiopharmacy
19. Radiophysician
20. Radiotherapist
21. Radiotherapy
22. Radiotracer
23. Re-staging
24. Rectum
25. Rem
26. Reporter-gene systems
27. Risk-stratification

XVI. "S"

1. Sarcoma
2. Scanner
3. Schizophrenia
4. Scintigraphy

5. Sealed source
6. Sentinel lymph node
7. Sentinel node biopsy
8. Side-effects or undesirable effects
9. Sievert(Sv)
10. Source
11. Specific activity
12. Specific concentration
13. Specific/specificity
14. SPECT
15. Spleen
16. Stage
17. Stress perfusion study
18. Stroke
19. Sudden cardiac death
20. Synapse
21. Systolic

XVII. "T"

1. Tachycardia
2. Targeted or vectorized radiotherapy
3. Technetium-99m-Sestamibi (MIBI)
4. Technetium-99m-sulfur-colloid (Tc-99m-colloid)
5. Thymus
6. Thyroid
7. Thyroid gland
8. Tomographic reconstruction
9. Tomography
10. Transient ischemic attack
11. Translational medicine
12. Tumor
13. Tumor marker

XVIII. "U"

1. Ultrasound
2. Urethra
3. Uterus

XIX. "V"

1. Vector
2. Ventricular remodeling

XX. "X"

1. X-rays

XXI. "Y"

1. Yttrium-90 labeled octreotide

Lecture 2: Introduction to Survey Meters (60 minutes)

Keywords: Types of gaseous detectors, Survey Meters, Pocket Dosimeters, Cutie Pie, Dose Calibrators, Construction Principles of Gas- Filled Detectors, Ionization chambers, Proportional counters, Geiger-Mueller (GM) counters, Survey Meter Quality Control, The Ludlum Model 14C, Advantage and disadvantages of ionization detectors

Objectives:

- Discuss construction principles of gas filled detectors and the operating regions of gas filled detectors
- Explain the various types and the operating regions of gas filled detectors, and the general features of gas filled detectors
- Describe the relationship between applied voltage and ion pairs
- Discuss the various modes of operations of the ionization detectors and the advantage and disadvantages of ionization detectors
- Review the operations of a proportional counter and the quality control program for a Survey Meter
- Review how to perform a survey and how to read a G-M Scale
- Define of the operating principles of a Survey Meter
- Illustrate various forms used in the PET Lab for recordkeeping

Content:

I. Types of gaseous detectors

1. Survey Meters
2. Pocket Dosimeters
3. Cutie Pie
4. Dose Calibrators

II. Construction Principles of Gas-Filled Detectors

1. Gas-filled detectors
2. Construction
3. Types of gas-filled detectors
    a. Ionization chambers
    b. Proportional counters
    c. Geiger-Mueller (GM) counters
4. Instrumentation
5. Gas-Filled Detectors – Components
6. Indirect Ionization Process
7. Direct Ionization Process
8. Radiation detection
9. Operating Regions of Gas-Filled Detectors
    a. Region I - recombination
    b. Region II - ionization
    c. Region III - proportional
    d. Region IV - limited proportional
    e. Region V - Geiger-Mueller
    f. Region VI - continuous discharge
10. Saturation Current
11. Observed Output: Pulse Height
12. Other Aspects of Gas-Filled Detectors
    a. Accuracy of measurement
    b. Wall thickness
    c. Sensitivity
13. General features of gas detectors
14. Proportional Counters
    a. Distinguishing Alpha & Beta
    b. Alpha & Beta-Gamma Plateau
    c. Gas-Flow Proportional Counter
15. Geiger Mueller Detectors
16. Advantages/Disadvantages of ionization detectors
    a. Ion Chamber
    b. Proportional Counter

c. GM Tube
17. Points to Remember for Gas-filled Detectors
18. Modes of operation
19. Interaction Rate
20. Dead time
21. Paralyzable or Nonparalyzable
22. Current Mode Operation
23. Detection Efficiency (Sensitivity)
    a. Definition
    b. Formula for calculating
24. Ionization chambers
25. GM counters

III. Survey Meters

1. Definition and history of creation
2. Types of Survey Meters
    a. GM counters
3. Basic Design of the Gaseous
4. Specific Types of Gaseous Detectors
    a. The Geiger Counter (G-M Detector)
5. Prior to Use
6. Reading the GM Scales
    a. Sample readings - GM Detector
    b. Proper Surveying Technique
    c. Important Points to Remember Regarding GM Detectors

IV. Survey Meter Quality Control

1. Differences between ionization chambers and Geiger-Muller counter
2. Two types of survey instruments
    a. Ionization chamber or referred to as a cutie-pie
    b. A Geiger-Mueller counter
3. Describe the Quality control (QC) procedures required for survey instruments
    a. Definition of QC
    b. CPM ana DPM
    c. Check batteries
    d. Calibration
    e. Constancy
4. A Portable Survey Instrument

V. Operators Manual of the Ludlum Model 14C Survey Meter

1. General
2. Specification
3. Description of Controls and Functions
4. Operating Procedurs
    a. Reading the Meterface Dial
5. Calibration
    a. Detector Operating Point
    b. Setting Overload
    c. Range Calibration
6. Maintenance
7. Theory of Operation
    a. Input
    b. Amplifier
    c. Discriminator
    d. Audio
    e. Digital Analog Convertor
    f. Seale Ranging

g. Meter Drive
h. Fast/Slow Time Constant
i. Low Voltage Supply
j. High Voltage Supply
k. Overload
l. Low Battery Alarm
m. Switching

8. Safety Considerations and Warning Marking
9. Cleaning the Instrument

VI. Survey Meter Calibrations

1. Check Applicable Items
2. Records
3. Procedure for Calibrating Survay Instruments

VII. Procedures for Area Surveys

1. Ambient Dose Rate Surveys
2. Removable Contamination Surveys (Wipes)
3. Records

VIII. Radiation Detection Instrumentation

1. Survey Instruments
2. Other Radiation Detection Instruments
3. Wipe Test Procedure
4. Dose Calibrator
5. Decay-in-Storage Form
6. Survey Meter
7. Interpreting survey meter readings

IX. Pocket Dosimeters

1. Cross-section of the Pocket Dosimeter
2. Scale As Seen Through the Eyepiece
3. Operational Properties of Pocket Dosimeters
4. General Comments Regarding Pocket Dosimeters

X. Ionization Chambers or Cutie Pie

1. Reading Ionization Chamber Scales
2. Characteristics of Ionization Chamber Detector
3. General Comments Regarding Ionization Chambers

XI. Sample Area Survey Forms

Lecture 3: Introduction to Dose Calibrators (90 minutes)

Keywords: Radioisotope Calibrators, Dose Calibrators, Types of Gaseous Detectors, Survey Meters, Pocket Dosimeters, Cutie Pie, Construction Principles of Gas-Filled Detectors, Ionization Chambers, Proportional Counters, Geiger-Mueller (GM) Counters, Components of Gas-Filled Detectors, Operating Regions of Gas-Filled Detectors, Saturation Current, Accuracy of Measurement, Wall Thickness, Sensitivity, Advantages/Disadvantages of Ionization Detectors, Modes of Operation, Interaction Rate, Dead Time, Paralyzable or Nonparalyzable, Detection Efficiency

Objectives:

- Discuss construction principles of gas filled detectors and the operating regions of gas filled detectors
- Explain the various types of gas filled detectors and the general features of gas filled detectors
- Describe the relationship between applied voltage and ion pairs
- Discuss the various modes of operations of the ionization detectors and the advantage and disadvantages of ionization detectors
- Review the operations of a proportional counter
- Define the use of a dose calibrator
- Illustrate the dose calibrator quality control program

Part I

Content:

I. Purpose of Radioisotope Calibrators (Dose Calibrators)

II. Principles of Operation

III. Operation Considerations

IV. Reported Problems

Part II

Content:

I. Types of gaseous detectors

1. Survey Meters
2. Pocket Dosimeters
3. Cutie Pie
4. Dose Calibrators

II. Construction Principles of Gas-Filled Detectors

1. Gas-filled detectors
2. Construction
    a. Ion Pairs
    b. Anode
    c. Cathode
    d. Power Source
    e. Amplifier
    f. Counter
3. Types of gas-filled detectors
    a. Ionization chambers
    b. Proportional counters
    c. Geiger-Mueller (GM) counters
4. Instrumentation
5. Gas-Filled Detectors – Components
6. Indirect Ionization Process
7. Direct Ionization Process
8. Radiation detection
9. Operating Regions of Gas-Filled Detectors
    a. Region I - recombination
    b. Region II - ionization
    c. Region III - proportional
    d. Region IV - limited proportional
    e. Region V - Geiger-Mueller
    f. Region VI - continuous discharge
10. Saturation Current

11. Observed Output: Pulse Height
12. Other Aspects of Gas-Filled Detectors
    a. Accuracy of measurement
    b. Wall thickness
    c. Sensitivity
13. General Features of Gas Detectors
14. Advantages/Disadvantages of Ionization Detectors
    a. Ion chamber
    b. Proportional counter
    c. GM tube
15. Points to Remember for Gas-filled Detectors
16. Modes of Operation
    a. In pulse mode
    b. In current mode
17. Interaction Rate
18. Dead Time
19. Paralyzable or Nonparalyzable
20. Current Mode Operation
21. Detection Efficiency (Sensitivity)

III. Dose Calibrators

1. Definition of a Dose Calibrator
2. Basic Design of a Dose Calibrators
3. Dose Calibrator Quality Control
    a. Accuracy
    b. Constancy
    c. Linearity
    d. Geometric calibration
4. Procedure for Calibrating A Dose Calibrator
5. Constancy Test Procedures
6. Linearity Test Procedures
    a. Decay Method
    b. Shield Methods
7. Geometry Test Procedures
8. Accuracy Test Procedures

IV. Sample of Dose Calibrator Forms and Tests Data

Lecture 4: Introduction to Scintillator Detectors (60 minutes)

Keywords: Scintillation Detector, Collimators, Parallel Hole, Pinhole, Converging, Divergin, Crystal, Imaging Devices, Quality Control, Acquisition Types, Gamma Camera

Objectives:

- Discuss the operations of a scintillation detector and the components of a scintillation device
- Review energy discrimination capabilities
- Describe the properties of collimators
- Explain the various crystals used in imaging
- Review imaging devices and basic quality control of a gamma camera
- Define acquisition types used in nuclear medicine
- Illustrate gamma cameras on the market today

Content:

I. Scintillation Detector

5. First Scintillation Camera
6. Fluors
7. Operation of a Scintillation Detector
8. Basic Components of a Scintillation Detector
    a. Crystal
    b. PMT
    c. Preamp
    d. Pulse-Height Analyzer (PHA)
    e. Counter
9. Example

II. Collimators

1. Collimator Characteristics
2. Types of Collimators
    a. Photon Energy Imaged
    b. Resolution
    c. Sensitivity
3. Resolution vs. Sensitivity
4. Collimator Variations
    a. Parallel hole
    b. Converging
    c. Diverging
    d. Pinhole
    e. Fan beam
5. Properties of Collimators
6. Main Types of Collimators
    a. Parallel Hole
    b. Pinhole
    c. Converging
    d. Divergin
7. Collimator Efficiency
    a. Septal thickness
    b. Collimator thickness
8. Collimator Comparisons
9. Multihole collimators
10. Equation for a parallel-hole collimator

III. Crystals used in scintigraphic imaging

1. Introduction
2. Good Characteristics for a Crystal
3. Types of Crystals
    a. Organic
    b. Properties organic Crystals
    c. Inorganic
    d. Properties of inorganic Crystals
4. Types of Crystals
    a. NaI (Tl)
    b. BGO (Bismuth germanate)
    c. BaF2 (Barium fluoride)
    d. CsI:TI (Cesium iodide activated by Thallium)
    e. GSO (Gadolinium silicate doped with cerium)
    f. CWO: Cadmium Tungstate (CdW04)

IV. Imaging Devices and Quality Control

1. Anger Camera

2. Crystal Characteristics
    a. Hygroscopic
    b. Fragile
    c. Temperature sensitive
3. Photon Detection Process
4. Proportionality
5. Photomultiplier Tube
6. Positioning Logic Network
7. Pulse Height Analyzer
8. Uniformity Quality Control
    a. Uniformity Sources
    b. Uniformity Image
9. Resolution Quality Control
    a. Sensitivity
    b. Factors that Influence the Resolution
    c. Intrinsic Resolution
    d. Spatial Resolution
    e. Collimator Resolution
    f. Scatter Resolution
    g. Resolution Phantom
    h. Resolution Image
10. Acquisition Types
    a. Dynamic Image
    b. Static Image
    c. Whole-body Image
    d. Gated Image
    e. SPECT Image (Single Photon Emission Computed Tomography)

11. Gamma Cameras on the Market Today

2. Forte
3. Single Head Genesys
4. Dual Head Genesys
5. Siemens LEM Portable
6. Argus
7. Vertex Classic
8. Spectrum Dynamics
9. e.cam (Single / Dual Head)
10. c.cam
11. Siemens E-CAM (Single & Dual Head)
12. Philips/ADAC Cardio MD
13. Siemens Orbiter
14. SMV
15. Siemens DIACAM
16. Toshiba
17. MEDX InteCam: GE Starcam
18. Phillips Cardio 60
19. C-PET / C-PET Plus
20. Cardio MD
21. Vertex Cardio (Cardio 60)
22. Allegro (PET)
23. Vertex Solus
24. SINGLE HEAD SYSTEM

Lecture 5: The Electronics of Scintigraphy (60 minutes)

Keywords: Anger scintillation camera, Pulse Height Analyzer, Energy discrimination, Lower level discriminators (LLD), Spectrometers, Collimators, Imaging Formation Parameters, Gamma Camera Quality Control, National Electrical Manufacturers Association (NEMA), Uniformity parameters, Spatial Resolution, SPECT Phantoms, ICANL Recommendations, PET Scanners

Objectives:

- Review the basic principles of scintillation detection
- Discuss the components of a scintillation detector system
- Review energy discrimination
- Discuss pulse height analyzers
- Discuss the use of upper and lower level discriminators
- Discuss various collimators used in nuclear medicine
- Review basic imaging formation parameters
- Review basic quality control procedures performed on gamma cameras
- Review SPECT quality control procedures
- Review basic PET theory
- Review basic PET quality control procedures

Content:

I. Introduction

II. Development

1. Hal Anger
2. Anger scintillation camera
    a. Triple Head Gamma Camera
    b. Single Head Gamma Camera
    c. Dual Head Gamma Camera

III. The components of a scintillation detector system

1. Design
2. Photomultiplier Tubes
    a. PMT Key Points
3. High Voltage Power Supply
4. Preamplifier
5. Amplifier
6. Gain Control
7. Pulse Height Analyzer
    a. Lower level descriminators (LLD)
    b. Spectrometers
8. Analog camera
9. Hybrid camera
10. Digital camera

IV. Collimators

11. Collimator Characteristics
12. Types of Collimators
    a. Parallel-hole collimator
    b. Pinhole collimator
    c. Converging collimator
    d. Diverging collimator

V. Basic Imaging Formation Parameters

1. Image formation
2. Measures of performance
    a. System or extrinsic
    b. Intrinsic
3. Uniformity
4. Spatial resolution
    a. Multienergy spatial resolution
5. System efficiency
6. Collimator efficiency
7. Energy resolution
8. Count rate performance
9. Scintillation, Anger, and Gamma cameras
    a. Siemens LEM Portable
    b. Forte
    c. Spectrum Dynamics
    d. Single Head Genesys
    e. Dual Head Genesys
    f. Argus
    g. Vertex Classic
    h. Vertex Plus (V60)
    i. e.cam (Single / Dual Head)
    j. c.cam
    k. Siemens E-CAM (Single & Dual Head)
    l. Philips/ADAC Cardio MD
    m. Siemens Orbiter
    n. Digirad
    o. SMV
    p. Siemens DIACAM
    q. IS2 Pulse
    r. Toshiba
    s. MEDX InteCam: GE Starcam
    t. Phillips Cardio 60
    u. Forte
    v. C-PET / C-PET Plus
    w. Cardio MD
    x. Vertex Cardio (Cardio 60)
    y. Allegro (PET)
    z. SKYLight
    aa. Vertex Solus
    bb. SINGLE HEAD SYSTEM

VI. Gamma Camera Quality Control

1. Quality Control
2. Scintillation Camera Performance
    b. Extrinsic measurements
    c. Intrinsic measurements

13. Other QC Standards that must be measured

a. NEMA – National Electrical Manufacturers Association

14. Routine Camera Quality Control procedures
    a. Daily
    b. Weekly
    c. Monthly
15. Uniformity
    a. Intrinsic uniformity
    b. Extrinsic uniformity
16. Daily Flood

17. Uniformity parameters
    a. UFOV – useful field of view
    b. CFOV – center field of view
    c. Integral uniformity
    d. Differential uniformity
18. Spatial Resolution / System Linearity “BARS”
19. Resolution phantoms
20. UB gamma camera test pattern
21. Uniformity corrections
22. Camera uniformity analysis
23. Center of rotation – COR
24. SPECT Phantoms – system performance testing
25. SPECT Performance Phantoms
26. ICANL Recommendations

VII. PET Scanners

1. The Future of Nuclear Medicine
2. PET (Positron emission tomography)
    a. PET Radiation Detectors
    b. Dedicated PET
    c. Scintillation Crystals
    d. PET Scanner Design
    e. Coincidence Detection: True Scatter and Random Events
    f. Data Acquisition
    g. 2D and 3D Scanner Configuration
    h. Scanner Calibration and Quality Control
        - Characterization (or operation) calibration
        - Correction calibration
    i. PET Scanner Failures
3. PET/CT Scanners
4. Key Notes for PET

Lecture 6: PET Instrumentation (60 minutes)

Keywords: PET, PET/CT Scanner, Positron Emission, Detectors, Bed positions, Scanner Design, Crystals, Coincidence Dietician, Configuration, Data acquisition and processing, Attenuation Correction, Positron Radionuclides, Pharmaceuticals, Positron Emission Mammography (PEM), Non-invasive Medical Imaging Techniques, Multimodality imaging, Scanner-Block Diagrams, FPGAs (field programmable gate arrays)

Objectives:

- Review the History of PET
- Review the basics of PET Imaging
- Review system configurations
- Discuss Coincidence Imaging
- Review data acquisition and processing
- Identify common radiopharmaceutical compounds
- Discuss PET/CT applications in nuclear medicine
- Review the Block Diagram of a PET/CT Scanner

Content:

I. History of PET

1. In 1950 Brownell and Sweet
2. In 1968 PC-I
3. In early 1970 David Chesler
4. Modern PET/CT Scanner
   a. Increasing Image Quality

II. Basics of PET Imaging

3. PET (Positron emission tomography)
4. Positron Emission
5. How PET Scanner works
6. PET Diagram
7. PET Detectors
8. Patient in Scanner
   a. Bed positions
9. Reducing Scatter and Random Events
10. PET Advantage
11. Uses of PET: Oncology
12. PET/CT: Image Fusion
13. PET/CT Scanner
14. Advantages of PET/CT
15. The Future of PET/CT
16. What PET Equipment Looks Like
17. Scanner Design
18. Crystals Used in PET
    a. BaF2
    b. BGO
    c. LSO
    d. GSO
    e. YLSO
19. Coincidence Dietician
20. 2D Scanner Configuration
21. 3D Scanner Configuration
22. Data Acquisition
23. Reconstruction
24. Attenuation Correction
25. Positron Radionuclides
26. PET Pharmaceuticals
27. PET is Used to
28. GC (Coincidence) PET
29. PET/CT
30. PEM (Positron Emission Mammography)
31. PET vs. SPECT
32. Key Points

III. Physics and Instrumentation in Positron Emission Tomography

1. Non-invasive Medical Imaging Techniques
   a. Anatomical
      - X-ray
      - CAT
      - MRI
      - Ultrasound
   b. Functional («nuclear medicine»)
      - SPECT
      - PET

27. Positron Emission Tomography

28. Technical Challenges in PET Imaging
    a. Radiochemistry
    b. Imaging Physics
    c. Data Analysis & Biological Modeling
29. PET Imaging
30. Positron (B+) Decay
31. Positron annihilation
32. Raw Data & Image Reconstruction
33. Important Detector Properties
    a. Spatial resolution
    b. Detection efficiency (aka sensitivity, stopping power)
    c. Time resolution
    d. Energy resolution
    e. Deadtime
34. Prototypical PET Detector
35. New Developments
    a. Detectors
        - Scintillators
        - Photosensors
        - Solid-state detectors
        - Pb converters & ionization
        - 3D gamma-ray event positioning
        - Time of flight using LaBr3
    b. Multimodality imaging
        - PET/CT
        - PET/MRI
    c. Specialized applications
        - Brain, breast, prostate
        - Small animal - microPET
        - Arterial input function

IV. The PET/CT Scanner-Block Diagrams

1. Block Diagram: Front End
    a. Analog Subsection
    b. How Does the Analog Subsection Work
    c. Condition (Module Design #1)
    d. Condition (Module Design #2)
    e. Digitize Energy, X Ratio, and Y Ratio
    f. Digitize Time
    g. Process
    h. Detector Head Interface
2. Block Diagram: Back End
    a. Coincidence Processor
    b. How Does Coincidence Processor Work
    c. Host Computer
3. Photograph of Components
    a. Coincidence Processor
    b. Analog Subsection
    c. Detector Head Interface
    d. Flex Board & PD ASIC
    e. Detector Modules

V. Conclusions

1. PET Camera Electronics Consists Of
    a. Analog Subsection
    b. Detector Head Interface

c. Coincidence Processor
d. Host Computer
2. High Rate Capability
3. Extensive Use of FPGAs (field programmable gate arrays)

Lecture 7: PET Quality Control (60 minutes)

Keywords: PET, Quality Control, Problems with PET scanners, Types of PET Quality Control, Characterization calibrations, Correction calibrations, Absolute Activity Calibration, Phantoms, Weekly test, Monthly Tests, Semi-Annual Test, Annual Test

Objectives:
- Define quality control for PET
- List the QC procedures for PET
- Describe the different QC procedures for PET
- Display Before and After QC images
- Present images of phantoms used for PET QC

Content:

I. PET
1. Positron-emission tomography
2. Positron radionuclides for PET
3. PET Images

II. Quality Control
33. Quality Control for PET
34. Problems with PET scanners
    a. Detector malfunction
    b. High-voltage drift
    c. Energy drift
    d. Gain drift
    e. Cable breakage
    f. Power supply drift or failure
    g. Temperature drift or cooling system failure
    h. Coincidence timing malfunction
    i. Transmission source or robotics malfunction
    j. Septa mispositioning or misalignment
    k. Imaging table failure
35. PET Scanners Quality Control
36. Types of PET Quality Control
    a. Characterization calibrations
        - Energy Window Calibration
        - Gain Settings
        - Germanium Chemical Information
        - Coincidence Timing Calibration
    b. Correction calibrations
        - Blank Scan
        - Normalization Calibration
        - Absolute activity calibration (well counter calibration)
37. Fill Phantoms used for Absolute Activity Calibration
    a. Striatal Head Phantom
    b. Heart/Thorax Phantom
    c. Heart Filled Phantom Images

III. Quality Control in CT for PET

1. Weekly test (some perform daily)
    a. By the technologist
    b. For noise in machine
    c. CT number of Water
2. Monthly Tests
    a. By service personnel or technologist
    b. CT number uniformity
    c. Low Contrast Resolution
    d. High Contrast Spatial Resolution
    e. Hard Copy Output Devices
3. Semi-Annual Test
    a. Laser Alignment
    b. Slice Thickness
    c. Low Contrast Resolution
    d. High Contrast Resolution
    e. Index Accuracy and Couch Positioning
    f. Contrast Scale
    g. Linearity of CT with attenuation coefficient
    h. Distance Accuracy
4. Annual Test

IV. Summary

Lecture 8: Troubleshooting Image Artifacts (40 minutes)

Keywords: PET/CT, Transmission, Attenuation correction, Image Acquisition, Imaging Artifacts

Objectives:

- Define PET/CT
- Discuss transmission based attenuation correction in PET
- Discuss CT based attenuation correction in PET
- Review Image Acquisition
- List of Imaging Artifacts

Content:

I. Introduction to PET/CT

II. Transmission based attenuation correction in PET

III. CT based attenuation correction in PET

IV. Image Acquisition

V. Imaging Artifacts

1. Metallic Artifacts
2. Respiratory Motion
3. CT Contrast Media
4. Truncation

VI. Summary

VII. References

Lecture 9: Fundamentals of SPECT/CT principles (60 minutes)

Keywords: SPECT, Single photon emission computed tomography, Planar Imaging, Collimator, Parallel Hole, Pinhole, Converging, Diverging, Gray Scal and Color Display, Filters, Low Pass and High Pass Filters, Quality Control (QC), Uniformity correction, Patient motion, Center of rotation, Acquisition Modes, Circular and Body Contour Orbit, Attenuation correction, Quality Assurance, Computed Tomography, CT, CT Image, Scanner Generations, Slip Ring Technology, CT Number, Single Slice and Multi Slice CT, Spiral CT, Advantages and Disadvantages, SPECT/CT Scanner, GE Hawkeye, SIEMENS Symbia

Objectives:

- Discuss advantages of SPECT and SPECT/CT compared to Planar imaging
- Describe a few collimators used in SPECT
- Review Gray scales and Color displays
- Determine low pass filters and describe their functions
- List QC tests perform for SPECT
- Illustrate SPECT acquisition modes
- Explain attenuation corrections
- Define the difference between Quality Control and Quality Assurance

Content:

I. SPECT

1. SPECT - Single Photon Emission Computed Tomography
2. Study
   a. Bone scan
   b. Myocardial perfusion
   c. Brain scan
   d. Tumor scan
   e. White cell scan
3. Planar Imaging vs. SPECT
   a. The Difference between Planar imaging and SPECT
   b. Scan of the brain in the 3D world
   c. Example MR and SPECT datasets loaded directly
   d. Scan of the heart in the SPECT 3D world
4. Collimator
   a. Definition
   b. Collimators Used in SPECT
   c. Types of Collimator
      - Parallel Hole
      - Pinhole
      - Converging
      - Diverging
5. Gray Scal sv. Color Display
6. Filters
   a. Low Pass Filters
   b. High Pass Filter
7. Quality Control (QC) Performed in SPECT
   a. Uniformity correction
   b. Patient motion
   c. Center of rotation
8. SPECT Acquisition Modes
   a. Step and shoot mode (SSM)

b. Continuous mode (CM)
c. Continuous Step and shoot mode (CSSM)

9. Cardiac SPECT
10. Circular sv. Body Contour Orbit
11. Attenuation correction
    a. Definition
    b. Correcting for attenuation problems
12. Quality Assurance and Quality Control
    a. Quality Assurance
    b. Quality Control

II. Fundamentals of CT

1. Computed Tomography (CT)
2. CT Image
3. Scanner Generations
    a. 1st Generation
    b. 2nd Generation
    c. 3rd Generation
    d. 4th Generation
    e. 5th Generation
    f. 6th Generation
    g. 7th Generation
4. Slip Ring Technology
5. CT Number
    a. Hounsfield scale
    b. Windowing
6. Single Slice and Multi Slice CT
    a. Row of detectors
    b. Slice thickness
7. Spiral CT
8. Advantages and Disadvantages of CT

III. SPECT Gamma Camera

1. Advantages and Disadvantages of SPECT

IV. SPECT/CT Scanner

1. History
2. Hybrid SPECT/CT – two approaches
    a. 1st approach - GE Hawkeye
    b. 2nd approach - SIEMENS Symbia
3. Slow and High Speed
4. Advantages
5. Sources of Error and Artefacts
6. Attenuation Correction using CT Data
7. Conclusions
8. Refernce

V. SPECT (continued)

1. Image Acquisition
    a. Cardiac Image Acquisition
2. Orbits
3. Transverse Image Reconstruction
4. Filtered Backprojection
5. Filter Kernels
6. Interactive Reconstruction
7. Attenuation Correction
8. SPECT Collimators

9. Multihead SPECT Cameras
10. SPECT Performance
11. Spatial Resolution
12. Comparison with Conventional Planar Scintillation Camera Imaging
13. Magnification Factors
14. Multienergy Spatial Registration
15. Cor Calibration
16. Uniformity
17. Camera Head Tilt

Lecture 10: Basic Instrumentation of SPECT/CT (270 minutes)

Part 1

Keywords: SPECT, SPECT/CT, Single Photon Emission Computerized Tomographic, Basic Instrumentation, Scintillation Gamma Camera, Collimators, Performance, Image Formation, Computer hardware, Quality Control, Clinical Applications, Acquisition, Underlying and Physical Reconstruction, Transverse Image, Three-Dimensional Displays, Hard Copy, Hybrid SPECT/CT, PET-SPECT-CT Scanner, Advantages and Disadvantages

Objectives:

- Discuss SPECT acquisition modes
- Determine attenuation corrections
- Define the difference between Quality Control and Quality Assurance
- Discuss SPECT QC
- Brief review of SPECT Instrumentation principles
- Discuss various Iterative SPECT reconstruction algorythms
- Sample clinical applications of SPECT/CT
- Analysis of SPECT imaging

Content:

I. Introdution to SPECT

1. SPECT - Single Photon Emission Computerized Tomographic
2. SPECT/CT

II. Instrumentation of the SPECT

1. Gamma Scintillation Camera Components
   a. Scintigraphic Components
   b. Photomultiplier Tubes (PMT)
   c. High Voltage Power Supply
   d. Preamplifier
   e. Amplifier
   f. Gain Control
   g. Pulse Height Analyzer
   h. Spectrometers
2. Scintillation Detector
   a. Types: PM Tubes and Photodiode
   b. Crystals Used with PM Tubules
   c. Crystals Used with Photodiode
   d. Efficiency of Detectors - QDE
3. Position Circuitry

4. Collimators
   a. Parallel-Hole Collimator
5. SPECT Cameras
6. SPECT Performance
   a. Spatial resolution
   b. Magnification factors
   c. Multienergy spatial registration
   d. Alignment of projection images to axis-of-rotation
   e. Uniformity
   f. Camera head tilt
7. Factors Affecting Image Formation
   a. Distribution of radiopharmaceutical
   b. Collimator selection and sensitivity
   c. Spatial resolution
   d. Energy resolution
   e. Uniformity
   f. Count rate performance
   g. Spatial positioning at different energies
   h. Center of rotation
   i. Scattered radiation
   j. Attenuation
   k. Noise
8. Image Formation

III. The SPECT/CT Computer hardware

1. Host Computer
2. Array Processor
3. Data Acquisition System (DAS)
4. Amplifier
5. ADC
6. Sample/Hold Unit (S/H)

IV. SPECT Gamma Camera Quality Control

1. Frequency of Quality Control on a Gamma Camera
   a. Physicist
   b. Technician
2. Gamma Camera
3. Measures of Gamma Camera Performance
4. Uniformity
   a. Uniformity correction
   b. Tomographic uniformity
   c. Calculate Integral uniformity (IU)
   d. Calculate Differential uniformity (DU)
5. Collimator Efficiency
   a. Energy Resolution
   b. Count Rate Performance
   6. QC Performed in SPECT
   a. Uniformity correction
   b. Patient motion
   c. Center of rotation
7. Tomographic Resolution
8. Patient Motion
9. Cor Calibration
10. Center of Rotation
11. Camera Head Tilt

V. Clinical Applications of SPECT/CT

1. Cardiac
2. Bone
3. Renal
4. Gastric
5. Hepatobiliary
6. Thyroid
7. Pulmonary
8. Brain

VI. Gamma Camera Acquisition types

1. Static
2. Dynamic
3. Whole-body
4. SPECT
5. Gated SPECT
6. Dynamic SPECT
7. Whole-body SPECT
8. Coincidence imaging
9. List Mode SPECT/CT

VII. SPECT Image Acquisition

1. SPECT Data Acquistion Modes
   a. Orbits
   b. Step and shoot (SSM)
   c. Continuous (CM)
   d. Continuous Step and shoot (CSSM)
2. Continuous Acquisition
3. Hybrid SRECT/CT
   a. GE Hawkeye – 1st appriach
   b. SIEMENS Symbia – 2nd appriach
   c. Slow and High speed
   d. Hybrid SRECT/CT Advantadgest
4. Long Acquisition
5. Short Acquisition
6. 180-degree vs. 360-degree Data Acquistion
7. Other Factors
   a. Size of the image pixels
   b. Average number of counts collected for each pixel
   c. Number of views obtained

VIII. SPECT Reconstruction

1. Filtered Back Projection (FBP)
   a. FBP Reconstruction
   b. Filter kernels
2. Iterative Reconstruction (IR)
   a. Iterative Method
3. Nine Point Smoothing
4. Filtering
5. Transformation of Domains
6. Frequency Domains
7. Filters
   a. Low Pass
   b. High Pass
   c. Filter Kernels
8. Filtered BackProjection
9. Transverse Image Reconstruction

10. Signal vs. Noise
11. Attenuation correction
12. Image registration or functional anatomical mapping

IX. Transverse Image Reconstruction

1. Image Reorientation
   a. Transaxial Images
   b. Longitudinal Images
   c. Oblique Images
2. Cardiac Reorientation
   a. Vertical Long-axis Slices
   b. Horizontal Long-axis Slices
   c. Short-axis Slices

X. Three-Dimensional Displays

1. Categories of Displays
   a. Volume Rendering
   b. Surface Rendering
2. Color and Gray scales
3. Perfusion Quantification
4. Polar maps
5. Three-Dimensional Cardiac Displays

XI. Hard Copy

1. Hard Cope Formats
2. Image Recordinf Sistems (Laser Printers)
   a. Solid State Laser Printers
   b. GAS Laser Printers
3. Image Storage Media
   a. Magnetic Tapes
   b. Magneto-Optical Disk (MOD)
   c. CD
4. Communication
   a. Picture Archival Communication System (PACS)

XII. Todays hybrid SPECT/CT Scanners

XIII. PET-SPECT-CT Scanner - the next step in technology evolution

XIV. Advantages and Disadvantages of SPECT

Part 2

Keywords: CT Physics and Instrumentation, X-rays, X-ray Tube, Production of X-rays, Computed Tomography (CT), CT System, Instrumentation and Operation, Collimation, Rotation Speed, Pitch, Incensement, Multislice Helical CT Systems, Image Data Acquisition, Patient Orientation, Coordinate System, Isocenter, Scannable Range, Scan FOV, Scanning Methods, Topogram Regular Scan, Multislice CT, Axial Scan, Conventional and Spiral/Helical CT, Axial CT, Volume CT, Multislice Effectiveness, Spiral CT, Low–Dose, Attenuation Correction, Contrast Media, Quality Control, Basic Technologist skills, Dosimetry, Radiation Dose, Radiopharmaceuticals

Objectives:

- Describe the physics processes involved in the production of x-rays and the role of each component in the x-ray tube

- Discuss the role of proper adjustment of x-ray tube voltage and current in CT
- Name the principle parts of a CT scanner and the function of each CT scanner component
- Describe how a helical CT scanner operates and the component changes that made this technology possible
- Describe how CT image data are acquired and processed
- Describe the calculation process of Hounsfield units
- Describe CT number values assigned to various tissues and how these values are assigned into meaningful display windowing
- List parameters set by the operator for CT use and describe the effect of each on the images
- Discuss the CT image quality issues
- List the origin of CT image artifacts and describe their prevention
- Discuss appropriate parameters for the acquisition of low-dose CT for PET attenuation correction
- Describe the parameters and image characteristics required for a diagnostic-quality CT scan
- Discuss the integration of CT procedures into the combined PET/CT examination
- Discuss occupational radiation exposure from operating a CT scanner
- Discuss patient radiation exposure from a CT scanner
- Describe CT quality control program
- Discuss CT quality control
- Discuss basic SPECT/CT technology
- Describe SPECT/CT architecture
- Discuss the technical skills to operate a SPECT/CT system
- Discuss the advantages of SPECT/CT
- Discuss the effects of CT based attenuation correction in SPECT/CT
- Discuss new and current radiopharmaceuticals used in SPECT/CT
- Compare today's SPECT/CT systems

Content:

I. CT Physics and Instrumentation

1. Physics of X-rays
   a. Bremsstrahlung Radiation
   b. Characteristic x-rays
2. X-ray Tube and the Production of X-rays
   a. X-ray Tube Design
   b. Technique
      - kVp
      - mA
      - Time
      - Slice Thickness
      - Slice Incrementation
3. Voltage Variation
   a. kVp
   b. Too Low of kVp
   c. Tube Voltage (kVp) Change
   d. kVp in CT
   e. Advantages and Disadvantages of Voltage Variation
4. Current Variation
   a. Advantages and Disadvantages of Current Variation
   b. MA of Tube Current
   c. Tube Current Change
   d. Changing MA or Time
   e. S –Time of Exposure
   f. Focal Spot
5. X-ray Filter
   a. Filtration Material
   b. Filtration Change

6. Principles of Computed Tomography
7. CT Scanner Design
    a. CT System

II. Computed Tomography Instrumentation and Operation

1. CT Components
    a. Gantry
    b. Table/Couch
    c. Computer
    d. Console
2. Gantry Inside
3. Gantry Composition
    a. CT Detectors
    b. Detector Elements
4. CT Scanner Design
    a. The CT X-Ray Tube
        - Heat Units Calculation
        - Reduction of Heat Units – Technique Compensation
    b. High Voltage Generator (HVG)
5. Collimation
    a. Advantages of thinner collimation
    b. Compromises of thinner collimation
6. Rotation Speed
7. Pitch
8. Incensement
9. Multislice Helical CT Systems
10. Image Data Acquisition
    a. Basic Data Acquisition Scheme in CT
    b. Data Acquisition System (DAS)
11. CT Image Reconstruction
    a. Advantages and Compromise
12. CT Display
13. Control Console
    a. Set scan parameters
    b. Set scan mode
    c. IRS (Image reconstruction System)
    d. Review and archive images
    e. Post-processing
14. Original Clinical CT Scans Composed
    a. Early Days vs Today
15. Coordinate System
    a. Z
    b. X
    c. Y
    d. Isocenter
16. Patient Orientation
    a. Head First
    b. Feet First
17. Patient Couch
18. Scannable Range
19. Scan FOV
20. DFOV – Displayed Field of View
21. CT and CAT Scan
22. Scanning Methods
    a. Surview
    b. Conventional CT

c. Volumetric CT

23. Scanning - Topogram Regular Scan
    a. Topogram (Scout)
        - AP Scout
        - LAT Scout
    b. CT Data Acquisition

III. Fundamentals of Multislice CT

1. Axial Scan
2. Spiral
3. Conventional and Spiral/Helical CT
    a. Advantage of Spiral Imaging over Conventional
4. Digital Projection
5. Axial CT
6. Volume CT
    a. Pitch
    b. Advantages of Volume CT
7. Multislice Fundamentals
8. Multislice Effectiveness
    a. Single Slice
    b. Dual Slice
    c. Quad Slice
9. Dual Slice Detector Optimized for 2 Slice Acquisition
10. Quad Detector Technology
    a. Variable Wide Area Detector
    b. Variable slice thickness
    c. How it works
11. Slip Ring Technology
    a. Single Slice and Multi Slice CT
    b. Slice Thickness
12. Spiral CT
13. Display of Volumetric Image Data
14. Image Quality
    a. High-Contrast
    b. Low-Contrast
15. Image Noise
16. Low–Dose CT for SPECT Attenuation Correction
    a. Attenuation
17. Integrated SPECT/CT Protocols
    a. Sources of artifacs
        - Operator
        - Scanner
        - Patient
18. CT Protocols
19. Diagnostic CT
    a. Abdomen CT
    b. Chest CT
    c. Neck CT
20. Contrast Media
    a. CT Contrast Agents
        - Iodine
        - Barium Sulfate
        - Gastrografin
        - Gadolinium
        - Rectal Contrast
    b. Administration

21. Advantages and Limitations of CT
22. Goals of CT
23. Density Information
    a. Hounsfield scale
24. Windows Settings
    a. Window width
    b. Window level
25. CT Images Quality
    a. Spatial resolution
    b. Contrast resolution
    c. Isotropic Imaging
26. Post Processing Options
27. Pixel Size
    a. Reconstruction
    b. Pixel and Voxel
    c. Pixel Size Depends
    d. Vocal Size Depends
28. Image Display
    a. Computed Gray Scale and CT Numbers
    b. CT Image
    c. CT Number
29. Host Computer
    a. Functions
    b. CT Operating System
    c. Array Processor
    d. Data Acquisition System (DAS)
        - Amplifier
        - ADC
        - DAC
        - Generator
        - Sample/Hold Unit (S/H)
30. Image Display
    a. Image Display, Recording, Storage
    b. Image Recording Systems (Laser Printers)
    c. Heard Copy
    d. Image Storage Media
    e. Communication

IV. CT Quality Control

1. General Quality Control
    a. General QC Tests: Image Quality
        - Noise and Field Uniformity
        - CT Number Linearity
        - Low Contrast Detectability
        - Spatial Resolution
        - Display and Hard Copy Image Quality
    b. General QC Tests: Dosimetry
        - CTDI
        - Patient Dosimetry
    c. Alignment Laser Accuracy
    d. Table Incrementation Accuracy and Collimation (Axial Scan)
    e. Table Incrementation Scanned Volume Helical Pitch Accuracy
    f. KVP Accuracy
    g. Hale-Value Layer
    h. Exposure Reproducibility and Linearity
    i. Radiation Profile Width

j. Slice Sensitivity Profile
k. Image Quality Measures
l. Phantoms and Test Tools
   - Noise and Field Uniformity
   - CT Number Linearity
   - Low Contrast Detectability
   - Spatial Resolution
   - Reconstruction times
   - Scout view accuracy
m. Display and Heard Copy Image Quality
n. Dosimetry Measurement: CTDI
o. CT Equipment Quality Control Program
p. Acceptance Testing
q. Considerations for Acceptance Tests
   - Essential Tests
   - Optional Tests
   - Alternative Tests
r. Annual ACR Requirements
s. Monthly to Semi-annual Tests Per AAPM
t. Continuous Quality Control
u. Continuous Quality Control Tests
v. Daily Tests AAPM
w. Aids to Daily QC
x. Auto-QA Lite Overview

2. CT Radiation Safety

V. Basic SPECT/CT Technology

VI. General overview of SPECT/CT System Architecture

VII. Overview of basic SPECT/CT Protocols

VIII. Basic Technologist skills to operate a SPECT/CT System

IX. Advantages of SPECT/CT

X. Effects of CT Based Attenuation Correction in SPECT/CT

XI. Diagnostic quality CT Studies

XII. CT Internal Radiation Dose Dosimetry

XIII. Estimated Radiation Dose from a SPECT/CT Procedure

XIV. SPECT/CT Radiopharmaceuticals

XV. Comparing today's SPECT/CT systems

1. SPECT/CT

XVI. Conclusion

Lecture 11: SPECT Acquisition (90 minutes)

Part 1

Keywords: Imaging techniques, Image Acquisition, basic Parameters, Gamma rays, Gamma cameras, Radiation Energy Considerations, Detection, Attenuation, Inorganic scintillators, Nuclear Medicine Imaging Systems, PMT calibration, Anger position network, Detection window in context, Types of events, Signal-to-noise ratio (CNR), Digital Images, PIXEL Correlation, Collmator, Scintillator, Photomultiplier Tubes (PMTs), Scintillator and Photomultiplier Tube assemblies, SPECT Data Acquisition

Objectives:
- Discuss Image Acquisition
- Define Image Acquisition basic Parameters
- Review of Imaging Systems in Nuclear Medicine
- Explain SPECT Data Acquisition

Content:

I. Introdution
1. Varieties of the Imaging Techniques

II. Image Acquisition

III. Image Acquisition basic Parameters
1. Gamma rays
2. Gamma cameras: components and systems
    a. Two Types of Tomography
3. Radiation Energy Considerations
    a. X-ray CT
    b. Nuclear Medicine
4. Detection: Interactions of high energy photons with matter
    a. Photoelectric effect
    b. Compton scattering
    c. Pair production
    d. Coherent (Rayleigh) scattering (typically ignore)
5. Attenuation
    a. Attenuation coefficients
    b. Mass attenuation coefficient μm
    c. Example Calculation
6. Inorganic scintillators
    a. Scintillation Detection
7. Gamma camera operation
    a. Gamma camera components
    b. Operation
8. Nuclear Medicine Imaging Systems
9. PMT calibration
10. Anger position network
11. Pulse height analyser
    a. Operating principle
    b. Operation
    c. Multiple-channel analyser (MCA)
    d. Thresholds
12. Detection window in context
    a. Peaks in pulse-height diagram
    b. Types of events
13. Gamma camera

a. Energy resolution
b. Detection efficiency
c. Terms contributing to the detection efficiency
d. Dead-time
- Paralysable
- Non-paralysable

e. Spatial resolution
f. Terms contributing to spatial resolution

14. Signal-to-noise ratio (CNR)
    a. Contrast and contrast-to-noise ratio
15. Digital Images
    a. The Structure of a Digital Image
    b. Pixel Bit Depth
    c. Eight-bit Pixel Depth
    d. The Effect of Bit Depth on the Image
    e. Pixel Size and Digital Image Detail
    f. Factors Affecting Pixel Size and Image Detail
    g. The Effect of Matrix Size on Pixel Size and Image Detail
    h. Image Matrix Size for the Different Imaging Modalities
    i. Effect of Field of View on Digital Image Detail
    j. The Numerical Size of a Digital Image
    k. Image Compression
    l. Position
16. PIXEL Correlation
    a. Resolution Size
    b. Other factors
    c. Determining the matrix size
    d. Determine the best imaging resolution for the system
17. Summarized
    a. Multiheaded gamma cameras
    b. Single photon emission computed tomography (SPECT)

IV. Nuclear Medicine Imaging Systems

1. Types of Scanners
2. Collmator
    a. Operating principle
    b. Collimator Blurring
    c. Energy Resolution
    d. Collimator design
        - Parallel-hole collimator
        - Converging collimator
        - Diverging collimator
        - Pinhole collimator
        - Slanthole collimator
        - Fan-beam collimator
3. Scintillator
    a. □□□(□□) characteristics
4. Photomultiplier Tubes (PMTs)
5. Scintillator and Photomultiplier Tube assemblies

V. Image Acquisition in Nuclear Medicine

1. Major imaging techniques
    a. Scintigraphy
    b. SPECT (Single Photon Emission Computed Tomography)
    c. PET (Positron Emission Tomography)

VI. SPECT Data Acquisition

1. Arc of Rotation
2. Imaging characteristics of SPECT
    a. Effects of depth in SPECT
    b. Background and its effect
    c. Noise
    d. Attenuation and scatter with 99mTc
    e. Patient motion
    f. Energy window
    g. Matrix size
        - Size of the matrix
        - Zoom
3. Image Formation
    a. Frame Mode
    b. List Mode
4. Dual Isotope Imaging
5. Sampling
6. Information Density
7. Static Studies
8. Whole-Body Imaging
9. Dynamic Studies
    a. Windowing
    b. Cine
10. Gated Acquisition
11. SPECT Acquisition
    a. Angular Samples
    b. Acquisition Time
    c. Rotation Mode
    d. Collimator Selection and Patient Setup
    e. Gated SPECT
    f. Whole body SPECT
    g. Preprocessing
12. Image Acquisition
    a. Peaking
    b. Multiple Energy Windows
13. Techniques to improve image quality post acquisitio

Part 2

Keywords: Nuclear Medicine Computer System, Image Acquisition, Cardiology, Bone scintigraphy, Brain perfusion, Hepatic and Splenic, Parathyroid, Bone Marrow Scan, CSF Leak, Esophageal Transit, Gastric Emptying, Gastroesophageal Reflux, MECKEL'S Diverticulum Study, Protein Loss, Salivogram, Lung Provision Scan, WBC Imaging, Tumor Scan, Renal TX or Native Kidney Scan, Example of Protocols

Objectives:

- Discuss Nuclear Medicine Computer System
- Define Image Acquisition in Cardiology, Bone scintigraphy, Brain perfusion, Hepatic and Splenic, Parathyroid, Bone Marrow Scan
- Review CSF Leak, Esophageal Transit, Gastric Emptying, Gastroesophageal Reflux, MECKEL'S Diverticulum Study, Protein Loss, Salivogram, Lung Provision Scan, WBC Imaging, Tumor Scan, Renal TX or Native Kidney Scan
- Explain Example of Protocols in university of wisconsin in USA

Content:

I. Nuclear Medicine Computer System

2. Components
   a. Camera head
   b. Interface
   c. Processing system
   d. Display
      - Monitors
      - Hardcopy
      - Labeling
      - Archive
      - Networks

II. Image Acquisition in Cardiology

1. Cardiology
   a. Dose
   b. Position
   c. SPECT imaging overall comments
2. Delay Time
3. Energy Windows
4. Collimator
5. Types of cameras: Detector head positioning
   a. Single headed system
   b. Dual headed system
6. Angular Sampling Range
7. Number of Projections
8. Orbit Type
9. Pixel Size
10. Acquisition Type
    a. ‘‘Step-and-shoot’’ method
    b. ‘‘Continuous’’ mode
11. Matrix
12. Acquisition Time
13. Gating
14. Acquisition parameters
15. Patient Protocols
    a. Same-day rest-stress Tc-99m acquisition
    b. Two-day stress Tc-99m acquisition
    c. Separate dual-isotope acquisition
    d. Stress/redistribution Tl-201 acquisition
    e. Stress/reinjection/redistribution Tl-201 acquisition

III. Bone scintigraphy

1. Bone scintigraphy
2. Radiopharmaceuticals and dose
3. Patient preparation
4. Imaging Procedure
5. Angiographic and early blood pool phase imaging
6. Delayed bone phase imaging

IV. Brain perfusion SPECT

18. Positioning of the patient
19. Imaging devices
20. Acquisition parameters
    a. Rotational radius
    b. Matrix

c. Angular sampling
d. Zoom
e. Acquisition mode
f. Total detected events
g. Total scan time

V. Hepatic and Splenic SPECT

1. Hepatic and Splenic SPECT
2. Radiopharmaceutical
   a. Liver–spleen imaging
   b. Liver blood pool imaging
   c. Hepatic artery perfusion imaging
   d. Splenic imaging
3. Image Acquisition
   a. Liver–spleen imaging
   b. Hepatic blood pool imaging
   c. Hepatic perfusion imaging
   d. Splenic imaging

VI. Parathyroid SPECT

1. Parathyroid SPECT
2. Radiopharmaceuticals
   a. 99mTc-sestamibi or 99mTc-tetrofosmin
   b. 99mTc-pertechnetate
3. Protocol/image acquisition
   a. Dual-phase 99mTc-sestamibi protocol
   b. SPECT protocols
   c. Dual-isotope 99mTc-sestamibi/99mTc-pertechnetate protocol
   d. Dual-isotope 99mTc-sestamibi/123I-iodide protocol

VII. Bone Marrow Scan

1. Radiopharmaceutical
2. Route of Administration
3. Patient Preparation
4. Equipment Setup
   a. Collimator
5. SPECT images
6. Patient Positioning
7. Procedure

VIII. CSF Leak

1. Patient Preparation
2. Radiopharmaceutical and Dose
3. Imaging Device
4. Imaging Procedure

IX. Esophageal Transit

1. Indications
2. Patient Preparation
3. Scheduling
4. Radiopharmaceutical and Dose
5. Imaging Device
6. Imaging Procedure

X. Gastric Emptying

1. Indications
2. Patient Preparation

3. Radiopharmaceutical and Dose
    a. Meal Includes
    b. Meal Preparation
    c. Alternate Meals Infants
    d. For Egg Allergy or Intolerance
4. Imaging Device
5. Data Acquisition
6. Imaging Proceduure
    a. Routine Adult/Child
    b. Infant

XI. Gastroesophageal Reflux

1. Indications
2. Patient Preparation
3. Imaging Device
    a. Gamma camera with LEHR collimation
4. Imaging Procedure
    a. Audults
    b. Infants

XII. MECKEL'S Diverticulum Study

1. Indications
2. Rationale
3. Patient Preparation
    a. In Infants
    b. Newborns
4. Scheduling
5. Radiopharmaceutical and Dose
6. Imaging Device
7. Imaging Procedure

XIII. Protein Loss

1. Indications
2. Patient Preparation
3. Scheduling
4. Radiopharmaceutical and Dose
    a. Preparation of Tc99m Dextran
5. Imaging Device
6. Imaging Procedure

XIV. Salivogram

1. Indications
2. Patient Preparation
3. Scheduling
4. Radiopharmaceutical and Dose
5. Imaging Device
6. Data Acquisition

XV. Lung Provision Scan

1. Indications
2. Patient Preparation
3. Scheduling
4. Radiopharmaceutical and Dose
5. Caution
6. Imaging Device
7. Imaging Procedure

XVI. WBC Imaging

1. Radiopharmaceutical
2. Equipment Setup:
   a. Collimator
   b. Computer setup
3. SPECT images
4. Patient Positioning
5. Procedure

XVII. Tumor Scan with Gallium

1. Indications
   a. Evaluations of tumors
   b. Ga-67 has proven useful in the management of patients with lymphoma
   c. Additional tumors that have been shown to be gallium-avid include
2. Radiopharmaceutical and Dose
3. Patient Preparation
4. Imaging Procedure
5. Data Acquisition
   a. Whole Body Imaging

XVIII. Relative GFR & ERPF: Renal TX or Native Kidney Scan

1. Indications
2. Patient Preparation
3. Scheduling
4. Radiopharmaceutical and Dose
5. Imaging Device
6. Acquisition Procedure
7. Imaging Procedure

XIX. Abscess Infection Imaging Procedure

14. Example of Protocols in university of wisconsin in USA

Lecture 12: SPECT Quality Control (120 minutes)

Keywords: Gamma camera, Scintillation camera, Anger camera, Quality Contol (QC), Quality Assurance (QA), Image Types, Analog and Digital Images, Binary digits (Bits), Image Compression, Collimator, Photomultiplier Tubes (PMT's), Gamma Camera Characteristics, General Definitions, Test Equipment Conditions and Results, Quality Control procedures, Visual Inspection, Background level measurement, Photopeak and window setting, Sensitivity Measurement, Count Rate Performance, Sensitivity, Spatial Resolution, Linearity, Whole body scan Resolution, Intrinsic spatial resolution and linearity, System spatial resolution and linearity, Detector Head Tilt, Centre of Rotation (COR), Detector Alignment, High Count Field Uniformity, Tomographic Resolution, Rotational Uniformity, Reconstruction Phantom Studies, Main Features, Reconstruction Phantom Studies, Centre of Rotation (COR) Offset (x), Image Alignment in Y for Multihead SPECT Systems, Data Reconstruction - Attenuation Correction, System Uniformity, System Planar Sensitivity, Detector Shielding, System Alignment, Correction Tables, General Gamma Camera QC, Documentation, Record Keeping and Action Thresholds

Objectives:

- Discuss what is it a Quality Control (QC) and Gamma Camera QC
- Gives some guidelines regarding possible procedures to follow for troubleshooting and problem solving

- Describe Image Types, Fundamental component of Gamma Camera and Gamma Camera Characteristics
- Review General Definitions
- Determine Test Equipment Conditions and Results
- List and Examples Quality Control procedures and System Uniformity
- Explain System Planar Sensitivity, Detector Shielding, System Alignment and Correction Tables
- Illustrate General Gamma Camera QC
- Define Documentation, Record Keeping and Action Thresholds

Content:

I. Introduction

1. NEMA (National Electrical Manufacturer Association)
2. IEC (International Electrotechnical Committee)

II. Quality Control (QC)

16. Definition
17. Quality Assurance (QA) and Quolity Control (QC)

III. Image Types

7. Analog and Digital Images
8. The Digital Advantage
   a. Functions of digital image
9. Analog Images
10. Human Digits
11. Comparing Human and Computer Digits
    a. Ten different digits
    b. Binary digits (Bits)
12. Writing Numbers in Bits
13. Range of Values for Numbers in Binary Form
14. Pixel Bit Depth
15. Eight-bit Pixel Depth
16. The Effect of Bit Depth on the Image
17. Pixel Size and Digital Image Detail
    a. Factors Affecting Pixel Size and Image Detail
    b. The Effect of Matrix Size on Pixel Size and Image Detail
18. Image Matrix Size for the Different Imaging Modalities
19. The Numerical Size of a Digital Image
20. Image Compression
    a. Lossless compression

IV. Gamma Camera

21. Definition
22. Fundamental components
    a. Sodium iodide crystal
    b. Array of photomultiplier tubes
    c. Collimator
    d. Computer
23. Scintillation Camera Function
24. Collimator
    a. Micro-cast Technology
    b. Micro-linear Technology
    c. Collimator Quality
25. Types of Collimator
    a. Parallel hole collimator
    b. Slanthole collimators
    c. Converging and Diverging Collimators

d. Fanbeam collimators
e. Pinhole collimators

26. Scintillation
    a. Scintillation Counter
27. Photomultiplier Tubes (PMT's)
    a. Pre-Amplifier
    b. Position logic circuit
28. Computer
    a. Analog to digital converter (ADC)
29. Gamma Camera Characteristics

V. General Definitions

4. Absolute linearity
5. Central Field of View (CFO)
6. Detector
7. Differential linearity
8. Differential uniformity
9. Digital resolution
10. Energy resolution
11. Energy window
12. Foldover
13. Full width at half maximum (FWHM)
14. Full width at tenth maximum (FWTM)
15. Integral uniformity
16. Input count rate
17. Intrinsic
18. Linear interpolation
19. Observed count rate
20. Photopeak
21. Pixel
22. Scatter
23. Sensitivity
24. Spatial Linearity
25. Spatial resolution
26. Spectrum
27. Standard deviation
28. System
29. Test pattern
30. Useful Field of View (UFOV)

VI. Test Equipment Conditions and Results

1. Source Holders and Test Fixtures
2. Radiation Sources
3. Test Conditions
4. Reporting

VII. Gamma Camera QC

1. System Description
2. System Components
    a. Collimator
    b. Detector
    c. Typically a NaI(Tl) crystal
    d. Multiple PM tubes
    e. Preamplifier
    f. Amplifier
    g. PHA
    h. X-, Y- positioning circuit

i. Display or recording device
3. Performance parameters
   a. Contrast resolution
   b. Contrast
   c. Matrix size and time per frame

VIII. Quality Control procedures

1. Visual Inspection
   a. Rationale
   b. Methodology
   c. Acceptable Performance
   d. Frequency
2. Background level measurement
   a. Rationale
   b. Methodology
   c. Acceptable Performance
   d. Frequency
3. Photopeak and window setting
   a. Rationale
   b. Methodology
   c. Acceptable Performance
   d. Frequency
4. Sensitivity Measurement
   a. Rationale
   b. Methodology
   c. Acceptable Performance
   d. Frequency
5. Count Rate Performance
6. Sensitivity
7. Spatial Resolution
   a. Methodology
   b. Intrinsic Spatial Resolution
      - Test Conditions
      - Test Equipment
      - Measurement Procedure
      - Calculations and Analysis
      - Reporting
   c. Extrinsic Spatial Resolution
8. Linearity
   a. Rationale
   b. Methodology
   c. Acceptable Performance
9. Whole body scan Resolution
   a. Rationale
   b. Methodology
   c. Acceptable Performance
10. Energy Resolution
    a. Intrinsic Energy Resolution
       - Test Conditions
       - Measurement Procedure
       - Calculations and Analysis
       - Reporting
    b. Example: Wrong energy setting — uniformity
    c. Example: QC tests — unstable energy window setting
11. Intrinsic spatial resolution and linearity
    a. Examples

12. System spatial resolution and linearity
    a. General comments
    b. Examples

IX. System Uniformity

1. Methodology
2. Intrinsic Flood Field Uniformity
    a. Test Conditions
    b. Test Equipment
    c. Measurement Procedure
    d. Calculations and Analysis
    e. Integral Uniformity
    f. Differential Uniformity
    g. Reporting
3. Extrinsic uniformity
4. Acceptable Performance
5. Uniformity – Quantification
6. Uniformity – Not so Good
7. Low to High Count Rate Intrinsic Floods
8. Pre-Assigned Action Levels
9. Correction Tables
10. Examples
    a. Symmetric energy window — 99mTc
    b. Symmetric 10%, 15% and 20% energy windows
    c. Symmetric energy window — defective linearity map
    d. Uniformity with and without a uniformity correction map
11. Asymmetric energy windows
    a. Poor PM tube balance and crystal hydration
    b. Out of balance PM tubes
    c. Crystal hydration
    d. ADC problem related to internal corrections
12. Different radionuclides and photon energies
    a. Exemple: Comparison of intrinsic uniformity for 99mTc, 201Tl, 67Ga and 131I on the same scintillation camera
13. Uniformity — quantification
    a. Exemple: Uniformity — 99mTc at different count densities
14. Corrections (linearity, energy, uniformity)
    a. Exemples:
        - Illustration of the effect of no linearity or energy corrections being applied
        - Comparison of images acquired with and without a uniformity correction map
        - Problems with linearity correction
15. Cracked crystal — puncture/impact
    a. Crystal hydration
    b. Examples
        - Uniformity — defective PM tube (new digital generation camera)
        - Faulty PM tube preamplifier
16. Collimator
    a. Exemples
        - Representative extrinsic flood field uniformity images — low, medium and high energy parallel hole collimators
        - Collimator septa and hole alignment assessed by a distant point source — low energy collimator problems
17. Artefacts arising from sources/phantoms
    a. Fillable flood sources
        - General comments
        - Exemples

b. Cobalt sheet sources
- General comments
- Exemples

X. SPECT Quality Control procedures

1. Detector Head Tilt
   a. Rationale
   b. Methodology
   c. Acceptable performance
   d. Frequency
2. Centre of Rotation (COR)
   a. Rationale
   b. Methodology
   c. Acceptable performance
   d. Frequency
3. Detector Alignment
   a. Rationale
   b. Methodology
   c. Acceptable performance
   d. Frequency
4. High Count Field Uniformity
   a. Rationale
   b. Methodology
   c. Acceptable performance
   d. Frequency
5. Tomographic Resolution
   a. Rationale
   b. Methodology
   c. Acceptable performance
   d. Frequency
6. Rotational Uniformity
   a. Rationale
   b. Methodology
   c. Acceptable performance
   d. Frequency
7. Reconstruction Phantom Studies
   a. Rationale
   b. Main Features
   c. Methodology
   d. Acceptable performance
   e. Frequency
8. SPECT Uniformity
   a. Exemples
      - No noise (perfect uniformity)
      - Non-uniformity at the centre of the axis of rotation
      - High and low (clinical) count density
      - Dual head SPECT — partial ring artefacts
9. Centre of Rotation (COR) Offset (x)
   b. Exemple: Simulations of a point source reconstructed with different COR offset errors
30. Image Alignment in Y for Multihead SPECT Systems
   a. Exemple: Dual head SPECT system — misalignment in Y
31. Data Reconstruction — Attenuation Correction
   a. Exemple: Comparison of a phantom without and with attenuation correction

XI. System Planar Sensitivity

1. Test Conditions

2. Test Equipment
3. Measurement Procedure
4. Calculations and Analysis
5. Reporting

XII. Detector Shielding

1. Test Conditions
2. Test Equipment
3. Measurement Procedure
4. Calculations and Analysis
5. Reporting

XIII. System Alignment

1. Test Conditions
2. Test Equipment
3. Measurement Procedure

XIV. Correction Tables

XV. General Gamma Camera QC

1. Duties of the Personnel for QC of Gamma Camera
2. Good Practice tests
    a. Visual Check of Energy Spectrum
    b. Background Activity Check
    c. Cine Review of SPECT Data
    d. Sinogram Review of Data
3. Daily QC Tests
    a. Low Count Extrinsic or Intrinsic Flood
    b. Visual Inspection of Collimators
4. Less Frequentt ESTS
    a. Resolution Phantoms
    b. Center of Rotation (COR) Test
5. Summary of SPECT QC Tests

XVI. Documentation, Record Keeping and Action Thresholds

Lecture 13: SPECT/CT Protocols (90 minutes)

Keywords: SPECT/CT scan, Single photon emission computed tomography (SPECT), Computed tomography (CT), Types of SPECT, Nuclear Medicine, Dual-Modality Imaging Systems, Early Development, Image Registration, Attenuation Correction, Patient Table Design, Imaging, Hardware, Reconstruction, Protocols, Acquisition protocols, Technical staffing, General Procedures, Cardiac Image, Quality Control, Sources of Error, Display errors, Modern SPECT/CT Systems

Objectives:

- Discuss what is a SPECT-CT scan
- Brief review basic science
- Describe dual-modality imaging systems and early development of SPECT/CT
- Review fundamentals of SPECT/CT and general architecture of SPECT/CT devices
- List SPECT/CT imaging (Hardware)
- Determine processing, suggested protocols for SPECT/CT and SPECT/CT acquisition protocols
- Discuss technical staffing for SPECT/CT
- Explain general Nuclear Medicine SPECT/CT procedures

- Illustrate cardiac SPECT/CT Image
- Define quality control
- Describe modern SPECT/CT systems

Content:

I. Introduction

1. CT
2. Nuclear Medicine
3. Definitions
   a. SPECT/CT
   b. SPECT
   c. SPECT/CT cascade (Adding specificity)

II. SPECT-CT scan

18. Definitions
    a. SPECT/CT scanner
    b. SPECT/CT registration
    c. SPECT/CT fusion
    d. The method of attenuation correction
19. SPECT and the SPECT/CT cascade
20. Single photon emission computed tomography (SPECT)
21. Computed tomography (CT)
22. Types of SPECT
    a. SPECT/low-doseCT
    b. SPECT/multi-slice spiral CT: Siemens Symbia T series
    c. SPECT/multi-slice spiral CT: Phillips Precedence
    d. SPECT/CT: Dedicated Cardiac Solid-state Ultrafast CZT Camera
23. Clinical SPECT/CT Devices

III. Basic Science

IV. Dual-Modality Imaging Systems

V. Early Development of SPECT/CT

VI. Fundamentals of SPECT/CT

1. Image Registration
2. Attenuation Correction
3. Patient Table Design

VII. General architecture of SPECT/CT devices

VIII. SPECT/CT Imaging (Hardware)

1. Additional Considerations for Introducing a New SPECT/ CT System
   a. Communication and Patient Monitoring Aids
   b. Patient Positioning Supports
   c. Environmental Noise
2. SPECT/CT Imaging
   a. Hawkeye (GE Healthcear)
   b. Precedence (Philips Healthcear)
   c. BrightView XCT (Philips Healthcear)
   d. Astonish (Philips Healthcear)
   e. Symbia T (Siemens Medical Solution USA)
3. SPECT/CT Imaging: Reconstruction
   a. Flash3D (Siemens Medical Solution USA)

4. Radiopharmaceutical

IX. Processing

5. SPECT reconstruction
6. CT reconstruction
7. Display

X. Suggested Protocols for SPECT/CT

4. CT Protocols for Inclusion in Noncardiac SPECT/CT Protocols
5. CT Protocols for Inclusion in Cardiac SPECT/CT Protocols

XI. SPECT/CT acquisition protocols

13. Image Acquisition
    e. Field of view, positioning, and preacquisition preparation
    f. Protocol for CT imaging
    g. Protocol for SPECT emission imaging

XII. Technical staffing for SPECT/CT

XIII. General Nuclear Medicine SPECT/CT Procedures

6. 131 I-Iodide SPECT/CT in thyroid cancer
7. Neural crest and adrenal tumours
8. 111 In-octreotide SPECT/CT for assessing neuroendocrine tumours
9. Lymphoscintigraphy
10. Skeletal scintigraphy for staging malignant disease
11. Skeletal SPECT/CT in orthopaedics
12. 201Tl-chloride in cerebral masses
13. 99m Tc-depreotide in solitary pulmonary nodules
14. SPECT/CT in the preoperative localization of parathyroid adenomas
15. SPECT/CT for diagnosing infection and inflammation

XIV. Cardiac SPECT/CT Image

6. Myocardial perfusion imaging — CT based attenuation correction
7. Cardiac SPECT/CT Image Display
8. Myocardial perfusion imaging — CT based attenuation correction
9. Cardiac SPECT/CTA for assessing the significance of coronary artery lesions
10. Added values of CT in patients with coronary artery disease
    a. Coronary artery calcium
    b. Coronary computed tomography angiography
    c. Pulmonary artery imaging in pulmonary embolism

XV. Quality Control

4. Equipment performance guidelines
5. Equipment quality control
6. Emergency procedures

XVI. Sources of Error

1. SPECT/CT Image Fusion Errors
    1. Movement in the interval between SPECT and CT data collection
    2. Attenuation artifacts
    3. Software misalignment of SPECT and CT data
2. Display errors
    b. Inadequate windowing of SPECT or CT data on fused images
    c. Inadequate windowing of SPECT or CT data when viewed separately
    d. Cursor misalignment on SPECT and CT images
    e. Inappropriate color table selection for SPECT data

XVII. Modern SPECT/CT Systems

XVIII. Additional Considerations for Introducing a New SPECT/ CT System

1. Patient Weight Capacity of Patient Imaging Pallet (Bed)
2. Minimum Height of the Patient Imaging Pallet (Bed)
3. Travel Length of the Patient Imaging Pallet (Bed)
4. Auto Contour and Positioning Optimization
5. Automated Collimator Con fi guration
6. Type of CT Unit
7. CT Tube Loading
8. Laser Positioning Lights
9. Automated Routine Quality Control Mode
10. Size of CT Patient Bore
11. Degree of Flexibility with the Gamma Camera Detectors
12. Integrated ECG Hardware Port and Output Display

XIX. BrightView X and XCT onerview and specifications (Philips)

1. Camera Characterictics
2. Patient table
3. JETStream acquistion
4. Total body
5. Emission tomography
6. Detector
7. Collimator
8. XCT perfomance
9. BrightView X and XCT detector speciffication 3/4" crystal
10. Collimators
11. Environmental requirements for general equipment location
12. Philips BrightView XCT with Astonish
    a. Astonish reconstruction
    b. Dose reduction capabilities

XX. Infinia Hawkeye Hybrid SPECT/CT

1. System Description
2. Clinical Applications
3. 3/8” Detector Characteristics
4. Infinia Detector Performance NEMA Specifications Summary
5. Gantry
6. Patient Table
7. Acquisition System Features
8. Acquisition Types
9. HawkeyeTM CT Technology
10. Real-Time Auto-Body Contouring
11. Power Requirements
12. Room Layout
13. Environment

XXI. Symbia T Series SPECT/CT

1. Best-in-Class CT
2. Flash Reconstruction
3. SMARTZOOM Collimation
4. Cardio-Centric Acquisition
5. Advanced Reconstruction
6. Low-Dose CT AC

7. WorkStream4D
8. Automated Workflow
9. Features
10. SPECT Specifications
11. CT System Hardware
12. Minimum Room Size

Lecture 14: SPECT Troubleshooting Artifacts (60 minutes)

Keywords: Artifact (error), Instrument and computer-related artifacts in nuclear medicine, Instrumentation errors, Energy Resolution, Collimator, Sources/phantoms, Cobalt sheet sources, Spatial Resolution and Linearity, Uniformity, Myocardial perfusion, Patient-based artifact, Patient motion, Image processing, Display, Gating, Cardiac, CT artifacts, Ring artifact, Noise, Beam hardening, Scatter, Metallic Materials, Out of field, Hardware-based artifacts, Helical and Multisection CT Artifacts, Temperature and humidity, PECT/CT Artifact,

Objectives:

- Discuss what is an artifact (error)
- Review instrument and computer-related artifacts in nuclear medicine
- Describe patient-based artifact
- Explain image processing and display artifacts
- Brief review gating artifacts and cardiac artifacts
- Define CT artifacts
- Illustrate SPECT/CT Artifact

Content:

I. Artifact (error)

1. Definition
2. Medical imaging
3. Medical electrophysiological monitoring

II. Introduction

4. Artifact groups
    a. camera dependent artifacts
    b. radiopharmaceutical dependent artifacts
    c. patient-related artifacts

III. Instrument and computer-related artifacts in nuclear medicine

24. Artifacts associated with instrumentation errors
    e. Flood field non-uniformity
    f. Center-of-rotation (COR) error
    g. Camera head tilt
    h. Detector-to-patient distance
25. Energy Resolution
    a. Static clinical study — energy peak shift — electrical grounding problem
    b. Dynamic clinical study — energy peak shift — electrical grounding problem
    c. Clinical study — unstable energy window setting
    d. Asymmetric energy window — crystal hydration
    e. Asymmetric energy window — malfunction of energy calibration
    f. Asymmetric energy window — ADC problem related to internal corrections
26. Collimator
    a. Collimator septa and hole alignment assessed by a distant point source low energy collimator problems
    b. Examples

- The hot artefacts were caused by the asymmetry of the 123I energy window over the 99mTc photopeak in the presence of 99mTc
- Asymmetric energy window — clinical example with 123I and 99mTc
- Uniformity — 201Tl, defective linearity correction — clinical images and uniformity
- Clinical bone scan — defective PM tube

27. Artefacts arising from sources/phantoms
    a. Fillable flood sources
        - Air bubble
        - Adherence of activity to the container at the filling site (algae)
28. Cobalt sheet sources
    a. New 57Co sheet source
    b. Intrinsic uniformity — geometry of point source and detector — source too close to detector
29. Spatial Resolution and Linearity
    a. Intrinsic spatial resolution influence of digital matrix size
30. SPECT uniformity
    a. Non-uniformity at the centre of the axis of rotation
    b. Single head SPECT — ring artefacts — real data
    c. Dual head SPECT — partial ring artefacts
    d. Dual head SPECT — partial ring artefacts — clinical study
    e. With and without uniformity correction — single head
31. Myocardial perfusion SPECT
    a. With and without uniformity correction
    b. Dual head system — line source — incorrect COR in one head
    c. FBP streak artefacts — hot organ activity outside of organ of interest

IV. Patient-based artifact

4. Patient motion
    a. Upward creep of heart
    b. Soft Tissue Artifact
    c. Lateral chest wall fat attenuation
    d. Soft tissue attenuation
    e. Breast Attenuation
    f. Overlying visceral activity
    g. Myocardial Hot spots
    h. Apical variants
    i. Liver Activity
    j. Bowel Activity
5. Errors in Selecting Oblique Cardiac Axes and Subsequent Polar Map

V. Image processing and display artifacts

1. Filtering
2. Adjacent subdiaphragmatic activity
3. Scatter
4. Ramp filter artifact
5. Improper selection of the apex and base for polar map reconstruction
6. Errors in axis reorientation
7. Inadequate image display
8. Left bundle-branch block (LBBB)
9. Left ventricular hypertrophy

VI. Gating artifacts

VII. Cardiac artifacts

VIII. CT artifacts

1. Ring artifact
2. Noise
3. Beam hardening and Scatter
4. Metal artifact
5. Out of field “artifact”
6. Patient-based artifacts
    a. Motion artifact and Transient interruption of contrast
    b. Metallic Materials
        - Avoidance of metal artifacts by the operator
        - Software corrections for metal artifacts
    c. Patient Motion
        - Avoidance of motion artifacts by the operator
        - Built-in features for minimizing motion artifacts
    d. Incomplete Projections
7. Physics-based artifacts
    a. Beam hardening
        - Cupping artifact
        - Streak and darks bands
        - Metal artifact/high-density foreign material artifact
    b. Correct streak artifacts
    c. Built-in features for minimizing beam hardening
        - Calibration correction
        - Beam hardening correction software
        - Avoidance of beam hardening by the operator
    d. Partial volume averaging
    e. Photon starvation
        - Automatic Tube Current Modulation
    f. Quantum mottle (noise)
    g. Aliasing in CT
8. Hardware-based artifacts
    a. Ring artifact
        - Avoidance and Software Corrections
    b. Tube arcing
    c. Out of field artifact
9. Helical and Multisection CT Artifacts
    a. Helical Artifacts in the Axial Plane: Single-Section Scanning
    b. Helical Artifacts in Multisection Scanning
    c. Cone Beam Effect
    d. Stair Step Artifacts
    e. Zebra Artifacts
10. Temperature and humidity

IX. PECT/CT Artifact

5. Artifacts on SPECT-CT Images
6. Causes of Artifacts on CT
7. Causes of Artifacts on SPECT/CT
8. Long Bones and Knees
9. Abdomen and Pelvis
10. Pitfalls in Radionuclide Bone Scintigraphy
    a. Artifacts on Radionuclide Planar Bone Scintigraphy
11. Cold Spots on a Bone Scan
12. Contamination
13. SPECT/CT Misregistration
14. Respiration During SPECT/CT
15. Arms Up or Down?
16. Highly Attenuating (Metal) Foreign Bodies or Contrast Agents

17. Patient Size and CT Noise
18. Limitations of the CT Scanner
19. Extraosseus Uptake on Bone Scintigraphy
20. Cardiac
21. Image Display
22. Image Interpretation and Reporting
23. Attenuation Correction and Artifacts: Artifacts of Soft Tissue Attenuation
24. Artifacts of Subdiaphragmatic Radiotracer Activity
25. Artifacts of Patient Motion
26. Artifacts of Misregistration
27. Effects of Normal Apical Thinning

Lecture 15: SPECT/CT Case Studies (60 minutes)

Keywords: Clinical Impact of SPECT/CT, Anatomical localisation, Overall impact, Lymphoma / Tumours, Infection imaging, Bone imaging, Neuroendocrine tumours, MIBG scintigraphy, Parathyroid imaging, Thyroid cancer, Lymphoscintigraphy, Cavernous haemangioma and liver lesions, Brain disorders, Infinia Hawkeye, Siemens, Philips, Advantages of Philips, Full Iterative Technology (FIT)

Objectives:

- Discuss clinical impact of SPECT/CT
- Case Studies of Infinia Hawkeye 4
- Case Studies of Siemens
- Case Studies of Philips

Content:

I. Clinical Impact of SPECT/CT

4. Anatomical localisation
5. Overall impact of SPECT/CT
6. Lymphoma / Tumours
7. Infection imaging
8. Bone imaging
9. Neuroendocrine tumours
10. MIBG scintigraphy
11. Parathyroid imaging
12. Thyroid cancer
13. Lymphoscintigraphy
14. Cavernous haemangioma and liver lesions
15. Brain disorders

II. Case Studies (Infinia Hawkeye 4)

5. SPECT/CT in bone scintigraphy
   a. Case 1
   b. Case 2
6. SPECT/CT in leukocyte scintigraphy
   a. Case 3
   b. Case 4
7. SPECT/CT in nuclear oncology

a. Case 5
b. Case 6
c. Case 7
d. Case 8
e. Case 9

8. SPECT/CT in nuclear cardiology
   a. Case 10
9. SPECT/CT in general nuclear medicine
   a. Case 11
   b. Case 12
   c. Case 13

III. Case Studies (Siemens)

32. Partial Vertebral Compression Defined by xSPECT Bone
    i. History
    j. Diagnosis
    k. Comments
    l. Conclusion
    m. Examination Protocol
33. Delineation of Femoral Lytic Lesions with xSPECT Bone in a Patient with Multiple Myeloma
    a. History
    b. Diagnosis
    c. Value of xSPECT Bone Imaging
    d. Examination Protocol
34. xSPECT Imaging in a Patient with Diffuse Skeletal Metastases: Quantification of tracer uptake within lumbar vertebrae
    a. History
    b. Examination Protocol
    c. Analysis
    d. Comments

IV. Case Studies (Philips)

10. Advantages of Philips BrightView XCT nuclear medicine system
    a. Registration confidence with CoPlanar
    b. Flexible breathing
    c. High resolution – low dose
    d. Nuclear medicine – tailored workflow
    e. Fits the nuclear medicine space
11. Full Iterative Technology (FIT)
12. Cardiology
    a. Trusted attenuation correction
    b. Cardiology case study
       - Inferior wall attenuation correction
       - Anterior wall attenuation correction
13. Oncology
    a. Low dose localization
    b. Neuroblastoma
    c. MAA mapping for radioembolization
    d. Carcinoma of the penis
    e. Post Lu-177 DOTA-TATE therapy
    f. Incidental pulmonary nodule
    g. Benign reactive lymph node
    h. Right breast mass
    i. Metastatic neuroblastoma
    j. Lymphoscintigraphy of the penis
    k. Sarcoma in pubic symphysis

l. Pheochromocytoma in adrenal nodule
m. Calcification of tibial-fibular ligament
n. Thyroid cancer
o. Neuroendocrine tumor of ilium
p. Melanoma at the right ear
q. Pheochromocytoma
r. Bilateral breast cancer
s. Left adrenal mass
t. Hemangioendothelioma
u. Sclerotic bony metastases
v. Multiple degenerative mutations of spine
w. Lung cancer evaluation for bone mets

14. Orthopedics
    a. Multiple fractures in Down's Syndrome patient
    b. Early pars stress fracture
    c. Scaphoid fracture
    d. Right foot pain
    e. Torus palatini
    f. Biceps enthesopathy
    g. Osteonecrosis
    h. Calcaneal fracture
    i. Cervical spine pain
    j. Sacroiliitis
    k. Guide facet block or medial branch block
    l. Stress fracture of tibia
    m. Pseudoarthrosis
    n. Atypical insufficiency fractures
15. Infection
    a. Pelvic graft infection
    b. Foot and shin ulcers
    c. Apophysitis verses Brodie's abscess
    d. Osteomyelitis with sequester
    e. Occult fracture
16. Other localization
    a. Pulmonary embolism
    b. Biliary leak
    c. Lung perfusion with unusual anatomy
    d. Venogram
    e. Hyperparathyroidism

V. Conclusion

➢ Module IV: Introduction to Nuclear Cardiology

Lecture 1: Introduction to Nuclear Cardiology (120 minutes)

Part 1

Keywords: Cardiovascular disease (CVD), Atherosclerosis, Nuclear cardiology, History, Human Serum Albumin, Scintillation camera, Technetium-99m, Coronary Arteries, Coronary Artery Disease (CAD), Nuclear Cardiology imaging, Cardiovascular System, Cardic Anatomy, Dextrocardia,

Dextroversion, Cardiac Function, Electrocardiogram, ECG, EKG, High blood pressure, Coronary artery disease, Stroke, Congestive heart failure, Congenital cardiovascular disorders, Chest pain, Bayes' Theorem, Risk Stratification, Coronary Syndromes, Pathophysiology, Cardiac SPECT, Positron Emission Tomography (PET), MUGA (Multiple Gated Acquisition) Scan, Radiopharmaceuticals, Basic ECG skills, Stress testing methods, Patient care, Interpersonal Communication Skills, Myocardial Imaging Agents, Blood Pool Imaging agents, Myocardial Necrosis, Nuclear Scintigraphy, Risk and Prognosis, Myocardial Perfusion, Cold-spot Markers, 201 Thallium Scintigraphy

Objectives:

- Discuss the history of nuclear cardiology
- Review the cardiovascular system: structure and function
- Describe indicators of cardiac function
- Define the cardiovascular disease: assessing the patient
- Understanding Risk Factors
- Explain types of nuclear cardiology imaging
- Review the cardiac SPECT imaging
- Discuss the guidelines for the nuclear medicine technologist
- Describe 201 Thallium Scintigraphy

Content:

I. Introduction

10. Background
11. Objective
12. Introduction
    a. Cardiovascular disease (CVD)
    b. Atherosclerosis
    c. Nuclear cardiology

II. The History of Nuclear Cardiology

36. Herman Blumgart (1927)
37. Georg de Hevesy
38. Werner Forssmann (1929)
39. Paul Hahn (1936)
40. Fein and Seligman
41. Storaasli and Human Serum Albumin (HSA)
42. Benedict Cassen and Rectilinear Scanner (1951)
43. Holter (1954)
44. Two Important Tools in Nuclear Medicine
    a. The "scintillation camera" by Hal Anger (1958)
    b. The commercial development of Technetium-99m (1960)
45. H.William Strauss (1973)
46. Elliot Lebowitz and 201-Thallium (1973)
47. Berger (1979)
48. Hal Anger
49. Today
    a. 15-O water
    b. 15N-ammonia
    c. 82-Rubidium
    d. 18F-deoxyglucose
50. Coronary Artery Disease (CAD)
51. Nuclear imaging

III. The Cardiovascular System: Structure and Function

5. Location and Size

6. Structure: Cardic Anatomy
    a. Pericardium
    b. Fibrous pericardium
    c. Serous pericardium
    d. Pericardial fluid
7. Heart Wall
8. Chambers
9. Circulation
    a. Heart Valves
    b. Atrioventricular valves
    c. Semilunar valves
10. Functions
    a. To deliver oxygen and essential nutriens
    b. To remove cellular waste products
11. Systole and Diastole
12. Heart Sounds

IV. Dextrocardia and Dextroversion

12. Definition
13. Three conditions characterized by dextrocardia
14. Dextrocardia and SPECT Imaging
15. SPECT Pκocessing

V. Coronary Arteries

1. The Coronary Arteries Supply Nutrients and Oxygen to the Myocardium
2. The Right Coronary Artery
3. The Left Coronary Artery
    a. The left anterior descending artery (LAD)
    b. The left circumflex (LCx)

VI. Indicators of Cardiac Function

1. Determination of Cardiac Output
2. Circulation Time and Shunting
3. Left Ventricular Ejection Fraction
4. Indicators of Function: Calculating Ventricular Volumes, Stroke Volumes, Cardiac Output and Cardiac Index Manually with the Routine Muga Scan
5. Worksheet
    a. Patient and Acquisition Data
    b. Left Ventricle
    c. Right Ventricle
    d. Calculations for LV
    e. Calculations for RV

VII. Electrocardiography

1. Electrocardiogram (“ECG”, “EKG”)
2. The Normal Electrocardiogram
3. Electrocardiographic Markers of Ischemia and Scar
    a. Coronary artery disease (CAD)
    b. Myocardial Ischemia (MI)
    c. Clinical manifestations of myocardial
    d. Ischemia Cascade and Stunting
    e. Electrical Changes
        - Prominent Q wave
        - ST-segment elevation
    f. Hibernating Myocardium
    g. Myocardial Infarction

h. Transmural Myocardial Infarction
i. Deadly Rhythms
- Ventricular Tachycardia
- Ventricular Fibrillation

4. Summing Up: Electrocardiogram in Myocardial Ischemia

VIII. Cardiovascular Disease: Assessing the Patient

1. Cardiovascular disease includes
   a. High blood pressure
   b. Coronary artery disease
   c. Stroke
   d. Congestive heart failure
   e. Congenital cardiovascular disorders
2. History and Physical, Laboratory Evaluation
3. Pretest Likelihood of Disease
   a. Three types of chest pain
      - Typical angina
      - Atypical chest pain
      - Non-anginal chest pain
      - Sensitivity
      - Specificity
      - Positive Predictive Value
      - Negative Predictive Value
4. Bayes' Theorem
   a. Sensitivity
   b. Specificity
   c. False Negative
   d. False Positive

IX. Risk Stratification, Coronary Syndromes, Pathophysiology

1. Risk Stratification
2. Soft events
3. Hard events
4. Pathophysiology
5. Coronary Syndromes
   a. Range
6. Understanding Risk Factors
   a. Diabetes
   b. Family history
   c. Age and gender
   d. Elevated serum cholesterol
   e. Hypertension
   f. Cigarette smoking
   g. Obesity
   h. Personality and lifestyle
7. Some common uses of the procedure

X. Types of Nuclear Cardiology Imaging

1. Cardiac SPECT (single photon emission computed tomography)
2. Positron Emission Tomography (PET)
3. MUGA (Multiple Gated Acquisition) Scan
4. SPECT
   a. Basic concept
   b. MPI Axis Views
   c. MPI images

XI. Cardiac SPECT Imaging

1. Steps to Successful SPECT Imaging
   a. Patient comfort
   b. A word about Claustrophobia
   c. Remember ‘cardiac creep’
   d. Processing software
   e. Acquisition Setup

XII. Guidelines for the Nuclear Medicine Technologist

1. The Nuclear Medicine Technologist working in nuclear cardiology must
2. Acquisition
3. Processing
4. Radiopharmaceuticals
   a. Myocardial perfusion agents
   b. 99m-Tc-labeled red blood cell imaging
   c. Myocardial infarct avid imaging
5. Anatomy and physiology
6. Basic ECG skills
7. Stress testing methods
   a. Physical (bicycle)
   b. Physical (treadmill)
   c. Pharmacological
8. Patient care
9. Interpersonal Communication Skills
10. Systems-based Practice
11. Professionalism
12. Practice based learning and improvement
13. Medical Knowledge
14. The Role of Radiopharmaceuticals in the Evaluation of Heart Function
    a. Myocardial Imaging Agents
       - “hot spot” infarct-avid agents
       - “cold spot” markers of hypoperfused tissue
    b. Blood Pool Imaging agents
       - tagged autologous red blood cells
       - radiolabeled microspheres
15. Imaging Myocardial Necrosis with Infarct-Avid agents
    a. 99mTc Pyrophosphate
    b. Indium-111-labeled antimyosin antibodies
16. Significance of Nuclear Scintigraphy with Respect to Risk and Prognosis
    a. Risk stratification and prognosis following MI
    b. Assessment of thrombolytic therapy
    c. Myocardial Viability
17. Myocardial Perfusion Imaging: Evaluation of Myocardial Function and Therapy
    a. Radiopharmaceuticals approved for myocardial perfusion imaging
    b. Historical Note
    c. Cold-spot Markers of Hypoperfused Tissue
       - 201-Thallous Chloride
       - c99m Sestamibi (Cardiolite)
       - Tc99m Tetrofosmin (Myoview)
       - Tc99m Teboroxime
       - Tc99m Noet
       - Mechanism of localization and pharmacokinetics
       - Tc99m Myocardial Perfusion Imaging Agents
18. Positron Emission Tomography (PET)
    a. Overview of Metabolic Imaging
    b. Advantages of PET

XIII. 201 Thallium Scintigraphy

1. Indications for Thallium Imaging
    a. Diagnosis of myocardial infarction
    b. Diagnosis of myocardial ischemia
    c. Risk stratification and prognosis following myocardial infarction
    d. Assessment of thrombolytic therapy
    e. Assessment of myocardial viability
2. Dose
3. Dynamic Equilibrium
4. Factors that contribute to the washout rate of Tl-201
5. Normal Appearance of the Thallium-201 Scintigram
6. Redistribution and Viability
7. Artifact and Limitations

Part 2

Keywords: Tc99m Myocardial Perfusion Imaging Agents, Nuclear cardiology imaging, Positron Emission Tomography Imaging, CAD (Coronary Artery Disease), Metabolic imaging, Clinical applications, Tracers of myocardial perfusion, Rubidium -82 Chloride, N-13 Ammonia, O-15 Water, Myocardial metabolism, Metabolic tracers, Assessment of Tissue Viability, Cardiac Blood Pool Imaging, Planar MUGA Scan, Multigated Blood Pool Imaging Technique, Patient Preparation, MUGA Processing Methods, Quantitative analysis, Volumetric Curves, MUGA Analysis Reports Page, Planar Cardiac Imaging, Cardiac SPECT Imaging, Image Acquisition, Patient protocols, Perfusion Cardiac SPECT, Risk Stratification, Artifacts

Objectives:

- Discuss Tc99m Myocardial Perfusion Imaging Agents
- Describe Positron Emission Tomography Imaging
- Review Multigated Blood Pool Imaging Technique of Cardiac Function
- Interpretation of Perfusion Cardiac Spect
- Explain Risk Stratification And Prediction of Prognosis

Content:

I. Tc99m Myocardial Perfusion Imaging Agents

13. Types of Imaging Agents
14. Characteristics
15. Sestamibi and Tetrofosmin
16. Tc99m Sestamibi (Cardiolite)
17. Tc99m Tetrofosmin (Myoview)
18. Tc99m Teboroxime
19. Tc99m-N-Noet
20. Types of Nuclear Cardiology Imaging

II. Positron Emission Tomography Imaging

52. Using PET to Treat CAD (Coronary Artery Disease)
    a. Evaluating myocardial viability
    b. Assessing potential for successful coronary revascularization
    c. Early diagnosis of atherosclerosis
53. Metabolic Imaging
54. Advantages of PET
55. Clinical Applications of PET in Cardiology

III. Tracers of Myocardial Perfusion (PET)

13. Groups

a. Tracers that are Only Partly Extracted by the Myocardium
   - Rubidium -82 Chloride
   - N-13 Ammonia
b. Tracers that are Freely Diffusible
   - O-15 Water

14. Myocardial Metabolism
15. Metabolic Tracers
16. Assessment of Tissue Viability (PET)
    a. Evaluation of Hypoperfused ischemic areas
    b. Detection of viable myocardium
       - Assess Function-Perfusion-Metabolism
       - Predict Recovery Post-Revascularization

IV. Cardiac Blood Pool Imaging

16. Radionuclide Ventricular Function Studies
    a. Multigated Blood Pool Imaging (MUGAScan)
    b. First Pass Ventricular Function Studies
17. Blood Pool Imaging Reveals
18. The Planar MUGA Scan
    a. Reasons for MUGA scans
       - Acute myocardial infarction
       - Evaluation following coronary bypass graft surgery (CABG)
       - Valvular heart disease
       - Cardiomyopathy
       - Pulmonary disease
       - Doxorubicin Cardiotoxicity

V. Multigated Blood Pool Imaging Technique

1. Radiopharmaceutical selection: Technetium-99m labeled red blood cell
2. Red Blood Cell Labeling Techniques
3. Patient Preparation
   a. Data Acquisition
   b. Positioning Images
4. MUGA Processing Methods
   a. Reporting Results
   b. Ejection Fraction
   c. Phase and Amplitude
5. Quantitative analysis
   a. Calculation of left ventricular ejection fraction
   b. Left and right ventricular stroke volume ratios,
   c. Cardiac output
   d. Ventricular volumes
   e. Rates of ventricular filling and emptying
6. Volumetric Curves
7. MUGA Analysis Reports Page

VI. Planar Cardiac Imaging

1. Planar Myocardial Perfusion Stress/Rest

VII. Cardiac SPECT Imaging

1. Steps to Successful SPECT Imaging
   a. Patient comfort
   b. A word about Claustrophobia
   c. Remember ‘cardiac creep’
   d. Processing software
   e. Acquisition Setup

2. SPECT Image Reconstruction
3. SPECT Image Reorientation
4. Processed Data Display: the Row Tomogram
5. Characteristic Appearance in the Normal Heart

VIII. Image Acquisition in Cardiology

1. Image Acquisition in Nuclear Medicine: Cardiology
    a. Dose
    b. Position
    c. SPECT imaging overall comments
    d. Delay Time
    e. Energy Windows
    f. Collimator
    g. Types of cameras: Detector head positioning
    h. Angular Sampling Range
    i. Number of Projections
    j. Orbit Type
    k. Pixel Size
    l. Acquisition Type
    m. Gating
    n. The Acquisition Parameters for Normal and Dextrocardia Patients
2. Patient protocols
    a. Same-day stress-rest Tc-99m acquisition
    b. Two-day stress Tc-99m acquisition
    c. Separate dual-isotope acquisition
    d. Stress/redistribution Tl-201 acquisition
    e. Stress/reinjection/redistribution Tl-201 acquisition

IX. Interpretation of Perfusion Cardiac SPECT

1. Nuclear Perfusion Imaging
    a. Processed Data Display: the Row Tomogram
    b. Characteristic Appearance in the Normal Heart
2. Coronary Territories
    a. The Left Anterior Descending artery
    b. The Right Coronary Artery
    c. The Left Circumflex Artery
3. Stress/Rest Myocardial Perfusion Exams Normal Scans
    a. Female Tl201 Norma
    b. Morbidly Obese Male
    c. Female Myoview Norma
    d. Normal Myoview, LBBB
4. Autoquant
5. Evaluation of Wall Motion and Thickening
6. Determination of LV Volumes and Ejection Fraction
7. Transient Ischemic Dilatation (TID)
8. Upper Limits of Normal Volumes and Ratios
9. Polar Map and LV Segmentation

X. Risk Stratification and Prediction of Prognosis

XI. Artifacts and Other Considerations

1. Patient-Related Artifacts: Motion Attenuation, Extracardiac Activity
2. What is Attenuation, and why is it a Problem?
3. Common Attenuation Problems
4. Gated SPECT vs Attenuation
5. Extacardiac Activity

Lecture 2: Cardiac Anomalies and Deformities (60 minutes)

Keywords: Developmental anomalies, Congenital Heart Defects, Heart Embryology, Dextrocardia, Coronary Arteries, Coronary Artery Disease (CAD), Indicators of Cardiac Function, Cardiac Output, Calculating, Routine MUGA Scan, Ventricular Volumes, Stroke Volumes Cardiac Output, Cardiac Index

Objectives:

- Discuss Developmental anomalies
- Describe the Congenital Heart Defects
- Review Heart Embryology
- Explain Dextrocardia
- Define Coronary Arteries
- Discuss Coronary artery disease and SPECT
- List of Indicators of Cardiac Function

Content:

I. Developmental anomalies

21. Definition

II. Congenital Heart Defects

III. Heart Embryology

17. Tube Formation
18. Looping
19. Atrial Septation
20. Outflow Tract Septation
21. Ventricular Septation
22. Rubella or Rubeola (measles) Virus defects
    a. Ventricular septal defect (VSD)
    b. Atrial septal defect (ASD)
    c. Defects in the arteries
23. Understanding the Heart

IV. Dextrocardia

19. Definition
20. Causes of Dextrocardia
21. Dextrocardia and Dextroversion
22. Dextrocardia and SPECT Imaging
    a. Case Report
23. Features of Dextrocardia

V. Coronary Arteries

1. The Coronary Arteries Supply Nutrients and Oxygen to the Myocardium
2. The Right and Left Coronary Arteries
3. Coronary Arteries Left circumflex (LCx)
4. Surface Vessels and End Arteries
5. Supply and Demand
6. Collateral Circulation
7. Myocardial Oxygen and Nutrient requirements
8. Low blood sodium levels (hyponatremia)
9. Increase or decrease in blood potassium levels (hyper- and hypokalemia)

10. Coronary Flow
11. Consequences of impaired blood flow to the conduction system
12. Coronary Artery Disease

VI. Coronary Artery Disease and SPECT

VII. Indicators of Cardiac Function

1. Determination of Cardiac Output
   a. Heart rate (HR)
   b. Stroke volume (SV)
2. Circulation Time and Shunting
3. Left Ventricular Ejection Fraction
4. Indicators of Functional: Calculating Ventricular Volumes, Stroke Volumes Cardiac Output and Cardiac Index Manually with the Routine MUGA Scan
   a. Patient and Acquisition Data
   b. Left Ventricle
   c. Right Ventricle
   d. Calculations for LV
   e. Calculations for RV

Lecture 3: Electrocardiography (90 minutes)

Keywords: Electrocardiography, Electrocardiogram, ECG, EKG, Electrochemical mechanism, Action potential, ECG paper, Electrodes and Electrocardiographic Leads, Electrode name, Electrode placement, Stress testing, Normal electrocardiogram, ECG complex, Sinus rhythm, Conduction system, Bradycardia, Tachycardia, Arrhythmia, Identification of arrhythmias, Premature atrial contraction (PAC), Atrial fibrillation, Atrial flutter, Supraventricular tachycardia, AV Block, Premature ventricular contraction, Deadly rhythms, Ventricular fibrillation, Electrocardiographic Markers, Ischemia, Scar, Myocardial Ischemia, Angina, Myocardial Infarction, Heart area label, Reducing artifact

Objectives:

- Discuss what Is electrocardiography
- Describe electrochemical mechanism and action potential
- Review ECG paper
- Explain electrodes and electrocardiographic leads
- Discuss detailed view of electrode placement for exercise stress testing
- Define the normal electrocardiogram
- Discuss the steps could identify arrhythmias on the ECG
- Review the electrocardiographic markers of ischemia and scar
- Explain reducing artifact

Content:

I. Electrocardiography

22. Electrocardiography
23. Electrocardiogram (ECG or EKG)
24. Why It Is Done

II. Electrochemical mechanism

1. What does the ECG register?
2. Electrical conduction system of the heart
3. The ECG represents the sum of the action potentials of millions of cardiomyocytes
4. Action Potential

a. This action potential entails a number of phases
   - Phase 4
   - Phase 0
   - Phase 1
   - Phase 3
   - Phase 3

III. ECG

24. ECG Paper

IV. Electrodes and Electrocardiographic Leads

24. Distinction between "Electrode" and "Lead"
25. Electrode Name and Electrode Placement

V. Detailed View Of Electrode Placement For Exercise Stress Testing

1. The Standard Limb (bipolar) Leads
   a. Limb leads: I, II, III (“bipolar leads”)
2. The Augmented Unipolar Leads
   a. Augmented leads: aVR, aVL, aVF (“unipolar leads”)
3. The Chest Leads
   a. Precordial leads: V1, V2, V3, V4, V5, V6 (“unipolar leads”)
4. The leads relate to the anatomy of the heart in the following way
   a. 1, aVR- right side of heart
   b. V2, V3, V4- transition between right and left sides of heart
   c. V5, V6, I, aVL- left side of heart
   d. II, III, aVF- inferior part of the heart
   e. Limb Leads
   f. Chest Leads

VI. The Normal Electrocardiogram

1. ECG Complex
   a. P wave
   b. PR Interval
   c. QRS complex
      - Q Wave
      - R Wave
      - S Wave
   d. ST segment
   e. T Wave
   f. QT Interval
   g. RR Interval
2. Sinus Rhythm
3. Conduction System
4. Sinus Bradycardia
5. Sinus Tachycardia
6. Sinus Arrhythmia
7. Normal Duration Times for the 3 Waves
   a. The P-R Interval
   b. Regularity
   c. The U Wave

VII. Identification of Arrhythmias

1. Arrhythmias can be identified on the ECG by following these steps
   a. Calculate the heart rate
   b. Examine the P wave
   c. Measure the PR interval

d. Measure the QRS complex
2. Normal sinus rhythm
3. Sinus bradycardia
4. Sinus tachycardia
5. Premature atrial contraction (PAC)
6. Atrial fibrillation
7. Atrial flutter
8. Supraventricular Tachycardia
9. First-degree AV Block
10. Second-degree AV Block (Wenckebach Mobitz Type I)
11. Second-degree AV Block (Mobitz Type II)
12. Third-degree AV Block with Ventricular Pacemaker
13. Premature Ventricular Contraction
14. Deadly Rhythms
15. Ventricular Fibrillation

VIII. Electrocardiographic Markers of Ischemia and Scar

1. Myocardial Ischemia
2. T wave abnormalities
3. Electrocardiogram ST segment changes
4. Impairment of Conduction
5. Ischemia Cascade and Stunning
6. Electrical Changes
7. Prominent Q wave
8. ST-segment elevation
9. Angina
   a. Silent angina (or silent ischemia)
10. Hibernating Myocardium
11. Transmural Myocardial Infarction
12. Deadly Rhythms
    a. S-T Changes
    b. S-T Elevation and Depression
13. Myocardial Infarction
    a. Q-wave MI
    b. Non Q-wave MI
14. Summing Up: ECG in MI

IX. ECG and heart area label

1. Contiguity of leads
   a. Inferior leads
   b. Lateral leads
   c. Septal leads
   d. Anterior leads

X. Looking for Ischemia / Angina on an ECG

XI. Reducing Artifact

1. Patient Positioning
2. Electrode Application

Lecture 4: Cardiovascular Diseases and Stress Testing (90 minutes)

Keywords: Cardiovascular Diseases (CVD), Symptoms, History, Laboratory Evaluation, Risk Factors, Non-modifiable Risk Factors, Modifiable Risk Factors, Pretest Likelihood of Disease, Chest

pain, Angina, Bayes Theorem, Risk Stratification, Soft events, Hard events, Percutaneous coronary intervention (PCI), Coronary artery bypass grafting (CABG), Myocardial infarction (MI), Cardiac death, Coronary Syndromes, Acute Coronary Syndrome (ACS), Pathophysiology, Atherosclerosis, Normal Artery Wall, Fatty Streak, Vulnerable Plaque, Stable Plaque, Plaque Rupture, Trombosis, Occlusion, Coronary Artery Disease, Ischemia, Biochemical Markers, Cardiac Stress Testing, ExerciseTreadmill Test, Noninvasive cardiac procedures, Pharmacologic Stress Agents, Cardiac Medications, Noninvasive Approach, Invasive Approach

Objectives:

- Discuss what is cardiovascular diseases
- Review the history and physical, laboratory evaluation
- Describe Risk Factors of CVD
- Explain pretest likelihood of disease
- Define the risk stratification
- Discuss what is Coronary Syndromes, Angina and Myocardial Infarction (MI)
- Review radionuclide imaging in acute coronary syndromes
- Review intrinsic myocardial pathology
- Describe atherosclerosis and risk factors of atherosclerosis
- Explain Cardiac Stress Testing: Exercise Treadmill Test
- Explain Cardiac Stress Testing: Pharmacologic Stress Agents
- Overview of cardiac medications

Content:

I. Cardiovascular Diseases (CVD)

25. Definition
26. Cardiovascular disease includes
    a. High blood pressure
    b. Coronary artery disease
    c. Stroke
    d. Congestive heart failure
    e. Congenital cardiovascular disorders
27. Spectrum of Cardiovascular Disease
    a. Vascular
    b. Cardiac
28. Symptoms of Cardiovascular Diseases

II. History and Physical, Laboratory Evaluation

III. Risk Factors Of CVD

25. Non-modifiable Risk Factors
    a. Increasing age
    b. Gender
    c. Genetic factors
    d. Racial and ethnic background
26. Modifiable Risk Factors
    a. Smoking second-hand smoke
    b. Abnormal blood lipids
    c. Hypertension
    d. Diabetes mellitus
    e. Abdominal obesity
    f. Psychosocial factors
    g. Lifestyle
    h. Other factors

IV. Pretest Likelihood of Disease

26. Types of chest pain

a. Tipical angina (definite)
b. Atypical angina (probable)
c. Noncardiac chest pain

27. Angina (Chest Pain)
    a. Sensitivity, specificity, and other terms
        - True positive
        - False positive
        - True negative
        - False negative
        - Positive predictive value (PPV)
        - Negative predictive value (NPV)
        - Sensitivity
        - Specificity
28. Bayes Theorem
    a. Sensitivity
    b. Specificity
    c. False Negative
    d. False Positive
29. Complementary Diagnostic Imaging Modalities

V. Risk Stratification

5. Definition
6. Soft events
    a. Percutaneous coronary intervention (PCI)
    b. Coronary artery bypass grafting (CABG)
7. Hard events
    a. Myocardial infarction
    b. Cardiac death
8. ACC/AHA/ACP-ASIM guidelines describe a patient's risk as a function of the following factors

VI. Coronary Syndromes

1. Acute Coronary Syndrome (ACS)
2. The Causes Acute Coronary Syndrome
    a. Coronary atherosclerosis
    b. ST elevation myocardial infarction
    c. Non ST elevation myocardial infarction
    d. Unstable angina
3. Angina
    a. Angina Pectoris (Stable Angina) - Effort Angina
    b. Unstable Angina - Crescendo angina
    c. Less common kinds of angina
        - Variant angina
        - Microvascular angina
        - Atypical angina
4. Myocardial Infarction (MI)
    a. Heart Attack
    b. Non–ST-segment elevation myocardial infarction (NSTEMI)
    c. ST-segment elevation myocardial infarction (STEMI)
    d. Pathophysiologically, NSTEMI is somewhat different from STEMI
    e. Congestive heart failure (CHF)
5. Radionuclide Imaging In Acute Coronary Syndromes
6. Summing Up Coronary Syndromes
7. Pathophysiology: Consequences of Disease
8. Intrinsic myocardial pathology

VII. Atherosclerosis

1. Normal Artery Wall
2. Fatty Streak
3. Vulnerable Plaque
4. Stable Plaque
5. Plaque Rupture
6. Trombosis
7. Occlusion
8. Coronary Artery Disease
9. The development of ischemia depends upon the
10. The three major clinical manifestations of myocardial ischemia are
    a. Angina pectoris
    b. Myocardial infarction
    c. Sudden cardiac death
11. Understanding Risk Factors
    a. Diabetes
    b. Family history
    c. Age and gender
    d. Elevated serum cholesterol
    e. Hypertension
    f. Cigarette smoking
    g. Obesity
    h. Personality and lifestyle

VIII. Ischemia

1. The main determinants of myocardial oxygen demand in the ischemic heart include
    a. Contractile state of the myocardium
    b. Heart rate
    c. Tension of the myocardial wall

IX. Angina Pectoris

1. The major features of the anginal process
    a. Site
    b. Character
    c. Duration
    d. Exertion
2. Myocardial infarction (MI)

X. Biochemical Markers of Myocardial Infarction

1. Laboratory Evaluation
2. Biochemical Markers
    a. Total creatine kinase (CK)
    b. Creatine kinase isoenzyme (CK-MB)
    c. Lactate dehydrogenase (LDH)
    d. Troponin T and I
    e. Myoglobin

XI. Cardiac Stress Testing: ExerciseTreadmill Test

1. Noninvasive cardiac procedures for the diagnosis of coronary artery disease include
    a. Electrocardiography
    b. Radiography
    c. Echocardiography
    d. Nuclear Imaging
    e. Positron Emission Tomography (PET)
2. Stress Electrocardiography
3. Indications and Clinical Value

4. Contraindications and Precautions
    a. Absolute contraindications to stress testing
    b. Relative contraindications to exercise testing
    c. Special considerations
5. Rationale and Procedure
6. Equipment
7. Preparation
8. Monitoring
9. Performance
10. The test is terminated when any of the following occur
11. Interpretation

XII. Cardiac Stress Testing: Pharmacologic Stress Agents

1. The Role of Pharmaceuticals in the Evaluation of Heart Disease
2. Mechanism of action of coronary vasodilators. ADP, Adenosine diphosphate; AMP, adenosine monophosphate; ATP, adenosine triphosphate; AV,natrioventricular; and cAMP, cyclicadenosine monophosphate
3. IV Dobutamine
4. IV Dipyridamole (Persantine)
5. IV Lexiscan (Regadenoson)
    a. Contraindications to Regadenoson include
6. Side effects to Pharmacologic Vasodilation
7. IV Aminophylline as an Antidote to Vasodilation

XIII. An Overview Of Cardiac Medications

1. The Noninvasive Approach
    a. Antilipemic Agents
    b. Antidysrhythmic Agents
    c. Antianginal Agents
    d. Beta-adrenergic blockers
    e. Calcium channel blockers
    f. Nicardipin, Bepridil
    g. Antifailure agents
2. The Invasive Approach
    a. Percutaneous Transluminal Coronary Angioplasty (PTCA)
    b. Atherectomy
    c. Intracoronary Stents
    d. Transmyocardial Revascularization (TMR)
    e. Coronary Artery Bypass Graft Surgery

Lecture 5: Quantitation (90 minutes)

Part 1

Keywords: Myocardial perfusion imaging (MPI), Stunned myocardium, Myocardial ischemia, Hibernating myocardium, Myocardial infarct, Single photon emission tomography (SPECT), SPECT Imaging, Patient comfort, Claustrophobia, Radiotracers, Protocols, Acquisition, Quality control, Processing Protocols, Processing Errors, Artifactual defect, Designation of Left Ventricular Segments

Objectives:

- Discuss the Myocardial perfusion imaging
- Review single photon emission tomography (SPECT)
- Define steps to successful SPECT imaging
- Describe modern clinical systems

- Explain designation of left ventricular segments

Content:

I. Myocardial perfusion imaging

29. Myocardial perfusion scan (MPI)
30. Terminology
    a. Stunned myocardium
    b. Myocardial ischemia
    c. Hibernating myocardium
    d. Myocardial infarct

II. Single photon emission tomography (SPECT)

1. Underlying Principles of SPECT
2. Modern Clinical Systems
    a. Digirad Cardius 3 XPO
    b. CardiArc (Canton, MI)
    c. Spectrum Dynamics
3. Instrumentation Quality Assurance and Performance
4. Detectors
5. Scintillation camera (anger camera)
6. Semiconductor/solid-state detectors
7. Energy Resolution
8. Spatial Resolution
9. Detector Sensitivity
10. Count Rate Limitations
11. Collimation
    a. Typical performance parameters for low-energy (\150 keV) collimators
12. System Design
13. Multi-purpose SPECT
14. Dedicated cardiac
15. Patient configuration
16. QC Procedures

III. Steps to Successful SPECT Imaging

1. Patient comfort
    a. A word about Claustrophobia
2. Radiotracers and Protocols
3. Tc-99m-Labeled Tracers

a. Mechanism of action

4. Imaging Protocols
    a. Tracer-specific imaging times
    b. Two-day protocol
    c. One-day protocols
    d. Dose
    e. Tl-201, Mechanism of action
    f. Patient protocol
5. Acquisition
    a. Position
    b. Delay Time
    c. Energy Windows
    d. Collimator
    e. Angular Sampling Range
    f. Number of Projections
    g. Orbit Type
    h. Pixel Size

i. Acquisition Type
j. Matrix
k. Gating
l. Cine review
m. Cardiac Gating Parameters

6. Quality control
   a. Counting statistics
   b. Tracer biodistribution
   c. Patient motion
   d. Soft tissue attenuation
   e. Interposition of metallic objects
   f. Position of subdiaphragmatic organs
   g. Extracardiac abnormal areas of focal increased or decreased uptake
   h. Missing projections
   i. Acquisition zoom
   j. Position of the arms
   k. Truncation of the heart in some projections
   l. Raw SPECT image data
   m. Motion correction
7. Processing Protocols
   a. Image reconstruction
   b. Filtering
   c. Filtered back projection
   d. Iterative reconstruction
8. Reorientation
   a. Image display
   b. Reconstructed images
9. Processing Errors
   a. Artifactual defect
   b. Normalization
   c. Reconstruction and Review Basics: Volume Data
   d. Display
      - Cine review
      - Study review

IV. Cardic SPECT Imaging: Designation of Left Ventricular Segments

30. Short Axis Slices (Mid Ventricle)
31. Horizontal Long Slice (Mid Ventricle)
32. Examples
    a. 4DM software and Polar map with defective point
    b. Stress only data in 4DM software and Polar map with defective point
    c. Perfusion defect in the LAD, LCX and RCA territories
    d. Polar map,, thickness, motion and Perfusion defect in the LAD, LCX and RCA territories
    e. Segments Image + Raw data
    f. Segments Image + Scoring
    g. Polar map, perfusion , wall thickness and wall motion
    h. LV and RV curve and count calcuation
    i. Quantitative perfusion scan processing
    j. Quantitative perfusion scan and reversibility

Part 2

Keywords: Cardiac SPECT, Row Tomograms, Display, SPECT Imaging, Technical Sources of Error, Ventricular dilation, Lung uptake, Right ventricular uptake, Non cardiac findings, Perfusion defect location, Five-points model, Perfusion defect, Gated Myocardial Perfusion, Transient

ischaemic dilation (TID), Myocardial Viability, Reporting of SPECT, Myocardial Perfusion Scan Results, Transmission-Based Attenuation Correction, Attenuation, Scatter Correction, Resolution Recovery, Reconstruction, Filtering Methods, Extracardiac Activity, Initial/Post Clearance, MPI Reports, 123I-mIBG imaging protocols, Acquisition setup for 123I-mIBG

Objectives:

- Discuss Interpretation and Reporting
- Review Transmission-Based Attenuation Correction for Cardiac SPECT
- Describe Cardiac Iodine-123 metaiodobenzylguanidine (123I-mIBG) Imaging
- Explain Acquisition setup for 123I-mIBG

Content:

I. Interpretation and Reporting

31. Row Tomograms
32. Display
    a. Recommended medium for display
33. Conventional slice display of SPECT images
    a. Three sets of tomographic images
    b. Three-dimensional display
34. Evaluation of the Images for Technical Sources of Error
    a. Patient motion
    b. Attenuation and attenuation correction
    c. Reconstruction artifacts
    d. Myocardial statistics
35. Ventricular dilation
36. Lung uptake
37. Right ventricular uptake
38. Non cardiac findings
39. Perfusion defect location
    a. The five-point model
40. Perfusion defect severity and extent
    a. Quantification
    b. Perfusion defect severity
    c. Summed scores
    d. Polar maps
    e. Bull's Eye Polar Maps
    f. Qualitative
    g. Semiquantitative
    h. Perfusion defect size
    i. Quantitative
    j. 3-D images and quantitative analysis
    k. Reversibility
41. Gated Myocardial Perfusion SPECT
    a. Gated Display
    b. Gated Quality Control
    c. Gated SPECT
    d. LVEF
    e. Regional LV function
    f. LV volumes
    g. Gated Images
    h. Transient ischaemic dilation (TID)
        - TID of the LV
        - Lung-to-heart ratio (LHR)
        - Overall image quality
        - Right ventricular (RV) uptake

i. Left ventricular ejection fraction and volume
j. Integration of perfusion and function results

42. Myocardial Viability
    a. Qualitative assessment
    b. Semiquantitative assessment
43. Reporting of SPECT Myocardial Perfusion Scan Results
    a. Principles of reporting
    b. Components of SPECT myocardial perfusion imaging reports
        - Subject information
        - Type of study
        - Date
        - Referring clinician
        - Indication for study
        - ECG findings
        - Summary of stress data
        - Overall study quality
        - Results - perfusion
        - Results - function
        - Conclusions - general
        - Conclusions - diagnosis and prognosis of CAD

II. Transmission-Based Attenuation Correction for Cardiac SPECT

1. What is Attenuation, and Why is it a Problem?
2. Common Attenuation Problems
3. Scatter Correction and Resolution Recovery
4. Reconstruction and Filtering Methods
5. Gated SPECT vs Attenuation
6. Extracardiac Activity
    a. Hot Bowel Effect
    b. Lung uptake
    c. RV tracer uptake
7. Initial/Post Clearance

III. General information

1. Information about the laboratory and study date
    a. Name of referring physician and contact information
    b. Patient demographics
        - Name
        - Age and sex
        - ID number
        - Nstitution
        - Contact information (telephone number, address)
2. Clinical background
    a. Clinical reason for test
    b. Clinical history
3. Methods
    a. MPI protocol
        - Imaging position
        - Stress protocol
    b. Stress ECG changes
    c. Perfusion (rest and stress 99mTc perfusion imaging)
    d. Ventricular function

IV. Examples of MPI Reports

V. Cardiac Iodine-123 metaiodobenzylguanidine (123I-mIBG) Imaging

1. Mechanism of action
2. 123I-mIBG imaging protocols

VI. Acquisition setup for 123I-mIBG

VII. Steps to Successful SPECT Imaging

1. Indications
2. Procedure
    a. Performing cardiac 123ImIBG imaging
    b. Tracer Administration
    c. Adverse Reactions
    d. Imaging Techniques

Lecture 6: MUGA SPECT (60 minutes)

Keywords: Cardiac Blood Pool Imaging, MUltiple Gated Acquisition (MUGA) Scan, Gated Blood Pool Exam (ERNA), LVG (left ventricular gated) function scan, Ventricular Function Studies, Equilibrium radionuclide angiography, Radionuclide ventriculography, Congestive heart failure (CHF), Patient Instructions, Radiopharmaceuticals, 99mTc-labelled erythrocytes (red blood cells, RBC), 99mTc-labelled human serum albumin (HSA), Position and Acquisition, First-pass radionuclide ventriculography, Planar equilibrium radionuclide ventriculography, Tomographic equilibrium radionuclide ventriculography, Right Ventricular Ejection Fraction

Objectives:

- Discuss the Cardiac Blood Pool Imaging and What is a MUGA SCAN
- Review Common Indications
- Describe Patient Instructions
- Review Radiopharmaceuticals
- Explain Position and Acquisition
- Discuss the Right Ventricular Ejection Fraction

Content:

I. Cardiac Blood Pool Imaging

44. History
45. Background Information and Definitions
46. Purpose
47. Radionuclide ventricular function studies can be broadly divided into two types
    a. Multigated Blood Pool Imaging
        - MUltiple Gated Acquisition (MUGA) Scan
        - Gated Blood Pool Exam (ERNA)
        - LVG (left ventricular gated) function scan
    b. First Pass Ventricular Function Studies
48. The Radionuclide Angiogram
49. The Planar MUGA Scan
    a. Gated Cardiac Blood Pool exams have a variety of names
        - MUGA - multigated acquisition
        - ERNA - equilibrium radionuclide angiography
        - RNV and RVG - radionuclide ventriculography
    b. The reasons for Routine MUGA Scans
        - Acute myocardial infarction
        - Coronary artery disease

- Evaluation following coronary bypass graft surgery (CABG)
- Valvular heart disease
- Cardiomyopathy
- Pulmonary disease
- Doxorubicin Cardiotoxicity

II. Introduction

1. The ACC/AHA/ASNC classifications
   a. Class I
   b. Class II
   c. Class III
2. Levels of evidence for individual class
3. The most important indications
4. Prognosis after acute MI with ST elevation
5. Heart failure: diagnosis and prognosis
6. Sub-populations without coronary disease

III. Common Indications

1. Parameters obtained from RVG include
   a. Global ventricular systolic function
   b. Regional wall motion
   c. Ventricular volumes (qualitative or quantitative)
   d. Responses of above parameters to exercise or other interventions
   e. Systolic and diastolic function indices
   f. Stroke volume ratios
2. Common clinical settings in which RVG may be useful
   a. Known or suspected coronary artery disease (CAD)
   b. To help distinguish systolic from diastolic causes of congestive heart failure (CHF)
   c. Evaluation of cardiac function in patients undergoing chemotherapy
   b. Assessment of ventricular function in patients with valvular heart disease

IV. Patient Instructions

1. Examination Time
2. Rest
3. Exercise
4. Information Pertinent to Performing the Procedure
5. Precautions

V. Radiopharmaceuticals: Dosimetry

1. Introduction
   a. 99mTc-labelled erythrocytes (red blood cells, RBC)
   b. 99mTc-labelled human serum albumin (HSA)
   c. First-pass (FP) radionuclide ventriculography (RNV)
2. Pre-tinning
3. Red blood cells (RBCs)
4. Labelling
   a. In vivo
   b. In vitro
   c. Calculate labelling efficiency
5. Overdosage
6. The 99mTc-pertechnetate or 99mTc-labelled RBCs
   a. Administered activity
   b. Drug interactions
   c. Radiation dosimetry
      - Pregnancy
      - Breast feeding

7. 99mTc-labelled HSA
    a. Administered activity
    b. Drug interactions and side effects
    c. Radiation dosimetry
        - Pregnancy
        - Breast feeding
8. Other radiopharmaceuticals
9. Formulation Problems with Tagged RBC'S

VI. Position and Acquisition (First-pass radionuclide ventriculography)

1. Functional, radionuclide cardiac studies include several techniques
    a. FP radionuclide angiography (FPRNV)
    b. Equilibrium radionuclide angiography (ERNV)
    c. Gated myocardial perfusion scintigraphy (MPS)
    d. Gated cardiac PET and FDG metabolic imaging
    e. Non-imaging techniques
2. First-pass radionuclide ventriculography
3. Image acquisition
4. Collimator
5. Acquisition protocol
6. Quality control

VII. Position and Acquisition (Planar equilibrium radionuclide ventriculography)

1. Acquisition parameters
2. Stress studies
    a. Stress types

VIII. Position and Acquisition (Tomographic equilibrium radionuclide ventriculography)

1. Patient Positioning
2. Procedure
3. Imaging field of view
4. Radionuclide ventriculography with non-imaging systems
5. Data registration
6. Quality control
7. Summary

IX. Right Ventricular Ejection Fraction

33. Introduction
34. First-pass study
    a. Processing
    b. Interpretation
35. Equilibrium radionuclide ventriculography
36. Tomographic radionuclide ventriculography
37. Summary

Lecture 7: Patient Care and Emergency Procedures (60 minutes)

Keywords: Patient care, Assessment, Assessment questions, Side effects from chemotherapies, Infection control, Patient record, Laboratory Values, Routes of Administration, Injection Technique, Diabetic Patient, Emergency Care, Pediatric Considerations

Objectives:

- Discuss Patient Assessment
- Review Infection Control
- Overview Patient Record

- Explain Laboratory Values and Point of Care Testing
- Review Routes of Administration and Injection Technique
- Discuss the Diabetic Patient: Care, Complications, Education, and Emergencies in PET
- Discuss Emergency Care
- Describe Pediatric Considerations

Content:

I. Assessment

50. Example of Assessment Questions for General Patient Care
51. General Survey of Attributes
52. Key factors and ranges
    a. Blood Pressure
        - Common Errors Associated With Inaccurate Blood Pressure Measurements
    b. Temperature
    c. Pulse
        - Factors Affecting Pulse Rate
    d. Respiration
53. Side Effects From Commonly Used Chemotherapies

II. Infection Control

III. The Patient Record

1. Common Prescriptions Seen in Patient Undergoind PET: a Brief Encounter With Medication Reconciliation
    a. Antiarrhythmics
    b. ACE inhibitors
    c. Acetylsalicylic acid
    d. Adenosine
    e. Aminophylline and theophylline
    f. Analgesics
    g. Anticoagulants
    h. Antiemetics
    i. Benzodiazepines
    j. Beta-blockers
    k. Calcium channel blockers
    l. Cholesterol-lowering medications
    m. Dexamethasone
    n. Dipyridamole
    o. Diuretics
    p. Nicotinic acid

IV. Laboratory Values at a Glance

1. Representative CBC Parameters With Some Sample Normal Ranges

V. Point of Care Testing

VI. Routes of Administration

1. 5 Rights of Drug Administration
2. Review of IV Injection Technique

VII. The Diabetic Patient: Care, Complications, Education, and Emergencies in PET

1. Types of Diabetes Mellitus
2. Molecular structure of D-glucose
3. Normal Glucose Ranges
4. Some Common Types of Insulin

VIII. Emergency Care

IX. Pediatric Considerations

X. Additional Reading

Lecture 8: EKG Theory (90 minutes)

Keywords: EKG, Heart, Cardiac conduction system, Cardiac testing, Rhythm, Rate, P wave, P-R interval, QRS interval, QRS complex, ST segment, T wave, U wave, Q-T duration, EKG equipment, Standardization, 12-lead EKG, Cardiac Axis, Myocardial infarction (MI), Interpretation

Objectives:

- Discuss the Basics of EKG
- Explain Interpretation of Results
- Review Clinical Pearls
- Describe Practice Recognition

Content:

I. The Normal Conduction System

II. Heart

1. Three Layes
    a. Endocardium
    b. Myocardium
    c. Epicardium
2. Four Chambers
    a. Right Atria
    b. Right Ventricle
    c. Left Atria
    d. Left Ventricle
3. Cardiac Conduction System
4. Evaluating Modalities in Cardiac Testing
    a. Modality
        - ECG
        - Echocardiogram
        - Radionuclide tracer (thallium/technetium)
    b. Stressing Modality
        - Treadmill
        - Dobutamine
        - Adenosine or dipyridamole (with nuclear imaging)

III. EKG

1. Features to examine and assess systematically
    a. Rhythm
    b. Rate
    c. P wave
    d. P-R interval
    e. QRS interval
    f. QRS complex
    g. ST segment

h. T wave
i. U wave
j. Q-T duration

2. EKG equipment
3. Standardization
4. 12-lead EKG

IV. Cardiac Axis

1. Cardiac axis
   a. Right axis deviation
   b. Left axis deviation
2. Rhythm
3. Rate
4. P wave
5. P-R interval
6. QRS complex
7. ST segment
8. T wave
9. QT segment
10. U wave

V. Myocardial infarction (MI)

1. Symptoms
2. Changing pattern of ECG
   a. Within minute
   b. Within hours
   c. After 24-48 hours
   d. After weeks
   e. ECG
3. Lead Placement
4. All Limb Leads
5. Precordial Leads
6. EKG Distributions
7. Waveforms

VI. Interpretation

1. Rate
   a. Differential Diagnosis of Tachycardia
   b. What is the heart rate?
2. Rhythm (including intervals and blocks)
   a. Sinus
   b. Normal sinus rhythm
   c. Normal Intervals
   d. Prolonged QT
   e. Blocks
   f. Exercises: What is this rhythm?
3. Axis
   a. The Quadrant Approach
   b. Exercise: What is the axis?
4. Hypertrophy
5. Ischemia
   a. Elevation - Acute infarction
   b. Depression - Ischemia
6. What is the diagnosis?
7. What do you see in this EKG?
8. Normal Sinus Rhythm
9. First Degree Heart Block

10. Accelerated Idioventricular
11. Junctional Rhythm
12. Hyperkalemia
13. Wellen's Sign
14. Brugada Syndrome
15. Premature Atrial Contractions
16. Atrial Flutter with Variable Block
17. Torsades de Pointes
18. Digitalis
19. Lateral MI
20. Inferolateral MI
21. Anterolateral / Inferior Ischemia
22. Left Bundle Branch Block
23. Right Bundle Branch Block
24. First Degree Heart Block, Mobitz Type I (Wenckebach)
25. Supraventricular Tachycardia
26. Right Ventricular Myocardial Infarction
27. Ventricular Tachycardia
28. Prolonged QT
29. Second Degree Heart Block, Mobitz Type II
30. Acute Pulmonary Embolism
31. Wolff-Parkinson-White Syndrome
32. Hypokalemia
33. 12-Lead EKG Interpretaation Checklist

Lecture 9: Cardiac Emergencies Response and Equipment (90 minutes)

Part 1

Keywords: Cardiovascular Diseases (CVD), High blood pressure, Coronary artery disease, Stroke, Congestive heart failure, Congenital cardiovascular disorders, Cardic Anatomy, Cardiovascular System Structure, Cardiovascular System Function, Electrical Conduction System of the Heart, Heart Wall, Chambers, Circulatory System, Systole, Diastole, Heart Sounds, Cardiac Output, Nerve Supply, Risk Factors, Pretest Likelihood of Disease, Chest Pain, Bayes' Theorem, Risk Stratification, Angina, Angina Pectoris, Myocardial infarction (MI), Congestive heart failure (CHF), Radionuclide Imaging, Radionuclide Imaging, Atherosclerosis, Ischemia

Objectives:
- Discuss Cardiovascular Diseases
- Describe the Cardiovascular System: Structure and Function
- Review Nerve Supply
- Explain Circulatory System
- Discuss Risk Factors of CVD
- Review Pretest Likelihood of Disease
- Overview Angina
- Describe Myocardial infarction (MI)
- Explain Atherosclerosis and Ischemia

Content:

I. Purpose/Goals

II. Introduction

54. Cardiac compromise
55. Cardiovascular emergencies

III. Cardiovascular Diseases (CVD)

1. Definition
2. Cardiovascular Disease Includes
   a. High blood pressure
   b. Coronary artery disease
   c. Stroke
   d. Congestive heart failure
   e. Congenital cardiovascular disorders
3. Spectrum of Cardiovascular Disease
   a. Vascular
   b. Cardiac
4. Symptoms of Cardiovascular Diseases

IV. The Cardiovascular System: Structure and Function

1. Anatomy
   a. Thoracic Cavity
   b. Structures
   c. Arteries and Veins
   d. Coronary Arteries
2. Location and Size
3. Structure: Cardic Anatomy
   a. Pericardium
   b. Fibrous pericardium
   c. Serous pericardium
   d. Pericardial fluid
4. Electrical Conduction System of the Heart
   a. What controls the timing of your heartbeat?
   b. How does the heart's electrical system work?
   c. How does the heart's electrical system regulate your heart rate?
   d. What makes your heart rate speed up or slow down?
   e. How does your body control your heart rate?
   f. Sympathetic and parasympathetic nervous systems
5. Heart Wall
6. Chambers
7. Circulation
   a. Heart Valves
   b. Atrioventricular valves
   c. Semilunar valves
8. Functions
   a. To deliver oxygen and essential nutriens
   b. To remove cellular waste products
9. Systole and Diastole
10. Heart Sounds
11. Cardiac Output

V. Nerve Supply

VI. Circulatory System

1. Main Types of Blood Vessels
   a. Arteries
   b. Capillaries
   c. Veins
2. Blood Composition
   a. Red blood cells

b. White blood cells
c. Plasma
d. Platelets

VII. Risk Factors of CVD

1. Non-modifiable risk factors
   a. Increasing age
   b. Gender
   c. Genetic factors
   d. Racial and ethnic background
2. Modifiable risk factors
   a. Smoking and second-hand smoke
   b. Abnormal blood lipids
   c. Hypertension
   d. Diabetes mellitus
   e. Abdominal obesity
   f. Psychosocial factors
   g. Low physical activity level
   h. Poor fruit/vegetable consumption
   i. Poor alcohol consumption

VIII. Pretest Likelihood of Disease

1. Three Types of Chest Pain
   a. Typical angina
   b. Atypical chest pain
   c. Non-anginal chest pain
2. Sensitivity, Specificity, and Other Terms
3. Bayes' Theorem
   a. Sensitivity
   b. Specificity
   c. False Negative
   d. False Positive
4. Complementary Diagnostic Imaging Modalities
5. Risk Stratification
   a. Soft events
   b. Hard events
   c. ACC/AHA/ACP-ASIM guidelines
6. Coronary Syndromes
   a. Acute coronary syndrome (ACS)
   b. Causes of coronary syndrome

IX. Angina

1. Definition
2. Angina Pectoris (Stable Angina)
3. Unstable Angina
4. Less Common Kinds of Angina
   a. Variant angina
   b. Microvascular angina
   c. Atypical angina

X. Myocardial infarction (MI)

1. Congestive heart failure (CHF)
2. Radionuclide Imaging in Acute Coronary Syndromes
3. Summing Up Coronary Syndromes
4. Pathophysiology: Consequences of Disease
5. Intrinsic myocardial pathology

XI. Atherosclerosis

1. Definition
2. Normal Artery Wall
3. Fatty Streak
4. Vulnerable Plaque
5. Stable Plaque
6. Plaque Rupture
7. Trombosis
8. Occlusion
9. Coronary Artery Disease
10. The development of ischemia
11. The three major clinical manifestations of myocardial ischemia
    a. Angina pectoris
    b. Myocardial infarction
    c. Sudden cardiac death
12. Understanding Risk Factors
    a. Diabetes
    b. Family history
    c. Age and gender
    d. Elevated serum cholesterol
    e. Hypertension
    f. Cigarette smoking
    g. Obesity
    h. Personality and lifestyle

XII. Ischemia

1. The main determinants of myocardial oxygen demand in the ischemic heart include
    a. Contractile state of the myocardium
    b. Heart rate
    c. Tension of the myocardial wall

XIII. Angina Pectoris

1. The major features of the anginal process
    a. Site
    b. Character
    c. Duration
    d. Exertion

Part 2

Keywords: Cardiac Emergency, Heart Attack Warning Signs, Simptoms, Typesof Cardiovascular emergencies, Basic Life Support (BLS), Advanced Life Support (ALS), Emergency Medical Technicians-Basic (EMT-B), ABCDE approach, Crash Cart, Crash Cart Equipments, Organizing a Crash Cart, Medicinein Crash Cart, ABC (medicine)

Objectives:

- Discuss Cardiac Emergency: Sign and Symptoms
- Describe Typesof Cardiovascular emergencies
- Review Basic life support
- Discuss Crash cart
- List Crash cart equipments
- Describe Medicine in crash cart
- Explain ABC (medicine)

Content:

I. Cardiac Emergency: Sign and Symptoms

56. Heart Attack Warning Signs
    a. His and Hers Simptoms
    b. Anxiety
    c. Chest Pain
    d. Chest Discomfort
    e. Cough
    f. Syncope (loss of consciousness)
    g. Dizziness
    h. Fatigue
    i. Nausea or Lack of Appetite
    j. Pain In Other Parts of the Body
    k. Rapid or Irregular Pulse
    l. Palpitations
    m. Shortness of Breath
    n. Symptoms Dyspnoea (difficulty in breathing)
    o. Sweating
    p. Swelling
    q. Weakness
57. Signs of Cardiac Emergency

II. Typesof Cardiovascular emergencies

1. Atherosclerosis
    a. Pathophysiology
    b. Causes
2. Acute Coronary Syndrome (ACS)
3. Angina Pectoris
    a. Pathophysiology
    b. Symptoms
    c. Emergency Medical care
4. Acute Myocardial Infarction (AMI)
    a. Symptoms
    b. Females, Diabetics and Elderly
    c. Emergency Medical Care
5. Aortic Aneurysm
    a. Definition
    b. Symptoms
    c. Emergency Medical Treatment
6. Aortic Distention
    a. Definition
    b. Symptoms
    c. Emergency Medical Treatment
7. Heart failure
    a. Definition
    b. Left Ventricular failure (Pathophysiology)
    c. Right Ventricular failure (Pathophysiology)
    d. Cardiogenic Shock
    e. Symptoms
    f. Emergency Medical Treatment
8. Hypertensive Emergencies
    a. Primary Hypertension: idiopathic
    b. Secondary hypertension
    c. Emergency Medical Care

d. Symptoms
9. Congenital heart disease
10. Cardiac Arrest
    a. Causes
    b. Difference between a heart attack and cardiac arrest

III. Basic Life Support (BLS)

1. Basic Life Support (BLS)
    a. Definition
    b. Advanced Life Support (ALS)
2. United States
    a. Emergency Medical Technicians-Basic (EMT-B)
3. The ABCDE approach
    a. Definition
        - Airway
        - Breathing
        - Circulation
        - Disability
        - Exposure
    b. The aims of the ABCDE approach
    c. Which patients need ABCDE?
    d. ABCDE principles

IV. Crash Cart

1. Crash Cart or Code Cart, or "MAX cart"
2. History in the United States
3. Why a Crash Cart?
4. Who needs a crash cart?

V. Crash Cart Equipments

1. Defibrillation
    a. Automated external defibrillator (AED)
    b. Mechanism of operation
    c. Self-adhesive electrodes
    d. Placement
2. Portable Ventilator
    a. Description
    b. Features
3. Suction in Airway Management
    a. Role of Suction in Airway Management
4. Bag valve mask
    a. Mask
    b. Bag and valve
    c. Method of operation
5. Stethoscope
6. Tongue depressor
7. Laryngoscope

VI. Organizing a Crash Cart (Medicinein Crash Cart)

1. Top of the crash cart
2. First drawer
    a. The common set of first drawer medications

58. Pediatric medications
59. Dopamine
60. Sodium Bicarbonate
61. Atropine

62. Atropine
63. Glycopyrrolate
64. Calcium Chloride
65. Lidocaine
66. Dexmethasone Injectable
67. Heparin
68. Vasopressin
69. Amiodarnone VF
70. Adenosine
    a. Antiarrhythmic agent
    b. Dosage
    c. Contraindications
    d. Side effects
71. Third drawer
    a. Adult Intubation Materials
    b. Pediatric Intubation Materials
72. Fourth drawer
    a. Intravenous lines
    b. Contents
73. Procedure drawer
74. Right Side of Cart
75. Left Side of Adult Cart
76. Maintenance
77. Conclusion

VII. ABC (medicine)

1. Airway, Breathing, and Circulation - ABC
2. The ABCDE approach
    a. Underlying principles
    b. First steps
3. A – Airway
    a. Give oxygen at high concentration
4. Basic Life Support
    a. Introduction
    b. Inspection
    c. Preparation
    d. Airway Assessment
    e. Airway Intervention
        - Maintain the airway
        - Anaphylaxis
5. B - Breathing
    a. Breathing Assessment
        - Observations
        - Examination (Inspect, Feel, Percuss, Auscultate)
    b. Artificial Breathing (Mouth to Mouth Respiration)
    c. The steps of Artificial Breathing
    d. Breathing Investigations/Procedures
        - ABG
        - Chest X-Ray
        - Oxygen
        - Acute severe asthma
        - Acute exacerbation of COPD
        - Other

i. C – Circulation: is the circulation sufficient?
    a. Circulation Assessment
        - Observations

- Examination
- Auscultate
- Fluid output

b. Circulation Investigations/Procedures
- Cannulation
- Bloods and blood cultures
- ECG
- Bladder scan
- Urine pregnancy test
- Other cultures/swabs
- Fluid output/catheterization

ii. D – Disability: what is the level of consciousness?
   a. The AVPU method

iii. Next Steps
   a. Take a history
   b. Review
   c. Document
   d. Discuss
   e. Handover

Part 3

Keywords: Chain of Survival, Cardiopulmonary resuscitation (CPR), Automated External Defibrillator, CPR methods, Chest Compressions, Cardiovascular Emergencies and uses of Drugs, Cardiac Arrest, Beta-Adrenergic Antagonist Overdose, Rapid Sequence Intubation, Cardiogenic Shock, Coronary Pain Syndromes, Stable angina, Unstable angina, Myocardial infarction, Cardiac Arrhythmias, Bradyarrhythmias, Acute Pulmonary Oedema, Hypertensive Emergency, Hypoglycaemia, Emergency Parenteral Drugs, Acute Hospital Care

Objectives:
- Discuss Chain of Survival
- Explain Cardiopulmonary resuscitation (CPR)
- Describe Cardiovascular Emergencies and uses of Drugs
- Review Emergency Parenteral Drugs List (adudults dose only)
- Overview Acute Hospital Care

Content:

I. Chain of Survival

1. The Chain of Survival Concept
2. The Links in the Chain of Survival
   a. Early Access
   b. Early CPR
   c. Early Defibrillation
      - Using an Automated External Defibrillator
   d. Early Advanced Care

II. Cardiopulmonary resuscitation (CPR)

78. Definition
79. Description
   a. Unconsciousness
   b. Not breathing
   c. No pulse detected
80. Automated External Defibrillator: Jump-Starting the Heart

81. CPR methods
    a. Standard CPR
    b. Compression only CPR
82. Opening an Airway in an Adult
83. Performing Chest Compressions in an Adult
84. Performing Chest Compressions in a Child
85. Performing CPR on a baby
    a. Compressions: Restore blood circulation
    b. Airway: Clear the airway
    c. Breathing: Breathe for the baby
86. Performing Chest Compressions in an Infant or a Child
87. Prone CPR / Reverse CPR
88. Pregnancy
89. Precautions
90. Normal results

III. Cardiovascular Emergencies and uses of Drugs

1. Cardiac Arrest
    a. Basic cardiac life support (BCLS)
    b. Advanced cardiac life support (ACLS)
2. Types of Cardiac Arrest Rhythms
    a. Pulseless ventricular tachycardia or ventricular fibrillation (VF)
    b. Asystole or severe bradycardia
    c. Pulseless ventricular activity (formerly called electromechanical dissociation [EMD])
        - Tension pneumothorax
        - Hypovolaemia
        - Hyperkalaemia or metabolic acidosis
        - Hypocalcaemia (Calcium channel blocker overdose)
        - Cardiac tamponade
        - Toxins, poisons, drugs
        - Thrombosis – pulmonary or coronary
3. Beta-Adrenergic Antagonist Overdose
4. Rapid Sequence Intubation
    a. Pre-oxygenation
    b. Preparation
    c. Sedation
    d. Cricoid pressure
    e. Paralysis
    f. Intubation
    g. Maintenance of sedation and paralysis
5. Cardiogenic Shock
    a. Definition
    b. Maintain airway and breathing
    c. Optimise intravascular volume
    d. Inotropic agents
        - In adults
        - In children
6. Coronary Pain Syndromes
    a. Stable angina
        - Acute attack
        - Subsequent treatment
        - Use of glyceryl trinitrate as prophylaxis
        - Refractory stable angina
    b. Unstable angina
7. Myocardial infarction
    a. Immediate management

b. Limiting infarct size
    - Streptokinase
c. Management in the post-infarct period
    - Beta-blockers
    - Angiotensin converting enzyme inhibitors (ACEIs)

8. Cardiac Arrhythmias
    a. Causes of cardiac arrhythmias
    b. Aims of treatment
    c. Tachyarrhythmias
        - Atrial tachyarrhythmias
        - Ventricular arrhythmias
9. Bradyarrhythmias
    a. Sinus bradycardia
    b. Atrioventricular block
        - Wenckebach phenomenon (Mobitz type I)
        - Mobitz type II
        - Third degree heart block
        - Sinoatrial block and sick sinus syndrome
10. Acute Pulmonary Oedema
    a. Maintain airway and give oxygen
    b. Positioning
    c. Bronchodilators
    d. Morphine
    e. Vasodilators
    f. Diuretics
    g. Inotropes
11. Hypertensive Emergency
12. Hypoglycaemia

IV. Emergency Parenteral Drugs List (Audults Dose Only)

1. Table of Abbreviations and Definitions

V. Acute Hospital Care – Adult

1. Airway and Breathing
2. Circulation
3. Other Items
4. Cardiac Arrest and Peri-Arrest Drugs for intravenous use
5. Other Drugs

➢ Module V: Introduction to Molecular Cardiology

Lecture 1: Cardiac PET Guidelines (60 minutes)

Part 1

Keywords: PET, PET/CT, PET/MR, Myocardial perfusion, Metabolic imaging, Perfusion Imaging, Diagnosis, Risk Stratification, Instrumentation, Quality Control (QC) Procedures, Acquisition, Cardiac Stress Testing

Objectives:

- Discuss Indications and Contraindications

- Review PET, PET/CT and PET/MR Instrumentation
- Describe PET and PET/CT or PET/MR Imaging Quality Control
- Explain PET Acquisition and Processing Parameters
- Discuss PET Myocardial Perfusion Imaging
- Define Cardiac Stress Testing Pharmacologic Stress Agents

Content:

I. Introduction

91. Common radiation exposure in millisievert based on testing modality

II. Indications and Contraindications

56. Indications and contraindications for the clinical use of PET myocardial perfusion and metabolic imaging
57. Advantages and disadvantages of cardiac PET compared to cardiac SPECT
58. Diagnosis and Risk Stratification
    a. Cardiac PET

III. PET, PET/CT and PET/MR Instrumentation

27. PET Imaging Systems
    a. 2-D Mode
    b. 3-Dimensional (3D) or «septa-out»
28. PET Imaging: Crystal Types
29. PET Time-of-Flight (TOF) Imaging
30. Hybrid PET/CT and PET/MR Cameras
31. PET Imaging: Attenuation Correction

IV. PET and PET/CT or PET/MR Imaging QC

38. PET Quality Control (QC) Procedures
    a. Acceptance testing
    b. Daily QC scan
    c. Sensitivity
    d. Spatial resolution
    e. Accuracy of attenuation correction and overall clinical image quality
    f. Variations among manufacturers
39. CT QC Procedures
    a. Calibration
    b. Field uniformity
40. Combined PET/CT QC Procedures
    a. Registration
    b. Attenuation correction accuracy
41. PET-MR QC Procedure

V. PET Acquisition and Processing Parameters

1. Patient Positioning
2. Dose Considerations
3. Total Counts
4. Pixel Size
5. Imaging Mode (Static, Gated, or Dynamic)
6. Image Reconstruction
7. Attenuation Correction
   a. General guidelines for CT-based transmission PET imaging

VI. PET Myocardial Perfusion Imaging

1. The goal of evaluating myocardial perfusion with PET imaging
2. Patient Preparation

3. Cardiac Stress Testing
4. 82Rb Perfusion Imaging
    a. Tracer properties
    b. Dosimetry
    c. Scout scanning
    d. Imaging parameters
5. 82Rb Perfusion Imaging “Imaging parameters”
6. 13N-Ammonia Perfusion Imaging
    a. Dosimetry
    b. Acquisition parameters
    c. Dose
7. Non-FDA-Approved Myocardial Perfusion Agents
8. Sample PET protocols adapted from the American Society of Nuclear Cardiology

VII. Cardiac Stress Testing: Pharmacologic Stress Agents

1. The Role of Pharmaceuticals in the Evaluation of Heart Disease
2. Mechanism of action of coronary vasodilators. ADP, Adenosine diphosphate; AMP, adenosine monophosphate; ATP, adenosine triphosphate; AV,natrioventricular; and cAMP, cyclicadenosine monophosphate
3. IV Dobutamine
4. IV Dipyridamole (Persantine)
5. IV Adenosine (Adenocine)
6. IV Lexiscan (Regadenoson)
    a. Contraindications to Regadenoson include
7. Side effects to Pharmacologic Vasodilation
8. IV Aminophylline as an Antidote to Vasodilation

Part 2

Keywords: Polar Map Display, 3D Display, Normalization, Technical Errors, Image Analysis, Interpretation of PET Images, Perfusion Data, Glucose Metabolism, 18F-FDG, Tracer dosimetry, Viable myocardium, Glucose utilization, Inflammation, Infection, Cardiac Sarcoidosis, Cardiovascular Device Infections, Myocardial Perfusion, Myocardial viability study, Sarcoidosis/infection study

Objectives:

- Discuss about Image Display, Normalization, and Evaluation for Technical Errors
- Review Interpretation of PET Perfusion Data
- Explain PET Imaging of Glucose Metabolism
- Describe Detection of Inflammation and Infection
- Discuss Reporting of Myocardial Perfusion and Metabolism PET Studies
- Review Image Description and Interpretation

Content:

I. Image Display, Normalization, and Evaluation for Technical Errors

1. Standard Segmentation and Polar Map Display
2. 3D Display
3. Recommended Medium for Display
4. Image Evaluation for Technical Sources of Errors
    a. Patient motion
    b. Reconstruction artifacts
    c. Image count statistics
5. Image Analysis and Interpretation of PET Images
    a. LV and RV size
    b. Lung uptake

c. RV uptake
d. Blood pool activity
e. Extra-cardiac findings
f. Normal variants

II. Interpretation of PET Perfusion Data

1. Perfusion defect location, severity, and extent
2. Qualitative scoring
3. Semiquantitative scoring system
4. Absolute quantification of myocardial blood flow
5. Gated PET images

III. PET Imaging of Glucose Metabolism

1. 18F-FDG PET imaging
2. Glucose Metabolism
   a. Cardiac Myocyte
   b. Pro-inflammatory Cells
3. 18F-FDG metabolic imaging
4. Tracer dosimetry
5. Detection of viable myocardium
   a. Study protocol
   b. Patient preparation
   c. Diabetic patients
   d. Acquisition parameters
   e. Dose
   f. Scan start time and duration
   g. Assessment of myocardial viability
   h. Comparison of myocardial metabolism to perfusion
   i. Special considerations for combining SPECT perfusion with PET metabolism images
6. Absolute myocardial glucose utilization
7. Integration of perfusion and metabolism Results
8. Interpretation of 18F-FDG images when images have not been obtained

IV. Detection of Inflammation and Infection

1. Assessment of Cardiac Sarcoidosis
2. Study protocol
3. Patient preparation
   a. Methods to suppress glucose utilization by normal myocardium
4. 18F-FDG acquisition parameters
5. Dose
6. Scan start time and duration
7. Interpretation of cardiac inflammation
   a. Sarcoidosis
8. Assessment of Cardiovascular Device Infections

V. Reporting of Myocardial Perfusion and Metabolism PET Studies

1. Patient Information
2. Indication for Study
3. History and Key Clinical Findings
4. Type of Study
5. Summary of Stress Data
6. Summary of Clinical Laboratory Data and Dietary State
7. Image Description and Interpretation
   a. Perfusion

VI. Image Description and Interpretation

1. Metabolism for Myocardial Viability, Sarcoidosis, and Cardiovascular Infection
    a. 18F-FDG myocardial viability study
    b. 18F-FDG sarcoidosis/infection study
    c. Final interpretation

Lecture 2: PET/MR Cardiology (90 minutes)

Keywords: Circulatory system, Cardiovascular system, Vascular system, Heart Anatomy, Magnetic resonance imaging (MRI), Heart MRI, MRI scanner, Gadolinium Contrast Medium, Cardiovascular Magnetic Resonance (CMR), CMR Sequences, MRI Equipment, Myocardial Viability, PET Scanner, Imaging Modes, Multidimensional PET acquisition, Image reconstruction, Hybrid PET/MR, Future Challenges

Objectives:

- Discuss the Cardiovascular System and Heart Anatomy
- Review a heart MRI and how a heart MR is performed
- Overview the Benefits and Risks and the limitations of MR
- Explain PET scanner, Principles of Coincidence Detection and PET Tracer of Myocardial Blood Flow
- Discuss imaging modes and PET image reconstruction
- Overview the benefits and limitations of a cardiac PET scan
- Describe Hybrid PET/MR cardiac and technical advances of PET/MR system
- Understanding what MR Imaging can bring to Cardiac PET Imaging
- Understanding what PET can bring to other CMR
- applications
- Define the future challenges

Content:

I. The Cardiovascular System

6. Definition
7. Functions
8. Blood Flow
9. Blood Vessel
    a. Arteries
    b. Capillaries
    c. Veins

II. Heart Anatomy

6. Heart Anatomy
    a. Pulmonary circuit
    b. Systemic circuit
    c. Right atrium
    d. Right ventricle
    e. Left atrium
    f. Left ventricle
7. Coverings of the Heart
    a. The Function of the Pericardium
8. Heart Wall
    a. Epicardium
    b. Myocardium
    c. Fibrous skeleton
    d. Endocardium

9. Thickness of Cardiac Walls
10. Location of the Heart in the Thoracic Cavity

III. Heart MRI

1. Magnetic resonance imaging (MRI)
2. Background of the MRI scanner
3. The Reasons for Heart MRI
4. The Risks of a Heart MRI
5. Preparation for a Heart MRI
6. Gadolinium Contrast Medium
7. How a Heart MRI Is Performed

IV. Cardiovascular Magnetic Resonance (CMR) Sequences

9. Bright Blood
10. Triple Inversion Recovery
11. Delayed Myocaridal Enhancement (MDE)
12. Phase Contrast
13. Axial Scouts
    a. Vertical Long Axis (VLA)
    b. Fake Short Axis
14. True 4 Chamber (4CH)

V. The Benefits vs Risks

1. Benefits
2. Risks

VI. limitations of MRI of the Body

1. Advantages of Cardiovascular Magnetic Resonance (CMR)
2. Evaluation of Myocardial Viability with CMR Imaging
3. MRI Equipment

VII. PET Scanner

9. Positron mission tomography (PET) Cardiac
10. Positron
11. Positron Annihilation
12. Principles of Coincidence Detection
13. Why a PET Scan Is Performed
    a. Symptoms of heart trouble
14. How to Prepare for a Heart PET Scan
15. How the Test is Performed
16. PET tracer of myocardial blood flow

VIII. Imaging Modes

1. Multidimensional PET acquisition

IX. Image reconstruction

1. Algorithm
   a. Filtered back projection
2. Attenuation correction
   2D/3D reconstruction

X. Benefits and Limitations of a PET Scan

XI. Hybrid PET/MR

1. Objective
2. Why we need Hybrid PET/MR

3. Technical Advances of PET/MR System
    a. Software Advances
    b. Myocardial Perfusion Imaging and Blood Flow Quantitation with PET/MRI
4. What MR Imaging can bring to Cardiac PET Imaging
5. What PET can bring to others CMR Applications
    a. Inflammatory Cardiomyopathies
6. Workflow Considerations
7. Advance Research on PET/MR

XII. Future Challenges

Lecture 3: PET/MR Patient Care, safety, preparation and infection control (90 minutes)

Keywords: Hybrid PET/MRI, Installing PET/MR, Safety Issues, Access Restriction, Zoning, Hybrid PET/MR Zones, Shielding Requirements, Patient Preparation, Workflow, Logistic, Patient Care, Imaging, Instrumentation/Quality Control, The Clinical Performance Standards, Diagnostic Procedures, Adjunctive Medications, Radiopharmaceuticals, Radiation Safety, Infection control, Healthcare associated infections (HAI's), Methicillin Resistant Staphylococcus Aureus (MRSA), Oxacillin-resistant Staphylococcus aureus (ORSA), Black (ultraviolet) Light Detection, Technologist Responsibilities, Patient Management, Code of Ethics

Objectives:

- Discuss hybrid PET/MR and safety issues when installing PET/MR
- Review access restriction, zoning and hybrid PET/MR zones
- Discuss dedicated shielding requirements for simultaneous hybrid system
- Overview radiation safety and Hot-lab considerations
- Explain patient preparation, workflow and logistic considerations
- Describe patient care
- Define the clinical performance standards
- Discuss infection control in PET/MR
- Review technologist responsibilities for patient care, safety and patient management

Content:

I. Learning Objectives

II. Hybrid PET/MRI

10. Introduction

III. Safety Issues when Installing PET/MR

1. Effects on facilities
    a. Construction

IV. Access Restriction and Zoning

11. Zoning Purposes
12. Zone I
13. Zone II
    a. Security and Safety
14. Zone III
    a. Ferromagnetic Detector System
15. Zone IV
16. Hybrid PET/MR Zones

V. Dedicated Shielding Requirements for Simultaneous Hybrid System

1. Radiation safety & Hot-lab Considerations

VI. Patient Preparation

1. Resting Phase
2. Patient Preparation Before Examination
    a. Sedation and Anesthesia Preparation Instructions
    b. Other Preparation Instructions
        - Discogram Preparation
3. In-bed Patient Preparation
4. If physician ordered patient procedure with radiographic contrast
5. Instructions for the 24 hours prior to PET/MR scan time
6. Instructions for the 12 hours prior to your exam time
7. Day of the Exam
8. Follow up Care
9. Workflow and Logistic Considerations
    a. Patient schedule
    b. Pre scan preparation
    c. In-bed patient preparation
    d. Field of view
    e. Planning
    f. Acquisition
    g. Respiratory motion

VII. Patient Care

1. Patient Care
2. Imaging with Care
    a. The Need for High-Quality Imaging
    b. Reducing Health Care Costs
    c. Improving Medical Imaging
3. The Scope of Practice for Patient Care
4. Instrumentation/Quality Control
    a. Nuclear medicine and PET imaging systems
    b. Non-imaging instrumentation

VIII. The Clinical Performance Standards

1. Patient Care
    a. A nuclear medicine technologist
        - Prepares the patient
        - Provides patient care
        - Performs administrative procedures
2. Diagnostic Procedures
    a. A nuclear medicine technologist performs imaging procedures
3. Adjunctive Medications
4. Radiopharmaceuticals
    a. A nuclear medicine technologist
        - Displays
        - Maintains radiopharmaceutical products and adjunct supplies
        - Responsible for the identification and labeling of all radiopharmaceutical preparations
        - Prepares individual dosages under the direction of an authorized user
5. Radiation Safety

IX. Infection control in PET/MR

17. Healthcare associated infections (HAI's)

18. Methicillin Resistant Staphylococcus Aureus (MRSA) or Oxacillin-resistant Staphylococcus aureus (ORSA)
19. Center for Disease Control (CDC)
    a. Studies
20. The MRI Suite
21. Bacteria and Table Pads
22. The American College of Radiology Safe PET/MRI Practices
23. Infection Control (Zone IV)
24. Black (ultraviolet) Light Detection of Body Fluid Contamination that may Indicate Fraying
25. PET/MR Magnet Bore
26. Suggestions for Infection Control Procedures for Free-Standing Imaging Centers and Hospital Radiology Departments
    a. Eleven simple procedures
27. Conclusion
    a. Five Things you Can Do To Prevent Infection

X. Technologist Responsibilities for Patient Care, Safety and Patient Management

1. Technologist responsibilities for patient care and Safety
    a. Technologist Qualified to Perform Nuclear Medicine Procedures
    b. Code of Ethics
2. Overview of Document

Lecture 4: PET Imaging of the Heart (60 minutes)

Keywords: Function of the Heart, Contrast-enhanced CT, Blood Supply, PET Imaging , Coronary Perfusion, Coronary Artery Disease, Radiopharmaceuticals, Scan Technique, Data Analysis , Clinical Interpretation, Myocardial Viability, Metabolic Imaging

Objectives:

- Discuss the function of the heart
- Review PET imaging of coronary perfusion
- Describe imaging of myocardial viability

Content:

I. The Function of the Heart

1. The 4 Cardiac Chambers on Contrast-enhanced CT
    a. Right Atrium
    b. Right Ventricle
    c. Left Atrium
    d. Left Ventricle
2. The Cardiac Valves Visualized on Echocardiography and Contrast-enhanced CT
3. The 4 Major Coronary Arteries on CT
    a. Right Coronary Artery
    b. Left Mala Coronary Artery
    c. Left Circumflex Coronary Artery
    d. Left Anterior Descending Coronary Artery
4. Blood Supply

II. PET Imaging of Coronary Perfusion

11. Coronary Artery Disease
12. Radiopharmaceuticals
    a. 13-N-ammonia
    b. 82-Rb-chloride

c. Positron range
13. Scan Technique
    a. History and assessment
    b. Vasodilators Used in PET Cardiac Perfusion Imaging
    c. Positioning and scanning
    d. Stress procedures
    e. Electrocardiography
14. Data Analysis
15. Clinical Interpretation

III. Imaging of Myocardial Viability

1. Metabolic Imaging of the Heart
    a. Characteristics of Normal Myocardium, Hibernating Myocardium, and Myocardial Infarction on FDG PET Viability Imaging
2. Scan Technique
    a. History and assessment
    b. Patient preparation
    c. Scanning
    d. Patient positioning
3. Clinical Interpretation

IV. Additional Reading

Lecture 5: Cardiogen Generators (60 minutes)

Part 1

Keywords: Rubidium-82, 82Sr/82Rb Generator, Production of 82Sr, CardioGen-82, Rubidium Rb 82 Generator, FDA Drug Safety Communication, Infusion System, Chloride Injection, Eluting Rubidium Rb 82, Drug Handling

Objectives:

- Discuss Rubidium-82
- Discuss CardioGen-82
- Review FDA Drug Safety Communication: Planned return of CardioGen-82 to market with new Boxed Warning
- Describe Infusion System
- Define Directions for Eluting Rubidium Rb 82 Chloride Injection

Content:

I. Introduction

II. Rubidium-82

17. Rubidium-82
    a. Physical Data
    b. History
    c. Nuclear Properties
    d. Production
18. 82Sr/82Rb Generator
19. Production of 82Sr
20. Production Routes for 82Sr
21. Control of Product Radiopurity

22. Target Issues – RbCl
    a. Advantage and Disadvantage
23. Target Issues – Rb metal
    a. Advantage and Disadvantage
24. Facilities
25. Sr-82 Process Flow Chart
26. Sr-82 Product Specifications
    a. Radionuclidic Purity
    b. Specific Activity
    c. Activity Concentration
    d. Stable Elements
27. Decay scheme of 82Sr to 82Rb
28. Decay scheme of 82Rb to stable 82Kr
29. Relevant nuclear properties
    a. Photon emission of the daughter radionuclide

III. CardioGen-82 (Rubidium Rb 82 Generator)

15. The Generator: how does it work?
16. CardioGen-82® (Rubidium Rb 82 Generator)
17. Bracco Diagnostics Inc.
    a. Radiopharmaceuticals
    b. CardioGen-82
18. FDA Drug Safety Communication: Planned return of CardioGen-82 to market with new Boxed Warning
    a. The Root Cause: from the FDA's Safety Announcement of Jan 12, 2012
    b. Return to Market Requirements – from FDA
19. CardioGen-82, Characteristics
    a. Uses For Cardiogen-82 Generator
    b. Use in Positron Emission Tomography (PET)
        - Myocardial blood flow tracers with PET
        - History
20. Tools for Risk Stratification
21. The Cardiac Imaging Market is Transitioning
    a. From SPECT to PET
    b. From Cardiac catheterization to CT angiography
22. PET Perfusion Imaging
23. Transitioning the perfusion market
24. CardioGen-82's high sensitivity and specificity can improve diagnostic accuracy
25. PET MPI provides benefits for a diverse patient population
26. PET MPI for thriving practice
    a. Convenience
    b. Efficiency
    c. Certainty
    d. A Non-Invasive
27. Occupational Safety Data
28. Commonly used brand name(s)
29. Chemical Characteristics
30. Physical Characteristics
31. External Radiation
32. Strontium Sr 82 decays to rubidium Rb 82
33. Physical decay of rubidium Rb 82

IV. Infusion System

1. CardioGen-82 Infusion System
    a. Shielding
    b. Syringe Pump

c. Valve Shield Assembly
d. Display/Control Panel

2. Daily quality control
3. Dose delivery by Infusion System

V. Rubidium Rb 82 Chloride Injection Dosage

1. Drug Handling
2. Directions for Eluting Rubidium Rb 82 Chloride Injection

Part 2

Keywords: Cardiogen-82, Rubidium Rb 82 Generator, Eluate Testing Protocol, Rubidium Eluate, Strontium Eluate, Safety Information, Radiation Dosimetry, Absorbed Radiation Dose, Drug Interactions, Specific Populations, Clinical Pharmacology, Nonclinical Toxicology, Dose Calibrator, Dose Calibrator Settings, Quality control, QC Procedures, Patient Preparation, Imaging Protocols, Radioactive Tracer, Stress Testing, Side Effects, Safety Data Sheet, Hazard(s) identification, First-aid measures, Transport information, Advantages, Limitations

Objectives:

- Discuss Eluate Testing Protocol
- Review Radiation Dosimetry
- Define Dose Calibrator Settings for Rb 82
- Describe CardioGen-82 Quality control Procedures
- Discuss Patient Preparation and Imaging Protocols
- Explain Side Effects
- Discuss Safety Data Sheet
- Describe Hazard(s) identification and First-aid measures
- Review Transport Information
- Review Advantages and Limitations

Content:

I. Eluate Testing Protocol

16. Rubidium Eluate Level Testing
17. Strontium Eluate Level Testing
    a. Calculation
    b. Examples
18. Cardiogen-82 Expiration
19. Important Safety Information
    a. Perform generator eluate tests
    b. Alert Limits

II. Radiation Dosimetry

30. About Absorbed Radiation Dose Coefficient
31. Calculation
32. Dosage Forms and Strengths
33. Warnings and Precautions Unintended
    a. Risks Associated with Pharmacologic Stress
    b. Volume Overload
    c. Cumulative Radiation Exposure: Long-Term Risk of Cancer
    d. Adverse Reactions
        - Postmarketing Experience
34. Drug Interactions
35. Use in Specific Populations
    a. Pregnancy

b. Nursing Mothers
c. Pediatric Use
d. Geriatric Use
e. Renal Impairment
f. Hepatic Impairment

36. Cardiogen-82 - Clinical Pharmacology
    a. Mechanism of Action
    b. Pharmacodynamics
    c. Pharmacokinetics
37. Nonclinical Toxicology
    a. Carcinogenesis, Mutagenesis, Impairment of Fertility

III. Dose Calibrator

34. Dose Calibrator QC
    a. Calibration Tests include
        - Accuracy
        - Linearity
        - Geometry
        - Constancy
35. Dose Calibrator Settings for Rb 82

IV. CardioGen-82 QC Procedures

28. QC Preparation
29. Three Step QC Procedure: W-S-C
    a. 1st Elution: Generator Column Wash (W)
        - Control Panel Settings
    b. 2nd Elution: Sr-82 and Sr-85 Level Testing (S)
        - Control Panel Settings
    c. 3rd Elution: Infusion System Calibration (C)
        - Calibration Procedure
        - Control Panel Settings

V. Patient Preparation and Imaging Protocols

1. Patient Preparation
    a. Medications
    b. Patient should not be taken
    c. Clothing
2. Examination
3. Methods of Stress Testing
4. Examples of Radiotracers and their Applications
5. The Radioactive Tracer
6. Patient Radiation Dosimetry
7. Rubidium-82 Dosage
    a. Warnings
    b. Precautions
8. Study Time Frame
    a. Regadenoson vs. Dipyridamole
9. Imaging Protocols
    a. Regadenoson vs. Dipyridamole
10. 82Rb PET perfusion image acquisition and processing
11. Image processing and common artifacts
12. Images of PET MPI using Rb 82
    a. Case Study #1, 54-year-old woman
        - Patient History
        - SPECT Procedure

- SPECT Study CT Fusion
- SPECT Impression
- PET Rb-82 MPI Procedure
- PET Impression
- PET Rb-82 MPI Imaging

VI. Cardiogen-82® (Rubidium Rb 82 Generator)

1. How Supplied
2. Disposal
3. Storage
4. Expiration Date
5. Cardiogen-82 Generator Side Effects
6. Safety Data Sheet
   a. Product identifier
   b. How Supplied
   c. Emergency Overview
7. Hazard(s) Identification
   a. Classification of the substance or mixture
   b. Effects of Overexposure - Routes of Entry
      - Inhalation
      - Skin Contact
      - Ingestion
8. First-aid Measures
   a. General information
   b. After Inhalation
   c. After Skin Contact
   d. After Eye Contact
   e. After Swallowing
9. Transport Information
10. Advantages and Limitations

Lecture 6: Cardiovascular Terminology (90 minutes)

Keywords: Glossary, Molecular Cardiology, Terminology

Objectives:

- Discuss Cardiovascular Glossary
- Define Terms from "A" to "Z"

Content:

I. «A»

20. Abdomen
21. Abdominal aorta
22. Ablation
23. ACE (angiotensin-converting enzyme) inhibitor
24. Acetylcholine
25. Acquired heart disease
26. Alveoli
27. Amiodarone
28. Aneurysm
29. Angina or angina pectoris
30. Angiography
31. Angioplasty

32. Angiotensin II receptor blocker
33. Annulus
34. Antiarrhythmics
35. Anticoagulant
36. Antihypertensive
37. Antiplatelet therapy
38. Aorta
39. Aortic valve
40. Aphasia
41. Arrhythmia (or dysrhythmia)
42. Arrhythmogenic right ventricular dysplasia (ARVD)
43. Arteriography
44. Arterioles
45. Artery
46. Arteriosclerosis
47. Artificial heart
48. Ascending aorta
49. Aspirin
50. Atherectomy
51. Atherosclerosis
52. Atrium (right and left)
53. Atrial flutter
54. Atrial septal defect
55. Atrial tachycardia
56. Atrioventricular block
57. Atrioventricular (AV) node
58. Atrium
59. Autologous
60. Autoregulation

II. «B»

38. Bacteria
39. Bacterial endocarditis
40. Balloon catheter
41. Balloon valvuloplasty
42. Beta-blocker
43. Biopsy
44. Blalock-Taussig procedure
45. Blood clot
46. Blood pressure
47. Blue babies
48. Body mass index (BMI)
49. Bradycardia
50. Bridge to transplant
51. Bruit
52. Bundle branch block
53. Bypass

III. «C»

1. Calcium channel blocker (or calcium blocker)
2. Capillaries
3. Cardiac
4. Cardiac amyloidosis
5. Cardiac arrest
6. Cardiac cachexia
7. Cardiac catheterization
8. Cardiac enzymes

9. Cardiac output
10. Cardiologist
11. Cardiology
12. Cardiomegaly
13. Cardiomyopathy
14. Cardiopulmonary bypass
15. Cardiopulmonary resuscitation (CPR)
16. Cardiovascular (CV)
17. Cardiovascular Disease (CVD)
18. Cardioversion
19. Carotid artery
20. Cerebral embolism
21. Cerebral hemorrhage
22. Cerebral thrombosis
23. Cerebrovascular
24. Cerebrovascular accident
25. Cerebrovascular occlusion
26. Cholesterol
27. Cineangiography
28. Circulatory system
29. Claudication
30. Collateral circulation
31. Commissurotomy
32. Computed tomography (CT or CAT scan)
33. Conduction system
34. Congenital
35. Congenital heart defects
36. Congestive heart failure
37. Coronary arteries
38. Coronary artery anomaly (CAA)
39. Coronary artery bypass (CAB)
40. Coronary artery disease (CAD)
41. Coronary heart disease
42. Coronary occlusion
43. Coronary thrombosis
44. Cryoablation
45. Cyanosis
46. Cyanotic heart disease

IV. «D»

36. Death rate (age-adjusted)
37. Deep vein thrombosis
38. Defibrillator
39. Diabetes (diabetes mellitus)
40. Diastolic blood pressure
41. Digitalis
42. Dissecting aneurysm
43. Diuretic
44. Doppler ultrasound
45. Dysarthria
46. Dyspnea

V. «E»

1. Echocardiography
2. Edema
3. Ejection fraction

4. Electrocardiogram (ECG or EKG)
5. Electroencephalogram (EEG)
6. Electrophysiological study (EPS)
7. Embolus
8. Endarterectomy
9. Endocardium
10. Endothelium
11. Endocarditis
12. Enlarged heart
13. Enzyme
14. Epicardium
15. Estrogen
16. Estrogen (or hormone) replacement therapy (ERT or HRT)
17. Exercise stress test

VI. «F»

1. Familial hypercholesterolemia
2. Fatty acids (fats)
3. Fibrillation
4. First-degree heart block
5. Flutter
6. Fusiform aneurysm

VII. «G»

30. Gated blood pool scan
31. Genetic testing
32. Guidewire

VIII. «H»

1. Heart assist device
2. Heart attack
3. Heart block
4. Heart failure
5. Heart-lung machine
6. Heart murmur
7. Hematocrit
8. Hemochromatosis
9. Heredity
10. High blood pressure
11. High density lipoprotein (HDL)
12. Holter monitor
13. Homocysteine
14. Hormones
15. Hypertension
16. Hypertrophic obstructive cardiomyopathy (HOCM)
17. Hypertrophy
18. Hyperventilation
19. Hypoglycemia
20. Hypokinesia
21. Hypotension
22. Hypoxia

IX. «I»

1. Idiopathic
2. Immunosuppressants
3. Impedance plethysmography
4. Incompetent valve

5. Infarct
6. Infective endocarditis
7. Inferior vena cava
8. Inotropes
9. Internal mammary artery
10. Intravascular echocardiography
11. Introducer sheath
12. Ischemia
13. Ischemic heart disease
14. Ischemic stroke

X. «J»

1. Jugular veins

XI. «L»

1. Left ventricular assist device (LVAD)
2. Lesion
3. Lipid
4. Lipoprotein
5. Low density lipoprotein (LDL)
6. Lumen

XII. «M»

1. Magnetic resonance imaging (MRI)
2. Maze surgery
3. Mitral stenosis
4. Mitral valve
5. Mitral valve prolapse
6. Mitral valve regurgitation
7. mm Hg
8. Monounsaturated fats
9. Mortality
10. Murmur
11. Myocardial infarction
12. Myocardial ischemia
13. Myocarditis
14. Myocardium
15. Myxomatous degeneration

XIII. «N»

1. Nitroglycerin
2. Necrosis
3. Noninvasive procedures
4. NSTEMI

XIV. «O»

1. Obesity
2. Occluded artery
3. Open heart surgery

XV. «P»

1. Pacemaker
2. Palpitation
3. Pancreas
4. Pancreatitis
5. Paralysis

6. Paroxysmal supraventricular tachycardia (PSVT)
7. Patent ductus arteriosus
8. Patent foramen ovale
9. Percutaneous coronary intervention (PCI)
10. Percutaneous transluminal coronary angioplasty (PTCA)
11. Pericarditis
12. Pericardiocentesis
13. Pericardium
14. Plaque
15. Platelets
16. Polyunsaturated fat
17. Positron emission tomography (PET)
18. Postural orthostatic tachycardia syndrome (POTS)
19. Premature ventricular contraction (PVC)
20. Prevalence
21. Pulmonary
22. Pulmonary embolism
23. Pulmonary valve
24. Pulmonary vein

XVI. «R»

1. Radial artery access
2. Radionuclide imaging
3. Radionuclide studies
4. Radionuclide ventriculography
5. Regurgitation
6. Renal
7. Restenosis
8. Revascularization
9. Rheumatic fever
10. Rheumatic heart disease
11. Right ventricular assist device (RVAD)
12. Risk factor
13. Rubella

XVII. «S»

1. Saccular aneurysm
2. Sarcoidosis
3. Saturated fat
4. Second-degree heart block
5. Septal defect
6. Septum
7. Sheath
8. Shock
9. Shunt
10. Sick sinus syndrome
11. Silent ischemia
12. Sinus (SA) node
13. Sodium
14. Sphygmomanometer
15. Stem cells
16. STEMI
17. Stent
18. Stenosis
19. Stethoscope
20. Stokes-Adams disease
21. Streptococcal infection ("strep" infection)

22. Streptokinase
23. Sternum
24. Stress
25. Stroke
26. Subarachnoid hemorrhage
27. Subclavian arteries
28. Sudden death
29. Superior vena cava
30. Supraventricular tachycardia (SVT)
31. Syncope
32. Systolic blood pressure

XVIII. «T»

1. Tachycardia
2. Tachypnea
3. Tamponade
4. Thallium-201 stress test
5. Third-degree heart block
6. Thrombolysis
7. Thrombosis
8. Thrombolytic therapy
9. Thrombus
10. Thyroid
11. Tissue plasminogen activator (tPA)
12. Trans fat
13. Transcatheter aortic valve implantation (TAVI)
14. Transcatheter intervention
15. Transesophageal echocardiography
16. Transient ischemic attack (TIA)
17. Transplantation
18. Tricuspid valve
19. Triglyceride

XIX. «U»

1. Ultrasound

XX. «V»

1. Valve replacement
2. Valvuloplasty
3. Varicose vein
4. Vascular
5. Vasodilators
6. Vasopressors
7. Vein
8. Ventricle (right and left)
9. Ventricular Assist Device (VAD)
10. Ventricular fibrillation
11. Ventricular tachycardia
12. Vertigo

XXI. «W»

1. Wolff-Parkinson-White syndrome

XXII. «X»

1. X-ray

Lecture 7: Standards and Guidelines for Nuclear/PET Accreditation (90 minutes)

Keywords: Intersocietal Accreditation Commission (IAC), Accreditation Process, Personnel and Organization, Facility, Examination Reports and Records, Facility Safety, Administrative, Examinations and Procedures, Instrumentation and Equipment, Clinical Protocols, Quality Improvement (QI) Program, Quality Improvement Measures, Quality Improvement Meetings, Quality Improvement Documentation, Therapy Procedures, Therapy Protocols and Performance

Objectives:

- Discuss Standards and Guidelines for Nuclear/PET Accreditation
- Review Accreditation Process, Accreditation of Specific Areas of Nuclear Cardiology, Specific Areas of General Nuclear Medicine and Specific Areas of PET
- Describe Organization, Personnel and Supervision Guidelines
- Provide examples of Standards for Medical Director, Technical Director, Medical Staff, Technical Staff, Physician and Nuclear Medicine Technologist Trainees, Nuclear Medicine Assistants, Ancillary Personnel
- Describe Facility Guidelines and Facility Safety Guidelines
- Provide examples of Standards for Examination Areas, Interpretation Areas, Patient and Facility Safety, Radiation Safety and Radioactive Materials Handling Protocols, Facility operations, Radiation safety protocols, Radioactive Materials Storage and Disposal
- Describe Examination Reports and Records Guidelines
- Provide examples of Standards for Records, Image Interpretation and Reporting, Final Interpretation of Examinations, Final Report
- Describe Administrative Guidelines and Multiple Sites (Mixed and/or Mobile) Guidelines
- Provide examples of Standards for Patient Confidentiality, Patient or Other Customer Complaints, Primary Source Verification, Multiple Slides
- Describe Examinations and Procedures, Instrumentation and Equipment Guidelines, Clinical Protocols Guidelines
- Provide examples of Standards for Instrumentation, Equipment Quality Control Protocols, Imaging Equipment Quality Control, Non-imaging Equipment Quality Control, Other Equipment Quality Control, Procedures Volumes, General Protocol Guidelines, Clinical Procedure Protocols, Diagnostic Imaging Protocols and their Implementation
- Describe Quality Improvement (QI) Program, Measures, Meetings and Documentation
- Provide examples of Standards for QI Program, QI Measures, QI Meetings, QI Documentation
- Describe the Therapy Procedures
- Provide examples of Standards for Therapy Clinical Protocols and Therapy Performance
- Illustrate the Stress Test Supervision by Non-Physician Training and Competency Requirements

Content:

I. Introduction

1. The Intersocietal Accreditation Commission (IAC)
2. Nuclear Cardiology, General Nuclear Medicine, and/or PET Facility Standards
    a. Accreditation Process
    b. Accreditation of Specific Areas of Nuclear Cardiology
    c. Accreditation of Specific Areas of General Nuclear Medicine (other than cardiac)
    d. Accreditation of Specific Areas of PET

II. Organization

1. Personnel and Organization
    a. Standard - Medical Director
        - Required Training and Experience
        - Responsibilities
        - Continuing Medical Education (CME) Requirements
    b. Standard - Technical Director
        - Required Training and Experience

- Responsibilities
- Continuing Education (CE) Requirements

c. Standard - Medical Staff
- Required Training and Experience
- Responsibilities
- Continuing Education (CE) Requirements

d. Standard - Technical Staff
- Required Training and Experience
- Responsibilities
- Continuing Education (CE) Requirements

e. All direct patient care personnel must meet the following qualifications
- Basic Life Support
- Advanced Cardiac Life Support (ACLS)
- Stress Testing Oversight

f. Standard - Physician and Nuclear Medicine Technologist Trainees
- Supervision

g. Standard - Nuclear Medicine Assistants
h. Standard - Ancillary Personnel
i. Personnel and Supervision Guidelines

2. Facility
   a. Standard - Examination Areas
   b. Standard - Interpretation Areas
   c. Standard - Storage
   d. Facility Guidelines
3. Examination Reports and Records
   a. Standard - Records
   b. Standard - Image Interpretation and Reporting
   c. Final Interpretation of Examinations
   d. Final Report
   e. Examination Reports and Records Guidelines
4. Facility Safety
   a. Standard - Patient and Facility Safety
      - Patient Identification Policy
      - Pregnancy Screening Policy
      - Breast-feeding Screening Policy
      - Request for Services Policy
      - Infection Control/Communicable Diseases Policy
      - Hazardous Materials Policy
      - Handling of Non-Radioactive Pharmaceuticals Policy
      - Drug Administration Errors Policy
      - Adverse Drug Reactions Policy
   b. Standard - Radiation Safety and Radioactive Materials Handling Protocols
   c. Facility operations
   d. Radiation safety protocols
      - General Radioactive Materials Handling and Radiation Safety
      - Receipt of Radioactive Materials
      - United States Pharmacopeia (USP) Chapter 797
      - Preparation of Radiopharmaceuticals
      - Administration of Radiopharmaceuticals to Patients
      - Records of Radioactive Materials Administration Errors
      - Adverse Radiopharmaceutical Reactions
   e. Radioactive Materials Storage and Disposal
      - Radioactive trash
      - Security of areas
      - Adequate shielding

f. Facility Safety Guidelines

5. Administrative
   a. Standard - Patient Confidentiality
   b. Standard - Patient or Other Customer Complaints
   c. Standard - Primary Source Verification
   d. Administrative Guidelines
6. Multiple Sites (Fixed and/or Mobile)
   a. Standard - Multiple Slides
   b. Multiple Sites (Mixed and/or Mobile) Guidelines

III. Examinations and Procedures

1. Instrumentation and Equipment
   a. Standard - Instrumentation
   b. Standard - Equipment Quality Control Protocols
   c. Standard - Imaging Equipment Quality Control
      - Gamma Camera (Planar, SPECT, and SPECT/CT)
      - PET and PET/CT Scanner
   d. Standard - Non-imaging Equipment Quality Control
      - Survey Meter
      - Dose Calibrator
      - Well Counter
      - Intraoperative Probes
      - Organ Uptake Probes
   e. Standard - Other Equipment Quality Control
      - Emergency Equipment
      - Miscellaneous Equipment (Glucometer, Infusion pump, Xenon trap and Nebulizer)
   f. Instrumentation and Equipment Guidelines
2. Clinical Protocols
   a. Standard - Procedures Volumes
   b. Standard - General Protocol Guidelines
   c. Standard - Clinical Procedure Protocols
   d. Diagnostic Imaging Protocols and their Implementation
      - Radiopharmaceutical identity, dosage and route of administration
      - Detailed Description of Graded Protocols and/or Infusion Protocols Used
   e. Clinical Protocols Guidelines

IV. Quality Improvement

1. Quality Improvement (QI) Program
   a. Standard - QI Program
   b. Quantity Improvement Program Guidelines
2. Quality Improvement Measures
   a. Standard - QI Measures
      - Test Appropriateness
      - Technical Quality Review
      - Interpretive Quality Review
      - Final Report Completeness and Timeliness
   b. Quality Improvement Measures Guidelines
      - Administrative Quality
3. Quality Improvement Meetings
   a. Standard - QI Meetings
4. Quality Improvement Documentation
   a. Standard - QI Documentation

V. Therapy Procedures

1. Therapy Protocols and Performance
   a. The Report of the Therapy

b. Standard - Therapy Clinical Protocols
c. Standard - Therapy Performance

VI. Appendix A

1. Stress Test Supervision by Non-Physician Training and Competency Requirements
   a. Supervision Exercise Stress Testing
   b. Supervision of Vasobilator or Adrenergic-Stimulating Agent Stress