Radiation Safety Review Course

Outline

Module I: Content Pertaining to a RAM Licenses

• Nuclear Medicine and PET Terminology…….....	Lecture 1	120 min
• Basic Math Skills for Nuclear Medicine Technologists I……..	Lecture 2	60 min
• Basic Math Skills for Nuclear Medicine Technologists II…….	Lecture 3	60 min
• Introduction to Dose Calibrators…….	Lecture 4	60 min
• Introduction to Survey Meters…….	Lecture 5	60 min
• Introduction to ScintillatorDetectors…….....	Lecture 6	60 min
• The Electronics of Scintigraphy……	Lecture 7	60 min
• Radiation Detection and Measurements…….....	Lecture 8	90 min
• Gaseous Detectors Used in the PET Lab……..	Lecture 9	60 min
• Alpha & Beta Decay……..	Lecture 10	60 min
• Atomic Structure and Nuclear Stability……	Lecture 11.1	60 min
• Atomic and Nuclear Structure……..	Lecture 11.2	60 min
• Background Radiation……	Lecture 12	45 min
• Gamma Decay, Positron Decay, and Electron Capture……..	Lecture 13	60 min
• Radionuclide Production……	Lecture 14	90 min
• Production of Radionuclides…….	Lecture 15	60 min
• PET Radiopharmaceuticals……..	Lecture 16	60 min
• PET Quality Control……	Lecture 17	60 min
• The Nuclear Pharmacy……..	Lecture 18	60 min
• Radioactive Receipt……...	Lecture 19	60 min
• Radioactive Waste Disposal…….	Lecture 20	60 min
• Radiation Physics & Instruments…….	Lecture 21	90 min
• Radiation Dosimetry and Units…….	Lecture 22	90 min
• Radiation Protection of Personnel……...	Lecture 23	60 min
• Radiation Protection, ALARA & Personal Monitoring……...	Lecture 24	120 min
• NRC Part I……	Lecture 25	120 min
• NRC Part II……..	Lecture 26	120 min
• NRC Regulations Part III……...	Lecture 27	90 min
• Physics of Positrons and Production and PET Traces (Parts I and II)…….	Lecture 28	90 min
• CardioGen Generators……..	Lecture 29	120 min
• Photon and Particle Interaction in Matter……	Lecture 30	60 min
• Cellular Anatomy and Physiology……	Lecture 31	60 min
• Cellular Effects of Radiation Exposure……	Lecture 32	60 min
• Effects of Initial Exposure to Radiation……...	Lecture 33	60 min
• Effects of Long-Term Exposure to Radiation…….	Lecture 34	60 min
• Radiation Protection of Personnel (Parts I, II and III)……...	Lecture 35	90 min
• Radiation Safety in PET Imaging (Parts I, II and III)…….	Lecture 36	90 min

Module II: Content pertaining to CT

• Introduction to CT: The Fundamentals…….	Lecture 37	45 min
• CT Instrumentation……..	Lecture 38	45 min
• CT Physics and Instrumentation……	Lecture 39	45 min
• Computed Tomography Instrumentation and Operation……	Lecture 40	60 min
• CT Data Acquisition…….	Lecture 41	60 min
• CT Image Processing and Reconstruction……..	Lecture 42	60 min
• CT Image Quality…….	Lecture 43	60 min
• CT Quality Control Procedures……..	Lecture 44	60 min
• Artifacts in CT……	Lecture 45	45 min
• CT Radiation Dose Calculations……	Lecture 46	60 min
• Measuring Patient Dose from a CT Scanner……...	Lecture 47	60 min
• Fundamentals of SPECT/CT Principles……	Lecture 48	60 min
• Basic Instrumentation of SPECT/CT: CT component……...	Lecture 49	90 min
• Electronics of SPECT Detectors……	Lecture 50	45 min
• SPECT Quality Control……	Lecture 51	120 min
• SPECT Troubleshooting Artifacts……..	Lecture 52	60 min
• CT Safety and Protection……	Lecture 53	45 min
• Methods for Reducing the Radiation Exposure in a PET/CT Lab: CT Component…….	Lecture 54	90 min
• Methods for Reducing the Radiation Exposure in a PET/CT Lab: PET Component……..	Lecture 55	60 min

Module III: Content pertaining to MR Safety

• MR Fundamentals……...	Lecture 56	90 min
• Radiofrequency and Gradients…….	Lecture 57	90 min
• MR Image Quality……	Lecture 58	90 min
• MR Image Production Parameters……	Lecture 59	90 min
• MR Instrumentation…….	Lecture 60	60 min
• MR Pulse Sequences…….	Lecture 61	90 min
• MR Safety (Part I) ……..	Lecture 62	90 min
• MR Safety (Part II) …….	Lecture 63	90 min
• MR Safety (Part III) ……	Lecture 64	90 min
• Introduction to PET/MR Artifacts……..	Lecture 65	60 min
• PET/MR Instrumentation……	Lecture 66	60 min
• PET/MRI Attenuation Correction……	Lecture 67	90 min
• Image Distortion in Clinical PET/MR Imaging…….	Lecture 68	90 min
• PET/MR QC Standards…….	Lecture 69	90 min
• PET/MR System Designs……..	Lecture 70	90 min
• PET/MR Workflow……	Lecture 71	60 min
• PET/MR Site Planning…….	Lecture 72	90 min
• MR Artifacts……...	Lecture 73	90 min

Module IV: Content pertaining to X-Ray and Fluroscopy

- Xray and Fluoroscopy……. Lecture 74 120 min
- Dose Optimization …….. Lecture 75 120 min
- Internal Radiotherap…… Lecture 76 90 min

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 1

Title: Nuclear Medicine and PET Terminology (120 minutes)

Keywords: Glossary, Molecular Terms, Nuclear Terms, Terminology

Objectives:

- Discuss Glossary of Molecular Imaging Terms
- Discuss Glossary of PET Terms
- Define Terms from "A" to "Z"

Content:

I. "A"

1. Alzheimer's disease
2. Amino acid
3. Aneurysm
4. Angiography
5. Annihilation
6. Antibody
7. Antigen
8. Arrhythmia
9. Atherosclerosis
10. Atrophy
11. Automated external defibrillator
12. Automatic internal cardiac defibrillator
13. Axillary lymph node dissection
14. Axillary lymph nodes
15. Axillary lymph nodes, dissection
16. Axon

II. "B"

1. Benign
2. Beta-amyloid plaque
3. Biological pathway
4. Bioluminescent imaging
5. Biomarker
6. Biopsy
7. Bipolar disorder
8. Blood-brain barrier
9. Bone marrow
10. Bone scan
11. Bradycardia
12. 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. Colorectal
11. Colorectal cancer
12. Computed tomography
13. Congenital
14. Congestive heart failure
15. Contrast agent (contrast media or contrast material)
16. Coronary artery disease
17. Cryosurgery

IV. "D"

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

V. "E"

1. ECG stress test
2. Echo stress test
3. Echocardiography
4. Ejection fraction
5. Electrocardiography
6. Electrodessication and curettage
7. Electromagnetic radiation
8. Electron
9. Embolism
10. Endocrine
11. Enzyme
12. Epilepsy
13. Esophageal
14. Estrogen receptor-positive breast cancer
15. Estrogen, estrogen receptor
16. Exercise treadmill testing

VI. "F"

1. FDG
2. Fluorescence imaging (fluorescent molecular tomography [FMT])
3. Fluorine
4. Fluoroestradiol (FES)
5. Fluorothymidine (FLT)
6. Follicular thyroid cancer
7. Frontotemporal dementia
8. Frontotemporal disorders
9. Fusion imaging

VII. "G"

1. Gallbladder
2. Gamma camera
3. Gastric

4. Gastrointestinal (GI) tract
5. Glial cell
6. Gynecology

VIII. "H"

1. Heart attack
2. Heart failure
3. Hippocampus
4. Hodgkin's disease
5. Hurthle cell thyroid cancer
6. Hybrid imaging
7. 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. Indium-111-octreotide
10. Intravenous (IV)
11. Ionizing radiation
12. Isotope

X. "L"

1. Larynx
2. Lewy body dementia
3. Ligand
4. Lobules
5. Localize
6. Lumpectomy
7. Lymph
8. Lymph node biopsy
9. Lymph nodes
10. Lymph vessels
11. Lymphatic system
12. Lymphocyte
13. Lymphoma
14. 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. Metabolism
12. Metabolites

13. Metastasize
14. Micro- (PET, MR, CT, SPECT)
15. Microbubbles
16. Mild cognitive impairment (MCI)
17. Millisieverts (mSv)
18. Molecular imaging (MI)
19. Molecular markers
20. Molecular radiotherapy (MRT)
21. Molecular ultrasound
22. Monoclonal antibody
23. Monoclonal antibody imaging
24. MR spectroscopy
25. Myelin
26. Myocardial infarction (MI)
27. Myocardial perfusion imaging
28. Myocardial perfusion scan (MPI)

XII. "N"

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

XIII. "O"

1. Obsessive-compulsive disorder
2. Opacity
3. Optical imaging
4. Ovary

XIV. "P"

1. Pancreas
2. Papillary thyroid cancer
3. Parkinson's disease
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. Post-traumatic stress disorder (PTSD)
21. ProstaScint® scan (PSMA Study)
22. Prostate gland
23. Prostate-specific antigen (PSA)
24. Prostate-specific membrane antigen (PSMA) study
25. Prostatectomy

XV. "R"

1. Radiation therapy
2. Radioactivity
3. Radioimmunoscintigraphy (RIS) (monoclonal antibody imaging)
4. Radioimmunotherapy
5. Radioiodine
6. Radioisotope
7. Radiopharmaceutical
8. Radiotracer
9. Re-staging
10. Rectum
11. Reporter-gene systems
12. Risk-stratification

XVI. "S"

1. Sarcoma
2. Schizophrenia
3. Sentinel lymph node
4. Sentinel node biopsy
5. SPECT
6. Spleen
7. Stage
8. Stress perfusion study
9. Stroke
10. Sudden cardiac death
11. Synapse
12. Systolic

XVII. "T"

1. Tachycardia
2. Technetium-99m-Sestamibi (MIBI)
3. Technetium-99m-sulfur-colloid
4. Thymus
5. Thyroid
6. Thyroid gland
7. Tomography, tomographic reconstruction
8. Transient ischemic attack
9. Translational medicine
10. Tumor
11. Tumor marker

XVIII. "U"

1. Ultrasound
2. Urethra
3. Uterus

XIX. "V"

1. Ventricular remodeling

XX. "X"

1. X-rays

XXI. "Y"

1. Yttrium-90 labeled octreotide

Module I: "Content Pertaining to a RAM Licenses": You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 2

Title: Basic Math 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
      - Questions
      - Calculator Method
      - Features of TI 30XIIS Calculator
   b. Method II: Decay Charts
      - Principles
      - Calculation
      - Technetium 99m Half-life Chart
      - Thallium 201 Half-Life Chart
      - Iodine 131 Half-Life
      - Questions
   c. Method III: Universal Decay Table
      - Calculation
      - Universal Decay Table
      - Questions
5. 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

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 3

Title: Basic Math 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:
- Discuss the principles of Dose volume determination and Effective half-life
- Review the methods Radiation Dose versus Time, Radiation Dose versus Distance, Radiation Dose Versus Shielding Materials
- Discuss how to calculate dose volumes
- Discuss how to 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
   b. Question №1
   c. Question №2
   d. Question №3
3. Conclusion

IV. Radiation Dose versus Time Mathematics

1. Principles
2. Calculation the Total Radiation Dose Based on the Time of Exposure
   a. Formula
   b. Question №1
   c. Question №2
   d. Question №3
3. Conclusion

V. Radiation Dose versus Distance Mathematics

1. Principles
2. Calculation the Radiation Dose Based on the Distance (Inverse Square Law)
   a. Formula
   b. Question №1
   c. Question №2
   d. Question №3
3. Conclusion

VI. Radiation Dose versus Shielding Mathematics

1. Principles
2. Calculation the Change in Exposure Rate Due to Shielding
   a. Formula
   b. Question №1
   c. How to do on Calculator (TI30XIIS)
   d. Question №2
   e. How to do on Calculator (TI30XIIS)
   f. Question №3
3. Conclusion

VII. Units Conversion Mathematics

1. Principles
2. Conversion Curies to Becquerels and Becquerels to Curies
   a. Using Calculator to Solve a Problem
   b. Remember this formula
   c. Question №1
   d. Question №2
   e. Question №3
3. Conversion Rad to Grays and Grays to Rad
   a. The Properties of Rad and Grays
   b. Using Calculator to Solve an Equation
   c. Converting Rad to Grays
   d. Question №1
   e. Question №2
   f. Question №3
4. Conversion Rem to Sieverts and Sieverts to Rem
   a. Examples and How to Use on Calculator
   b. Question №1
   c. Question №2
   d. Question №3
5. Conclusion

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 4

Title: Introduction to Dose Calibrators (60 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 II
Content:

I. Types of gaseous detectors
1. Survey Meters
2. Pocket Dosimeters
3. Cutie Pie
4. Dose Calibrators

I. 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)

II. 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

III. Sample of Dose Calibrator Forms and Tests Data

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 5

Title: 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 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
    a. Indirect Ionization Process
    b. Direct Ionization Process
    c. Radiation detection
6. 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
7. Saturation Current
8. Other Aspects of Gas-Filled Detectors
    a. Accuracy of measurement

b. Wall thickness
c. Sensitivity

9. General features of gas detectors
10. Proportional Counters
    a. Distinguishing Alpha & Beta
    b. Alpha & Beta-Gamma Plateau
    c. Gas-Flow Proportional Counter
11. Geiger Mueller Detectors
    a. Advantages/Disadvantages of ionization detectors
    b. Modes of operation
    c. Interaction rate
    d. Dead time
    e. Paralyzable or nonparalyzable
    f. Current mode operation
    g. Detection efficiency
12. Ionization chambers
13. 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. 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. Two types of survey instruments: Ionization chamber or referred to as a cutie-pie
    b. A Geiger-Mueller counter
3. The Quality control procedures for survey instruments
    a. Check batteries
    b. Calibration
    c. 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
10. Parts List
    a. Model 14C Survey Meter
11. Drawings

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. Survay Instruments
2. Other Radiation Detection Instruments
    a. Wipe Test Procedure
    b. Dose Calibrator
    c. Decay-in-Storage Form
    d. Survey Meter
    e. 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

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 6

Title: 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

1. First Scintillation Camera
2. Fluors
3. The Operations of a Scintillation Detector
    a. Energy discrimination capabilities
4. Basic Components of a Scintillation Detector
    a. Crystal
    b. PMT
    c. Preamp
    d. Pulse-Height Analyzer (PHA)
    e. Counter
5. Example

II. Collimators

1. Collimator Characteristics
2. Collimators differ in the following parameters
    a. Photon Energy Imaged
    b. Resolution
    c. Sensitivity
3. Collimator Variations
    a. Parallel hole
    b. Converging
    c. Diverging
    d. Pinhole
    e. Fan beam
4. Properties of Collimators
5. Main Types of Collimators
    a. Parallel Hole
    b. Pinhole
    c. Converging
    d. Divergin
6. Collimator Efficiency
    a. Septal thickness

b. Collimator thickness
7. Collimator Comparisons
8. Multihole collimators
9. 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. Inorganic
   c. NaI (Tl)
   d. BGO (Bismuth germanate)
   e. BaF2 (Barium fluoride)
   f. CsI:Tl (Cesium iodide activated by Thallium)
   g. GSO (Gadolinium silicate doped with cerium)
   h. 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

V. Acquisition Types

1. Dynamic Image
2. Static Image
3. Whole-body Image
4. Gated Image
5. SPECT Image (Single Photon Emission Computed Tomography)

VI. Gamma Cameras on the Market Today

1. Forte
2. Single Head Genesys
3. Dual Head Genesys
4. Siemens LEM Portable
5. Argus
6. Vertex Classic

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

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 7

Title: 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
1. Collimator Characteristics

2. 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
3. Other QC Standards that must be measured
    a. NEMA – National Electrical Manufacturers Association
4. Routine Camera Quality Control procedures

a. Daily
b. Weekly
c. Monthly

5. Uniformity
   a. Intrinsic uniformity
   b. Extrinsic uniformity
6. Daily Flood
7. Uniformity parameters
   a. UFOV – useful field of view
   b. CFOV – center field of view
   c. Integral uniformity
   d. Differential uniformity
8. Spatial Resolution / System Linearity "BARS"
9. Resolution phantoms
10. UB gamma camera test pattern
11. Uniformity corrections
12. Camera uniformity analysis
13. Center of rotation – COR
14. SPECT Phantoms – system performance testing
15. SPECT Performance Phantoms
16. 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

Module I: "Content Pertaining to a RAM Licenses": You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 8

Title: Radiation Detection and Measurements (90 minutes)

Keywords: Radiation Detectors, Radiations Types, Classification, Radiation Interactions, Charged Particulate Radiations, Electron Range, Transmission Curves, Uncharged Radiations, General Properties, Radiation Monitoring Instruments, Dose Calibrators, Gamma Camera Detector, PET Detector, Radiation Instrument Choice, Equivalent rate measurement.

Objectives:

- Discuss Types and Classification of Detectors
- Review Radiation Interactions: Interaction of Heavy Charged Particles, Electron Range and Transmission Curves, Interaction of Gamma Rays
- Discuss General Properties of Radiation Detectors
- Review Ionization Chamber
- Review Geiger Counter
- Review Scintillation Counter
- Review Solid State Detectors
- Discuss Detector in Different Instruments
- Explain Choice of Radiation Instrument

Content:

I. Introduction to Radiation Detectors

1. Deffinition
2. Why to detect Radiation?
3. How to detect Radiation?

II. Types of Radiations

1. Electromagnetic Radiations
2. Particles Radiations

III. Classification of Detectors

1. Electric
   a. Ionization Chamber
   b. Proportional Counter
   c. Geiger-Muller Counter
   d. Semi-conductor detector
   e. Neutron Detector
   f. Scintillation Counter
2. Optical
   a. Photographic Emulsion
   b. Expansion Cloud Chamber
   c. Diffusion Cloud Chamber
   d. Bubble Chamber
   e. Spark Chamber

IV. Radiation Interactions

1. Charged Particulate Radiations
   a. Interaction of Heavy Charged Particles
      - Nature of the Interaction

- Stopping Power
- Energy Loss Characteristics
- Secondary Electron Emission from Surfaces

2. Electron Range and Transmission Curves
   a. Absorption of Monoenergetic Electrons
   b. Absorption of Beta Particles
   c. Backscattering
   d. Positron Interactions
3. Uncharged Radiations
   a. Interaction of Gamma Rays
      - Photoelectric absorption
      - Compton scattering
      - Pair production
   b. Gamma-Ray Attenuation
      - Attenuation Coefficients
      - Absorber Mass Thickness
      - Buildup

V. General Properties of Radiation Detectors

1. Simplified Detector Model
2. Modes of Detector Operation
   a. Pulse mode
   b. Current mode
   c. Mean square voltage mode (MSV mode or Campbelling mode)
3. Energy Resolution
4. Detection Efficiency
5. Dead Time
6. Ionization Chamber
7. Geiger Counter
   a. Principle of operation
   b. Readout
   c. Limitations
8. Proportional Counter
9. Scintillation Counter
   a. Operation
   b. Zinc Sulfide Scintillation Detectors
   c. Sodium Iodide Scintillation Detectors
   d. Plastic Scintillation Detectors
10. Solid State Detectors (or Simiconductor Detector)
    a. Detection mechanism
    b. Low-energy charged particle detectors
11. Neutron Detectors

VI. Detector In Different Instruments

1. Radiation Monitoring Instruments
   a. The smallest source – detector distance anticipated
   b. Ionization chambers
   c. Proportional counters
   d. Scintillator detectors
   e. GM Probe with Survey Meter
   f. Geiger–Müller counters
   g. Scintillation (NaI) Probe w/ Survey Meter
   h. Calibration of survey meters
   i. Properties of survey meters
      - Sensitivity

- Energy dependence
- Directional dependence
- Dose equivalent range
- Response time
- Overload characteristics
- Long term stability
- Discrimination between different types of radiation

2. Dose Calibrators
   a. Detector Design
   b. Calibration Procedure
   c. Types of Radionuclide Calibrators
   d. Example of some Radionuclide Calibrators
3. Gamma Camera Detector
   a. Gamma camera components and operation
   b. Scintillator
   c. $NaI\ Tl$ characteristics
   d. PMT array
   e. PMT calibration
   f. Anger' position network
   g. Pulse height analyser
   h. Detection window in context
   i. Types of events
   j. Gamma camera detection efficiency
   k. Terms contributing to the detection efficiency
   l. Dead-time
   m. Gamma camera spatial resolution
   n. Terms contributing to spatial resolution
4. Detector in Positron emission computed tomography
   a. Choice of PET Scintillator
   b. Comparative characteristics of PET Scintillators

VII. Choice of Radiation Instrument

1. Consider the following characteristics of an instrument
   a. Audio output
   b. Sensitivity
   c. Time Constant
   d. Statistical fluctuation
   e. The smallest source – detector distance anticipated
   f. The permitted averaging area
   g. Fail to danger
2. What is the right instrument?
   a. Geiger Muller detector
   b. Ionization chambers
   c. Advantages of the GM detector over the ionization chamber
   d. Plastic scintillator detectors
   e. Sodium iodide based scintillation detectors (Isotope Identifiers)
   f. For neutron dose equivalent rate monitoring
   g. For contamination monitoring
   h. The smallest source – detector distance anticipated

VIII. Equivalent rate measurement

1. X, Y, B Dose
   a. Detector Type
   b. Strengths
   c. Weaknesses
2. Neutron dose

   a. Detector Type
   b. Strengths
   c. Weaknesses
3. Alpha Contamination Monitoring
   a. Detector Type
   b. Strengths
   c. Weaknesses
4. Beta Contamination Monitoring
   a. Detector Type
   b. Strengths
   c. Weaknesses
5. X, δ Contamination Monitoring
   a. Detector Type
   b. Strengths
   c. Weaknesses
6. Detector types suitable for different radiations
   a. Radiation TYPE
   b. Energy Range
   c. Detector Type
   d. Typical characteristics
   e. Weaknesses

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 9

Title: Gaseous Detectors Used in the PET Lab (60 minutes)

Keywords: Gaseous detectors, Survey Meters, Pocket Dosimeters, Cutie Pie, Dose Calibrators, Gas-Filled Detectors, Construction, Ionization chambers, Proportional counters, Geiger-Mueller (GM) counters, Quality Control, The Ludlum Model 14C, Area Surveys, Radiation Detection Instrumentation, Sample Area Survey Forms.

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 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
- Discuss the use of a dose calibrator
- Review the dose calibrator quality control program

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
    a. Indirect Ionization Process
    b. Direct Ionization Process
    c. Radiation detection
6. 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

7. Saturation Current
8. Other Aspects of Gas-Filled Detectors
    a. Accuracy of measurement
    b. Wall thickness
    c. Sensitivity
9. General features of gas detectors
10. Proportional Counters
    a. Distinguishing Alpha & Beta
    b. Alpha & Beta-Gamma Plateau
    c. Gas-Flow Proportional Counter
11. Geiger Mueller Detectors
    a. Advantages/Disadvantages of ionization detectors
    b. Modes of operation
    c. Interaction rate
    d. Dead time
    e. Paralyzable or nonparalyzable
    f. Current mode operation
    g. Detection efficiency
12. Ionization chambers
13. 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. 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. Two types of survey instruments: Ionization chamber or referred to as a cutie-pie
    b. A Geiger-Mueller counter
3. The Quality control procedures for survey instruments
    a. Check batteries
    b. Calibration
    c. Constancy
4. A portable survey instrument
5. How to use portable survey instruments

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
10. Parts List
    a. Model 14C Survey Meter
11. Drawings

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. Survay Instruments
2. Other Radiation Detection Instruments
    a. Wipe Test Procedure
    b. Dose Calibrator
    c. Decay-in-Storage Form
    d. Survey Meter
    e. 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

XII. Dose Calibrator

1. Deffinition
2. Basic Design
3. Quality Control

4. Procedure for Calibrating
5. Constancy Test Procedures
6. Linearity Test Procedures
    a. Decay Method
    b. Shield Methods
    c. Calibration of the Sleeves
    d. Calibration of the Dose Calibrator
7. Geometry Test Procedures
8. Accuracy Test Procedures

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 10

Title: Alpha and Beta Decay (60 minutes)

Keywords: Molecular theory, Ion, Matter, Atom, Isotope, Negatron, Proton, Neutron, Electron, Alpha decay, Negative Beta Decay, Bremsstrahlung, X-rays, Emission

Objectives:
- Discuss the theory of matter
- Review scientific models
- Review the history of atoms
- Discuss atomic theory
- List the nuclear families
- Review the characteristics of nuclear decay
- Review radionuclide notation
- Review alpha decay
- Discuss properties of alpha decay
- Discuss alpha decay transformation
- Review beta particle theory
- Discuss beta decay
- Review beta nuclear transformation
- Discuss beta ionization pathways
- List common beta particles

Content:

I. **Atomic Molecular Theory of Matter**
1. Theory of matter
2. Scientific models
3. Atom
4. Indirect evidence
5. History of the atom
   a. Democritus
   b. Niels Bohr
   c. Isotopes
   d. Radioactive decay
   e. Henri Becquerel
6. Electrically Nutral Atom and Ion
7. Atom
8. Subatomic particles
   a. Proton
   b. Neutron
   c. Electron
9. Atomic structure

II. Radioactive Decay
1. Radioactive decay emission
   a. Alpha particle (a)
   b. Beta particle (b)
   c. Gamma ray(g)

III. Alpha decay

1. Helium nucleus
2. Alpha Particles Properties
    a. Mass
    b. Charge
    c. Specific Ionizations (SI)
    d. Linear Energy Transfer (LET)
    e. Energy
    f. Range in Air
    g. Penetrating Power
    h. Best Shielding
3. Straight Line Paths
4. Alpha Decay Equation
5. Method of Alpha Particle Interaction in Matter

III. Negative Beta (b-) Decay

1. Beta decay
2. Negatron
3. Negative Beta Particle
4. Negative Betas Properties
    a. Charge
    b. Mass
    c. Specific Ionizations (SI)
    d. Linear Energy Transfer (LET)
    e. Range in Air
    f. Energy
    g. Paths in matter
    h. Penetrating Ability
    i. Best shielding
5. Bremsstrahlung (braking radiation or x-rays)
6. Negative Beta Decay Equation
7. Used B-emitters in Medical Research and Therapy
8. Radioactive Decay Schemes
9. Radioactivity

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 11, Part 1

Title: 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 Law

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

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 11, Part 2

Title: Atomic and Nuclear Structure (60 minutes)

Keywords: Atoms, Electrons, Protons, Neutrons, Atomic Number (Z-Number), Mass Number (A-Number), Isotope, Isotones, Isobars, Isomers, Radioisotope, Radionuclide, Radioactivity, Radiation Energy Units, Radionuclide Production, Radiopharmaceuticals

Objectives:
- Review the properties of atomic particles
- Discuss nuclear terminology
- Discuss atomic nomenclature
- Review electronic transitions
- Examine energy units
- Discuss decay constants
- List the various decay modes
- Review decay schemes
- Discuss radionuclide production methods
- Discuss Cyclotrons
- Discuss Reactors
- Discuss Generators
- Review transient and secular equilibriums
- List ideal characteristics of radiopharmaceuticals
- List the various mechanisms of localization

Content:

I. Matter
1. Atoms
   a. Protons
   b. Electrons
   c. Neutrons
2. Properties of Atomic Particles

II. Atomic Nomenclature
1. Atomic Number (Z-Number)
2. Mass Number (A- Number)
3. Chemical identity
4. Designation technique

III. Nuclear terminology
1. Isotope
2. Isotones
3. Isobars
4. Isomers
5. Isotopes of hydrogen
6. Radioisotope
7. Radionuclide

IV. Radioactivity
1. Disintegration
2. Probability
3. Electronic transitions

4. Characteristic x-ray
5. Element
6. X-ray
7. Gamma ray

V. Radiation Energy Units

1. Energy
2. Penetrating power
3. Joule
4. Electron-volt (eV)
5. Comparison of Energies
6. Macroscopic scale
7. Microscopic and atomic level
8. Energy unit multiples

VI. Radioactivity, Radionuclide Production & Radiopharmaceuticals

1. Activity
2. Decay constant
3. Physical half-life
4. Fundamental decay equation
5. Nuclear transformation
6. Alpha decay
7. Beta-minus (Negatron) decay
8. Beta-plus decay (Positron Emission)
9. Electron capture decay
10. Isomeric transition
11. Decay schemes
12. Generalized decay scheme
13. Radionucleide productions
    a. Cyclotrons
    b. Nuclear reactors
    c. Neutron activation
    d. Radionuclide generators
    e. Transient equilibrium
    f. Secular equilibrium
14. Ideal radiopharmaceuticals
15. Mechanisms of localization

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 12

Title: Background Radiation (45 minutes)

Keywords: Radioactivity, Radioisotopes, Alpha rays, Gamma rays, Beta rays, Natural Background Radiation, Modifications of Natural Sources, Technologically Modified Sources, Dose Equivalent, Harmful radiation, Radioactive Decay, Energy barrier, Half-life, Hot Lab, PET Tracers

Objectives:
- Define radioactivity
- Discuss sources of ionizing radiation
- Review background radiation levels from state to state
- Discuss radiation effect outcomes
- Review the various radioisotopes found in the PET department

Content:

I. Radioactivity
1. History
2. Kinds of radiation
   a. Alpha rays
   b. Beta rays
   c. Gamma rays
3. Radioactive decay

II. Sources of Ionizing Radiation
1. Natural Background Radiation
   a. Cosmic
   b. Cosmogenic
   c. Terrestrial
2. Modifications of Natural Sources
   a. Fossil Fuels
   b. Phosphate Fertilizers
   c. Enhanced Exposure as a Result of Air Travel
   d. Consumer Products
3. Technologically Modified Sources
   a. Fallout
   b. Nuclear Power Production
   c. Occupational Exposure
   d. Medical Exposure

III. Radiation Levels
1. Estimated Annual Dose Equivalent (mrem) From Natural Sources
2. Sources of Radiation Exposure
   a. Technologically Underdeveloped Nations
   b. Technologically Developed Nations

IV. Radiation Effect Outcomes
1. Harmful radiation
2. Radioactive Decay
   a. Alpha decay

b. Gamma decay
c. Beta decay
3. Energy barrier
4. Half-life

V. Isotopes stored in the NM Department

1. Nuclear Medicine Hot Lab
2. PET Tracers
   a. F-18
   b. F-18 (FDG)
   c. Cs-137
   d. Ba-133
   e. Ge-68
   f. Co-56
   g. Tc99m

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 13

Title: Gamma Decay, Positron Decay, and Electron Capture (60 minutes)

Keywords: Atomic theory, Gamma Ray, Photons, General Gamma Decay Equation, Specific Ionizations, Type of Radiation, Positron (b+) Emissio, Protons, Annihilation processes, Positron Decay Equation, Electron Capture (EC)

Objectives:

- Review the pioneers of early Greek atomic theory
- Discuss how gamma rays are formed, the properties of gamma rays and common sources of gamma rays
- Calculating gamma ray equations, gamma ray isomeric transformation equations, positron nuclear transformation equations and electron capture nuclear transformation equations
- Review gamma ray specific ionizations
- Explain annihilation and resultant processes
- Describe the properties of positrons
- Review comparison of ionization events
- List biologically useful positron emitters
- Define electron capture
- Illustrate the properties of electron capture and common radioisotopes that decay via electron capture

Content:

I. Atomic theory

1. Early Greek atomic theory
    a. Democritus
    b. Aristotle
2. Modern atomic model
    a. John Dalton
    b. Adding Electrons to the Model
    c. Thompson
    d. The Rutherford model
    e. Bohr's model
    f. Bohr - Rutherford diagrams
    g. Isotopes and Radioisotopes

II. Gamma Rays

1. Photons
    a. Properties of Photon (x and g) Radiation
    b. Gamma photons and Electromagnetic Radiation
2. The Electromagnetic Energy Spectrum
    a. Cosmic
    b. X-rays and Yg-rays
    c. UV
    d. Visible
    e. IR
    f. Microwaves
    g. RF
3. General Gamma Decay Equation

4. Radionuclides that Emit Gamma Radiation
5. Important Facts to Remember
6. Gamma Ray Specific Ionizations
    a. Type of Radiation
7. Protection from Any Form of Radiation
    a. Time
    b. Distance
    c. Shielding

III. Positron (b+) Emission

1. Protons
2. Properties of Positrons
    a. Charge
    b. Mass
    c. SI and LET
3. Energy Requirement for Positron Emission

IV. Annihilation and resultant processes

1. Positron Interaction in Matter
2. Annihilation Radiation
3. Positron Decay Equation
4. Biologically Useful Positron Emitters

V. Electron Capture (EC)

1. The Properties of Electron Capture
2. Electron Capture Transformation
3. Electron Capture Decay Equation
4. Radionuclides That Decay by Positron Emission or EC

VI. Important Note

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 14

Title: Radioisotope Production (90 minutes)

Keywords: Radionuclide, Production, Reactor-Produced, Molybdenum-99, Gadolinium-153, Iodine-131, Xenon-133, Accelerator, Development of Linear Energy Accelerators (LINACS), Cyclotron, Current Cyclotron, Commercial cyclotron, Medical cyclotron, Thallium-201, Indium-111, Gallium-67, Fluorine-18, Iodine-123, Generator, Technetium Tc99m, Gallium-68, Rubidium-82

Objectives:

- Discuss Radionuclide
- Review Natural Radionuclide
- Review Artificial Radionuclide
- Describe Production of Radionuclide for Imaging
- Describe Reactor-produced Radionuclide
- Discuss Accelerator Produced Radionuclide
- Describe Development of Cyclotrons
- Discuss Radioisotope Generator
- Review Tc99m, Gallium-68 and Rubidium-82 Generators

Content:

I. Radionuclide

1. Natural Radionuclide
   a. Primordial radionuclides
   b. Secondary radionuclides
   c. Cosmogenic radionuclides
2. Methods of Production of Radioisotopes
   a. Thermal Neutron Reactor-produced
   b. Cyclotron-produced
   c. Fission reactor-produced
   d. Generator-produced
3. Artificial Radionuclide
   a. Specific activity
   b. Chemical purity
   c. Radiochemical purity
4. Flux/power level requirements
   a. Low flux reactors
   b. Medium flux reactors
   c. High flux reactors

II. Production of Radionuclide for Imaging

1. Reactor-Produced Radionuclides
   a. Enriched uranium
   b. Natural uranium
   c. Principles Of Operation
   d. Fission Fragments
   e. Neutron Activation
   f. Irradiation efficiency
      - Choice of target material
      - Target encapsulation

g. Laboratory facilities
h. Layout and basic infrastructure
i. Radioisotope handling facilities
   - Fume hoods
   - Glove boxes
   - Shielded tong boxes
   - Hot cells
   - Ventilation Ventilation
j. Management of radioactive waste
   - Solid wastes
   - Liquid wastes
   - Gaseous wastes
k. Surveillance and monitoring
   - Personnel monitoring
   - Area monitoring
   - Air monitoring
   - Contamination monitoring
l. Packing and transportation of radioisotopes
m. Transport regulations
   - Types of packages

2. Molybdenum-99 Production Processes
   a. Reactor neutron activation production of 99Mo
   b. Methods for the production
      - Reactor neutron activation of 98Mo
      - Fission of 235U
   c. Uranium fission produced 99Mo
   d. Target specification and preparation
   e. Irradiation
   f. Processing facility
   g. Analysis of raw materials, reagents and chemicals required for processing
   h. Chemical processing
   i. Dispensing, assay and quality control
   j. Final product specification
   k. Waste management
   l. Practical experience gained
   m. Comparison of Fission and Neutron Produced 99Mo
3. Gadolinium-153
4. Iodine-131 & Xenon-133

III. Accelerator Produced Radionuclides

1. Classification of Accelerators
2. Development of Linear Energy Accelerators (LINACS)
   a. Principle of operation
   b. Radiofrequency acceleration
   c. Structure of the linac
   d. High vacuum
   e. Radiofrequency quadrupole
   f. Current linacs
3. Development of Cyclotrons
   a. Principle of operation
   b. Radiofrequency acceleration
   c. Magnetic field for a circular path
   d. Ion sources
   e. Vacuum systems
   f. Extraction systems

4. Current Cyclotrons
   a. Negative and positive ion machines
   b. Extraction of beams
   c. Energies and particles
   d. Characteristics of commercial cyclotrons
      - Operating costs
      - Maintenance
      - Typical Spare Parts Inventory
   e. Medical cyclotrons
5. Main Radioisotopes for medical
   a. Thallium-201
   b. Indium-111
   c. Gallium-67
   d. Fluorine-18
   e. Iodine-123
   f. Bromine-77
   g. Rubidium-81
6. PET Radioisotope
7. Cyclotron Produced Radioisotopes

IV. Radioisotope Generator

1. Ideal Generator Systems
2. Why radionuclide generator?
3. Technetium Tc99m Generator
4. Gallium-68 generator
5. Rubidium-82

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 15

Title: Production of Radionuclides (60 minutes)

Keywords: History, Radionuclides, Radioisotopes, Generator, 99Mo-99mTc Generator, Strontium 82/Rubidium 82 Generator, High Energy RadioIsotopes, PET, Imaging

Objectives:

- Discuss the History and Founders of Radiochemistry
- Review the early uses of radioisotopes
- Discuss the ideal characteristics of radioisotopes
- Review the various sources of radioisotopes
- Outline the different generators systems
- Review the Mo99/Tc99 Generator System
- Review the Strontium 82/Rubidium 82 Generator
- Outline the components of a generator system
- Review the differences between Secular versus Transient Equilibriums
- Review other types of radionuclides used in Nuclear Medicine
- Review the PET Radioisotopes

Content:

I. History and Founders of Radiochemistry

1. George de Hevesy (1912)
2. Hermann Blumgart (1926)
3. John Lawrence (1937)
4. E. Segre and C. Perrier (1937)
5. Joe Hamilton (1939)
6. Charles Pecher (1939)
7. Samuel Seidlin (1946)
8. Tucker and Greene, Mo-99/Tc-99m generator (1957)
9. Powell Richards (1960)
10. Paul Harper (1963)

II. Ideal Characteristics of a Radionuclides

1. Nuclear Properties
2. Wide Availability
3. Effective Half life (Radio and biological)
4. High target to non target ratio
5. Simple preparation
6. Biological stability
7. Cost

III. Sources of Radioisotopes used in Nuclear Medicine

1. Generator Produced Radioisotopes
2. Reactor Produced Radioisotopes
3. Cyclotron Produced Radioisotopes
4. History
5. Ideal Characteristics for a Generator

IV. Different Generators Systems

1. 99Mo-99mTc Generator
2. Mallinckrodt/Tyco 99mTc Generator
3. Common radiochemical generators
4. Transient versus Secular Decay

V. Strontium 82/Rubidium 82 Generators Systems used in PET

1. Introduction
2. Generator system
3. Rubidium-82
4. Specialty of the generator
5. Patient care
6. Methods
7. Quality control
8. Assay

VI. Other types of Radionuclides used in Nuclear Medicine

1. Gallium & Indium Radionuclides
2. Thallium & Iodine Radionuclides

VII. High Energy RadioIsotopes used in PET Imaging

1. PET Radiotracers
2. PET RadioIsotopes
3. Oxygen 15 and Carbon 11
4. Nitrogen 13 and Fluorine 18
5. Reactor-Produced Radionuclides
6. Specific Activity
   a. Fission Product Separation
   b. Accelerator –Produced Radionuclides

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 16

Title: 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. Synthesis 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

1. F18- fluorodeoxyglucose
2. 6-F18-L-Fluorodopa
3. N13-Ammonia

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 17

Title: PET Quality Control Procedures (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
1. Quality Control for PET
2. 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
3. PET Scanners Quality Control
4. 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)
5. 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

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 18

Title: 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
1. Dose calibrator
2. Survey Meter
3. Unit Dose Manager
4. 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

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 19

Title: 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
- Describe packaging, marking and labeling
- Define documentation requirements
- Discuss emergency response information
- Illustrate the examples

Content:

I. Regulations
1. DOT 49 CFR
2. IATA
3. USPS Restrictions
4. Who Must be Trained?
5. Initial and Recurrent Training
6. DOT Training Requirements
7. 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

Module I: "Content Pertaining to a RAM Licenses": You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 20

Title: 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 I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 21

Title: Radiation Physics & Instruments (90 minutes)

Keywords: Atomic Structure, Nuclear Structure, Ionizing radiation, Non-ionizing radiation, Electromagnetic, Photon energy, Health risks, Directly ionizing, Indirectly ionizing, Radioactivity, Half-life Radioactivity, Decay Formula, Measurement

Objectives:

- Discuss Atomic and Nuclear Structure
- Review Radiation
- Discuss Non-ionizing radiation and types
- Discuss Ionizing electromagnetic radiation and types
- Explain Radioactivity
- Discuss Half-life Radioactivity
- Illustrate Formulas for half-life and Decay Formula
- Discuss Radiation Measurement Terms

Content:

I. Atomic and Nuclear Structure

1. Matter
    a. Solid
    b. Liquid
    c. Gas
    d. Plasma
2. Elements
3. Compound
4. Molecule
5. Atom
    a. Subatomic particles
    b. Atomic Nucleus
    c. Protons and Neutrons
6. Electronic Structure of Atoms
    a. Properties of Subatomic Particles
    b. Quantum
7. Fundamental properties of atoms
    a. Atomic number or Proton number
    b. Number of neutrons
    c. Mass number
    d. Atomic charge
8. Isotopes
9. Isobar and Isotones

II. Radiation

1. Ionizing and Non-ionizing radiation
    a. Excitation or Ionization
2. Electromagnetic radiation
3. Basic properties of waves
    a. Amplitude
    b. Wavelength
    c. Frequency

4. Photon energy
5. Basic Properties of Photons
6. Calculation the energy of a photon of electromagnetic radiation

III. Non-ionizing radiation

1. Types of non-ionizing electromagnetic radiation
    a. Near ultraviolet radiation
    b. Visible light
    c. Infrared
    d. Microwave
    e. Radio waves
    f. Very low frequency (VLF)
    g. Extremely low frequency (ELF)
    h. Thermal radiation
    i. Black body radiation
2. Health risks

IV. Ionizing electromagnetic radiation

1. Types of ionizing radiation
    a. Directly ionizing
        - Alpha Particles
        - Beta Particles
        - Bremsstrahlung Radiation
        - Production of beta particles
        - Positrons and other types of antimatter
        - Photon radiation
        - Photon Interactions
    b. Indirectly ionizing
        - Neutrons
    c. Penetration power
2. Sources of ionizing radiation
    a. Natural background radiation
        - Cosmic radiation
        - Terrestrial radiation
        - Inhalation
        - Ingestio
3. Summary of Different Types of Radiation

V. Radioactivity

1. Radioactivity and Radioisotopes
2. Causes Radioactivity
3. Nuclear transmutation

VI. Half-life Radioactivity

1. Formulas for half-life in exponential decay
2. Decay Formula
    b. Problems and Solved Examples
3. Measures of Radioactivity
4. Radiation Quantities and Units
    a. Unit Systems
    b. Radiation Units and Conversion Factors
    c. Quantities
    d. Photons
    e. Photon Concentration (Fluence)
    f. Total Photons

VII. Radiation Measurement Terms

1. Exposure (R) / Coulomb Per Kilogram of air (C/kg)
2. Air Kerma
3. Surface Integral Exposure
4. Dose Area Product (DAP)
5. Energy
6. Energy Fluence
7. Total Energy
8. Absorbed Dose
9. Absorbed Dose Units
10. Computed Tomography Dose Index (CTDI)
11. Mean Glandular Dose (MGD)
12. Mean Glandular Dose (MGD)
13. Integral Dose
14. Dose Length Product (DLP)
15. Biological Impacts
16. Dose Equivalent
17. Relative Biological Effectiveness
18. Effective Dose
19. Tissue Weighting Factors
20. Radio Frequency Radiation
21. Specific Absorption Rate (SAR)
22. Counts Per Minute (CPM)

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 22

Title: Radiation Dosimetry and Unit of Radiation (90 minutes)

Keywords: Linear Energy Transfer (LET), Health Effects, Dosimetric Quantities, Units, Radiation, Measurement, Terms, Protection Quantities, Relative Biological Effectiveness (RBE), Operational Quantities, Effective Dose, Equivalent dose, Committed dose equivalent (CDE), Committed effective dose equivalent (CEDE), Dosimetry, External Dosimetry, Film dosimeters (film badge), Thermoluminescent dosimeters (TLDs), Optically stimulated luminescence dosimeters (OSLDs), Direct reading dosimeters (DRDs), Neutron radiation, Photon and Beta radiation, Electronic personal dosimeter (EPD), MOSFET dosimeter, Quartz fiber dosimeter (QFD), Internal Dosimetry, In-vivo bioassay, Medical Dosimetry, Gel Dosimetry, Continuous particulate air monitors (CPAMs), Annual Limit of Intake (ALI)

Objectives:
- Background Overreview
- Review Linear Energy Transfer (LET)
- Describe Health Effects
- Discuss Dosimetric Quantities and Units
- Define Radiation Measurement Terms
- Discuss Protection Quantities
- Discuss Operational Quantities
- Discuss Committed Effective Dose
- Describe Dosimetry
- List External and Internal Dosimetry
- Calculating External and Internal Radiation Doses
- Discuss Medical Dosimetry
- Discuss Airborne particulate radioactivity monitoring
- Explain Annual Limit of Intake (ALI)

Content:

I. Background

II. Introduction

III. Linear Energy Transfer (LET)

IV. Health Effects
1. Stochastic Effects
2. Tissue Reactions

V. Dosimetric Quantities and Units
1. Quantities for radiation measurement and dose assessment
   a. Physical quantities
      - Fluence and Flux
      - Exposure
      - Kerma
      - Absorbed dose
   b. Protection quantities
   c. Operational quantities
2. Unit Sistem

3. Quantities
4. Photons
    a. Photon Concentration (Fluence)
    b. Total Photons

VI. Radiation Measurement Terms

1. Exposure (R) / Coulomb Per Kilogram of air (C/kg)
2. Air Kerma
3. Surface Integral Exposure
4. Dose Area Product (DAP)
5. Energy
6. Energy Fluence
7. Computed Tomography Dose Index (CTDI)
8. Mean Glandular Dose (MGD)
9. Integral Dose
10. Dose Length Product (DLP)
11. Biological Impacts
12. Total Energy
13. Absorbed Dose
    a. Units
14. Averaging of Dose
15. Mean Absorbed Dose
16. Radio Frequency Radiation
17. Specific Absorption Rate (SAR)
18. Counts Per Minute (CPM)

VII. Protection Quantities

1. Primary physical quantities are not used directly for dose limitation
    a. Radiation weighting factor, wR
    b. Tissue weighting factor, wT
    c. Equivalent dose
    d. Effective dose
2. Relative Biological Effectiveness (RBE)

VIII. Operational Quantities

1. Area Monitoring
    a. Ambient dose equivalent
    b. Directional dose equivalent
2. Personal dose
3. System of Quantities for Radiobiological Protection
4. Ambient Dose Equivalent
5. Directional Dose Equivalent
6. Expended radiation field
7. Personal Dose Equivalent
8. Different operational dose quantities and their use
9. Radiological Quantities and Units

IX. Committed Effective Dose

1. Committed equivalent dose
2. Committed effective dose
3. Dose intake
4. Duration
5. Measurement
6. Related quantities
7. Committed dose equivalent (CDE)
8. Committed effective dose equivalent (CEDE)

X. Dosimetry

1. Direct monitoring
2. Indirect monitoring
3. Types of radiation exposure
    a. External exposure
    b. Internal exposure
4. Methods for radiation doses to humans
    a. Personal dosimetry
    b. Indirect monitoring using measured dose rates or airborne concentrations of nuclear substances
    c. Indirect monitoring using environmental pathways analysis
5. Radiation Protection and Dose Limitation
    a. Regulatory Requirement
    b. Personnel Monitoring
    c. Area Monitoring
    d. Transportation of Radioisotopes

XI. External Dosimetry

1. Deffinition
2. About dosimeters
3. General characteristics
    a. Passive dosimeter
    b. Active dosimeter
4. Choosing a dosimeter
    a. Energy dependence and angle dependence
    b. Radiation type to be detected
    c. Fading
    d. The ability to be re-read
    e. Ruggedness and ease of wear
5. Dosimetry for photon and beta radiation
    a. Film dosimeters (film badge)
    b. Thermoluminescent dosimeters (TLDs)
    c. Optically stimulated luminescence dosimeters (OSLDs)
    d. Direct reading dosimeters (DRDs)
    e. Where and how to used?
6. Dosimetry for neutron radiation
    a. About dosimeters
    b. Solid-state nuclear track detectors
    c. Portable neutron survey meters
    d. Where and how to used?
7. Measurement uncertainty in external dosimetry
8. Methods to monitor workers for external radiation exposure
9. Other types of personal dosimeters for ionizing radiation
    a. Electronic personal dosimeter (EPD)
    b. MOSFET dosimeter
    c. Quartz fiber dosimeter (QFD)

XII. Internal Dosimetry

1. Deffinition
2. Methods for estimated the level of radiation inside a person's body
    a. In-vivo bioassay (direct measurement of radioactivity in the body)
        - Whole-body counters
        - Lung counters
        - Thyroid counters
    b. In-vitro bioassay (measurement of radioactivity in a person's urine or feces)

        - Liquid scintillation analyzer
        - Analysis of urine and feces for the presence of nuclear substances other than tritium
    c. Measurement of radioactivity in workplace air
3. Calculation internal radiation doses
4. Measurement uncertainty in internal dosimetry

XIII. Medical Dosimetry

1. Deffinition
2. Gel dosimetry

XIV. Airborne particulate radioactivity monitoring

1. Continuous particulate air monitors (CPAMs)
2. Monitoring vs. Sampling
3. CPAM types
    a. Fixed-filter
    b. Moving-filter
4. CPAM applications
    a. Effluent monitoring
    b. Occupational exposure assessment

XV. Annual Limit of Intake (ALI)

1. Deffinition
2. Derived Working Limits for Radon
3. Derived Air Concentration

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 23

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

Content:

I. The Rationale for Radiation Protection

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

II. Radiation Protection Programs

1. Reasons for Radiation Protection Programs
2. Regulations
   a. 10 CFR 20
   b. 10 CFR 35
3. 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
4. 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
      - Inhalation
      - Ingestion
      - Absorption
      - Injection
   b. Routes of Intake, Transfers and Excretion
   c. Tissue Damage and Health Effects
6. Waste Disposal Guidelines
   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. Why is PET Different?
   b. Higher Exposure Rate Constants
   c. Higher Dose Rate From Patients
   d. PET Shielding: Tenth Value Layers
   e. Shorter Physical Half-Life
   f. 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. 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 Calculati ons

1. Occupational Exposure Protection of the Worker
2. F-18 FDG PET
   a. Studies
   b. Exposure factors
   c. Dose Factors
3. Other PET Isotope Data
4. Exposure
5. Shields
   a. Bench top shield
   b. Vial shields
   c. Syringe shields
   d. Structural shielding
6. Shielding of Sources
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
3. Pregnant or Potentially Pregnant Radiation Worker
    a. Risks prenatal radiation exposure
    b. Occupational dose limit
    c. Notification of employer about pregnancy
    d. Mutual Responsibilities
4. Methods to Reduce Occupational Exposure for the Pregnant Worker
5. Radiation Safety Officer (RSO)

IX. Internet Resources

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 24

Title: Radiation Protection, ALARA and Personal Monitoring (120 minutes)

Keywords: Radiation, Protection, Radiation-induced, Biological effects, Ionizing, High LET, Low LET, Deterministic effects, Stochastic effects, Occupational exposures, Public exposures, Medical exposures, Principles, ALARA, Pregnant, Non-radiation, Dose Limits, Nuclear Energy Workers, Labeling, Signs, Monitoring, Bioassays, Employees standards, Areas, Lead Apron, Dosimeter, Dosimetry Terminology, Cesium-137, Iodine – 125, Iodine – 131, Iridium – 192, Pailadium – 103, Phosphorus – 32, Strontium – 89, Acute Radiation Syndrome (ARS), Cutaneous Radiation Syndrome (CRS), Reduce exposure, Shielding

Objectives:
- Discuss Radiation protection and how do we quantify the amount of radiation
- Explain Nature (mechanism) of radiation-induced biological effects
- Review Classification of radiation effects, Principles of radiological protection and Categories of exposure
- Define Principles of radiation protection in medical fields
- Explain ALARA principle
- Discuss Obligations of Licensees and Nuclear Energy Workers
- Describe Personnel Exposure Monitoring
- Review Notice to employees standards for protection
- Rewiew Classification of Areas
- Discuss Shielding and Lead Apron
- Describe General Instructions for Dosimeter and Dosimetry Terminology
- Define health Care Provider Radiation Safety
- Rewiew Radiation Emission Guidelines
- Rewiew Bioassay services
- Discuss Effects of High doses of radiation, Acute Radiation Syndrome (ARS) and Cutaneous Radiation Syndrome (CRS)

Content:

I. Introduction
1. Radiation protection
   a. International Committee on Radiation Protection (ICRP)
   b. International Commission on Radiation Units and Measurements (ICRU)
2. Principles
   a. Internrtional Policy Relationships for Radiological Protection
3. How do we quantify the amount of radiation?

II. Nature (mechanism) of radiation-induced biological effects
1. Biological Effects of Ionizing Radiation Cell
2. High LET radiation and Low LET radiation
3. DNA is a target of Radiation

III. Classification of radiation effects
1. Deterministic effects
2. Stochastic effects
   a. Malignant neoplasms (cancer)
   b. Hereditary mutations

IV. Principles of radiological protection

1. Principle of Justification
2. Principle of Optimization of Protection
3. Principle of Application of Dose Limits

V. Categories of exposure

1. Occupational exposures
2. Public exposures
3. Medical exposures of patients

VI. Principles of radiation protection in medical fields

1. Unique characteristics of radiological protection in medicine
2. Application of principles of radiation protection in medical fields
    a. Justification of exposure
    b. Optimization
    c. Diagnostic reference levels
3. Current Status of Medical Radiation Exposure
    a. Increasing use of medical radiation
    b. Dose Limits Recommended by ICRP
    c. Examples of Typical Radiation Doses and Dose Limits or Reference Levels

VII. ALARA principle

1. «As Low as Reasonably Achievable»
2. Biological Basis
3. Dose limits and optimization of protection
4. Operational Dose Limits
5. Collective Dose
6. Employee Responsibility
    a. Awareness
    b. Compliance
7. ALARA Principles for Mitigating External Radiation Hazards
    a. Acute amd Chronic exposure
    b. Three basic ways of controlling exposure
        - Time
        - Distance
        - Shielding
        - Examples Calculations
        - Calculating Intensity with the Inverse Square Law
        - Fume Hoods
8. General principles for mitigating internal radiation hazards
    a. Good Hygiene
    b. Control of Contamination
    c. Airborne Hazards
    d. Protective Clothing
    e. Disposable Gloves
    f. Respiratory Protection
9. ALARA Exposure Investigation Levels
    a. External Exposure
    b. Quarterly ALARA Investigation Levels
    c. Exposure Limits
    d. ALARA Level I
    e. ALARA Level II
10. Personal Protective Equipment (PPE)
11. Pregnant Worker and ALARA

VIII. Obligations of Licensees and Nuclear Energy Workers

1. Administration of Nuclear Substance for Medical Purposes
2. Radiation Protection Program
    a. Management control over work practices
    b. Personnel qualification and training
    c. Control of occupational and public exposure to radiation
    d. Planning for unusual situations
3. Action Levels
4. Provision of Information
5. Requirement to Use Licensed Dosimetry Service
6. Collection of Personal Information
7. Nuclear Energy Workers
8. Pregnant Nuclear Energy Workers
9. Non-radiation Workers and the Public
10. Radiation Dose Limits
    a. Interpretation
    b. Effective Dose Limits
    c. Emergencies
    d. When Dose Limit Exceeded
11. Labeling and Signs
    a. Labeling of Containers and Devices
    b. Shipping Labels
    c. Warning Labels
    d. Warning Loops
    e. Hazard Tape
    f. Nuclear Medicine Labels
    g. Plastic Caution Signs
    h. Pressure Sensitive Warning Labels
    i. Posting of Signs at Boundaries and Points of Access
    j. Use of Radiation Warning Symbol

IX. Personnel Exposure Monitoring

1. Determination of the Need for Personnel Monitoring
2. Procedures for Initiating Personnel Monitoring
3. Types of Personnel Monitoring
    a. Whole body badge
    b. Ring badge
4. Frequency of Personnel Monitoring
5. Exchanging Personnel Monitoring Devices
6. General Procedures for the Care and Use of Personnel Monitoring Devices
7. Exposure Reports and Histories
8. Bioassays
    a. Thyroid Bioassays
    b. Urine Bioassays

X. Notice to employees standards for protection

1. Employees Responsibilities
2. Scope of the Standards
3. Reports on your Radiation Exposure History
4. Inspections
5. Posting Requirements

XI. Classification of Areas

1. Purpose of Designated Areas
2. Controlled areas
3. Supervised areas

4. Uncontrolled areas
5. Public areas (public dose limits)

XII. Lead Apron

1. Definition
2. Understand Lead & Lead Equivalent Options
3. What Are the Minimum Required Levels for Lead Radiation Shielding?
4. How Much Radiation Protection Is Provided at Various Levels?
5. How Should Lead Aprons Be Stored?
6. Do Lead Aprons Need to Be Inspected?
7. Inspection and Inventory
   a. What are the requirements for lead apron inspection?
   b. What should the inspection method be?
      - Visual (looking at the apron)
      - Tactile (feeling the apron for holes)
      - Fluoroscopy or x-ray
   c. How do we know when an apron passes/fails inspection?
      - Tearing
      - Defective Velcro, Buckles or Ties
   d. Defects in relation to placement
   e. Keeping track of inspections
8. Medical personnel working with radiation

XIII. General Instructions for Dosimeter

1. How to ensure you get the best results from your Radiation Dosimetry Service
2. Dosimetry Terminology
   a. Fetal badge
   b. Dose History
   c. Spare Badge
   d. Area Monitor
   e. Whole-body
   f. Extremity Dosimeter
   g. Millirem (mrem)
   h. Webster Calculation
   i. Minimum Reportable Dose
   j. TEDE - Total Effective Dose Equivalent
   k. DDE - Deep-dose equivalent (Hd)
   l. EDE - Effective dose equivalent (HE)
   m. CDE - Committed dose equivalent (HT,50)
   n. CEDE - Committed Effective Dose Equivalent
   o. Rem
   p. Sievert
   q. Gray (Gy)
   r. RAD
3. How to ensure you get the best results from your Radiation Dosimetry Service
4. Personal Monitoring Equipment for External Exposures
   a. Individual monitoring (I, II, III)
   b. Individual monitoring when a lead apron is used (I)
5. Exposure assessment
6. Dosimeter Types
   a. Body Dosimeter
   b. Chest Badge (sometimes called Waist or Whole Body Badge)
   c. “Single-Badging" for Fluoroscopy Users
   d. Whole Body and Collar Dosimeters
   e. Ring dosimeter
   f. Wrist Band dosimeter

g. Fetal Badge
7. Dose limits – Typical staff doses
8. Badge Use
9. How to store your dosimetry?
10. Sharing badges
11. Emergency Processing

XIV. Health Care Provider Radiation Safety

1. Cesium-137
2. Iodine – 125
3. Iodine – 131
4. Iridium – 192
5. Pailadium – 103
6. Phosphorus – 32
7. Strontium – 89

XV. Radiation Emission Guidelines

1. Diagnostic Tests
2. Treatment or Therapy

XVI. Bioassay services

XVII. Effects of High doses of radiation

1. Deterministic effects
2. Stochastic effects
3. Acute Radiation Syndrome (ARS)
   a. Bone marrow syndrome
   b. Gastrointestinal (GI) syndrome
   c. Cardiovascular (CV)/ Central Nervous System (CNS) syndrome
   d. Stages of ARS
      - Prodromal stage (N-V-D stage)
      - Latent stage
      - Manifest illness stage
      - Recovery or death
4. Effects on Embryo / Fetus
5. Patients and Pregnancy
6. Cutaneous Radiation Syndrome (CRS)

XVIII. Reducing exposure

1. Use Available Shielding
2. Protective aprons
3. Lead glasses & thyroid shields
4. Protective screens & curtains
5. FDA Recommendations

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 25

Title: NRC Regulations Part 1 (120 minutes)

Keywords: NRC, Nuclear Regulatory Commission, Terminology, Definition, Notice, Instruction, Report, Inspection, Investigation, Licensee, Worker, Employee protection, Violation, Sequestration, Florida Administrative Code, Standard for Protection Against Radiation, Occupational Dose, External Dose, Internal Exposure, Dose Limit, Embryo, Fetus, Monitoring, Restricted Area, Source of Radiation, Precautionary Procedures, Waste Management, Record.

Objectives:
- Discuss Notices, Instructions and Reports to Workers: Inspection and Investigations
- Review Definitions
- Explain Information collection requirements: OMB approval
- Describe Instruction to workers
- Discuss Standards for Protection Against Radiation

Content:

I. Notices, Instructions and Reports to Workers: Inspection and Investigations (NRC: 10 CFR Part 19)

1. Purpose
2. Definitions
   a. Act
   b. Commission
   c. Exclusion
   d. License
   e. Regulated activities
   f. Regulated entities
   g. Restricted area
   h. Sequestration
   i. Worker
3. Interpretations
4. Communications
5. Information collection requirements: OMB approval
6. Instruction to workers
7. Notifications and reports to individuals
8. Presence of representatives of licensees and regulated entities, and workers during inspections
9. Consultation with workers during inspections
10. Requests by workers for inspections
11. Inspections not warranted; informal review
12. Sequestration of witnesses and exclusion of counsel in interviews conducted under subpoena
13. Employee protection
14. Violations

II. Standards for Protection Against Radiation (NRC: 10 CFR Part 20)

1. Purpose
2. Definitions
   a. "A"
      - Absorbed dose
      - Accelerator-produced radioactive material

- Act
- Activity
- Adult
- Airborne radioactive material
- Airborne radioactivity area
- Air-purifying respirator
- ALARA (acronym for "as low as is reasonably achievable")
- Annual limit on intake (ALI)
- Assigned protection factor (APF)
- Atmosphere-supplying respirator

b. “B”
- Background radiation
- Bioassay (radiobioassay)
- Byproduct material

c. “C”
- Class (or lung class or inhalation class)
- Collective dose
- Commission
- Committed dose equivalent (HT,50)
- Committed effective dose equivalent (HE,50)
- Constraint (dose constraint)
- Controlled area
- Critical Group

d. “D”
- Declared pregnant woman
- Decommission
- Demand respirator
- Derived air concentration (DAC)
- Derived air concentration-hour (DAC-hour)
- Discrete source
- Disposable respirator
- Distinguishable from background
- Dose or radiation dose
- Dose equivalent (HT)
- Dosimetry processor

e. “E”
- Effective dose equivalent (HE)
- Embryo/fetus
- Entrance or access point
- Exposure
- External dose
- Extremity

f. “F”
- Filtering facepiece (dust mask)
- Fit factor
- Fit test

g. “G”
- Generally applicable environmental radiation standards
- Government agency

h. “H”
- Helmet
- High radiation area
- Hood

i. "I"
   - Individual
   - Individual monitoring
   - Individual monitoring devices (individual monitoring equipment)
   - Internal dose

j. "L"
   - Lens dose equivalent (LDE)
   - Licensed material
   - Licensee Limits (dose limits)
   - Loose-fitting facepiece
   - Lost or missing
   - licensed material

k. "M"
   - Member of the public
   - Minor
   - Monitoring (radiation monitoring, radiation protection monitoring)

l. "N"
   - Nationally tracked source
   - NRC (Nuclear Regulatory Commission)

m. "O"
   - Occupational dose

n. "R"
   - Particle accelerator
   - Radiation (ionizing radiation)
   - Radiation area
   - Reference man
   - Respiratory protective device
   - Restricted area

o. "S"
   - Sanitary sewerage
   - Self-contained breathing apparatus (SCBA)
   - Shallow-dose equivalent (Hs)
   - Site boundary
   - Source material
   - Special nuclear material
   - Stochastic effects
   - Supplied-air respirator (SAR) or airline respirator
   - Survey

p. "T"
   - Tight-fitting facepiece
   - Total Effective Dose Equivalent (TEDE)

q. "U"
   - Unrestricted area
   - Uranium fuel cycle
   - User seal check (fit check)

r. "V"
   - Very high radiation area

s. "W"
   - Weighting factor WT, for an organ or tissue (T)
   - Working level (WL)
   - Working level month (WLM)

3. Florida Administrative Code 64E-3.002 (Definitions)
   a. Approved educational or training program
   b. General diagnostic radiographic and general fluoroscopic equipment

c. Physical presence
d. Positioning
e. Rule
f. Technique
g. Walk-in emergency center
h. Practice of radiologic technology
i. HIV/AIDS
j. Assist with managing patients undergoing radiation therapy treatments (or “assist with radiation therapy technology duties")
k. Brachytherapy
l. Duties of a medical physicist
m. Treatment planning

4. General Provisions
5. Implementation
6. Radiation Protection Programs
7. Occupational Dose Limits for Adults
8. Compliance with Requirements for Summation of External and Internal Doses
9. Determination of External Dose from Airborne Radioactive Material
10. Determination of Internal Exposure
11. Determination of Prior Occupational Dose
12. Planned Special Exposures
13. Occupational Dose Limits for Minors
14. Dose to an Embryo or Fetus
15. Dose Limits for Individual Members of the Public
16. Compliance with Dose Limits for Individual Members of the Public
17. Surveys and Monitoring
    a. General
    b. Conditions Requiring Individual Monitoring of External and Internal Occupational Dose
18. Control of Exposure from External Sources in Restricted Areas
    a. Control of Access to High Radiation Areas
    b. Control of Access to Very High Radiation Areas
19. Respiratory Protection and Controls to Restrict Internal Exposure in Restricted Areas
    a. Use of Process or Other Engineering Controls
    b. Use of Individual Respiratory Protection Equipment
20. Storage and Control of Licensed or Registered Sources of Radiation
    a. Security of Stored Sources of Radiation
    b. Control of Sources of Radiation Not in Storage
21. Precautionary Procedures
    a. Caution Signs
    b. Posting Requirements
    c. Exceptions to Posting Requirements
    d. Labeling Containers and Radiation Machines
    e. Exemptions to Labeling Requirements
    f. Procedures for Receiving and Opening Packages
22. Waste Management
    a. General Requirements
    b. Method of Obtaining Approval of Proposed Disposal Procedures
    c. Discharge by Release into Sanitary Sewerage
    d. Disposal of Specific Wastes
    e. Transfer for Disposal and Manifests
    f. Classification and Characteristics of Low Level Radioactive Waste for Near-Surface Land Disposal, Labeling and Manifest Requirements
23. Records
    a. General Provisions
    b. Records of Radiation Protection Programs
    c. Records of Surveys

d. Records of Tests for Leakage or Contamination of Sealed Sources
e. Records of Planned Special Exposures
f. Records of Individual Monitoring Results
g. Records of Waste Disposal or Transfers
h. Records of Testing Entry Control Devices for Very High Radiation Areas
i. Form of Records
j. Reports of Stolen, Lost, or Missing Licensed or Registered Sources of Radiation
k. Notification of Incidents
l. Reports of Exposures, Radiation Levels, Concentrations of Radioactive Material Exceeding the Constraints or Limits, Medical Events and Dose to an Embryo/Fetus or a Nursing Child
m. Reports of Planned Special Exposures
    - Notifications and Reports to Individuals
    - Reports of Leaking or Contaminated Sealed Sources
    - Vacating Premises
    - Reports of Transactions Involving Nationally Tracked Sources
    - Nationally Tracked Source Thresholds

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 26

Title: NRC Regulations, Part 2 (120 minutes)

Keywords: NRC, Nuclear Regulatory Commission, Byproduct Material, Definitions, Terminology, State requirements, License, ALARA, Written Directive (WD), Administrations requiring, Radiation, Safety, Training, Calibration, Labeling, Decay-in-storage, Uptake, Dilution, Excretion, Safety, Brachytherapy, Sealed Sources, Photon Emitting, Dosimetry equipment, Records, Reports, Agreement States, NUREG, US Nuclear Regulatory Commission Regulation,

Objectives:

- Discuss Medical Use Of Byproduct Material (NRC: 10 CFR Part 35)
- Discuss Possession, Use, and Calibration of Instruments Used to Measure the Activity of Unsealed Byproduct Material
- Define Unsealed Byproduct Material - Written Directive Not Required
- Define Unsealed Byproduct Material - Written Directive Required
- Discuss Manual Brachytherapy
- Review Sealed Sources for Diagnosis
- Discuss Photon Emitting Remote Afterloader Units, Teletherapy Units, and Gamma Stereotactic Radiosurgery Unit
- Review Other Medical Uses of Byproduct Material or Radiation From Byproduct Material
- Describe Records & Reports
- Discuss Agreement States
- Illustrate United States Nuclear Regulatory Commission Form

Content:

I. Medical Use of Byproduct Material

1. Law and Legal Definition
2. Purpose
3. Definitions
    a. Address of use
    b. Agreement State
    c. Area of use
    d. Authorized medical physicist
    e. Authorized user
    f. Brachytherapy
    g. Brachytherapy source
    h. Client's address
    i. Cyclotron
    j. Dedicated check source
    k. Dentist
    l. High dose-rate remote afterloader
    m. Low dose-rate remote afterloader
    n. Management
    o. Manual brachytherapy
    p. Medical event
    q. Medical institution
    r. Medical use
    s. Medium dose-rate remote afterloader
    t. Mobile medical service

u. Output
v. Patient intervention
w. Pharmacist
x. Physician
y. Podiatrist
z. Positron Emission Tomography (PET)
aa. Preceptor
bb. Prescribed dosage
cc. Prescribed dose
dd. Pulsed dose-rate remote afterloader
ee. Radiation Safety Officer
ff. Sealed source
gg. Sealed Source and Device Registry
hh. Stereotactic radiosurgery
ii. Structured educational program
jj. Teletherapy
kk. Temporary job site
ll. Therapeutic dosage
mm. Therapeutic dose
nn. Treatment site
oo. Unit dosage
pp. Written directive

4. Maintenance of Records
5. Provisions for the protection of human research subjects
6. FDA, other Federal, and State requirements
7. Information collection requirements: OMB approval
8. Implementation
9. Types of Licenses
    a. Specific License of Limited Scope
    b. Specific License of Broad Scope
10. License Required
11. Application for license, amendment, or renewal
12. License Amendments
13. Research Involving Human Subjects
14. General In Vitro License
    a. Timely Notification of Bankruptcy Proceedings
15. Other Requirements
    a. The "As Low As Is Reasonably Achievable (ALARA)" Concept
    b. Written Directive (WD) Procedures
    c. Timely Notification of Transfer of Control
16. General Administrative Requirements
    a. Authority and responsibilities for the radiation protection program
    b. Radiation protection program changes
17. Supervision
18. Written directives
19. Procedures for administrations requiring a written directive
20. Suppliers for sealed sources or devices for medical use
21. Training for Radiation Safety Officer
22. Training for an authorized medical physicist
23. Training for an authorized nuclear pharmacist

II. General Technical Requirements

1. Possession, use, and calibration of instruments used to measure the activity of unsealed byproduct material
2. Calibration of survey instruments
3. Determination of dosages of unsealed byproduct material for medical use

4. Authorization for calibration, transmission, and reference sources
5. Requirements for possession of sealed sources and brachytherapy sources
6. Labeling of vials and syringes
7. Surveys of ambient radiation exposure rate
8. Release of individuals containing unsealed byproduct material or implants containing byproduct material
9. Provision of mobile medical service
10. Decay-in-storage

III. Unsealed Byproduct Material - Written Directive Not Required

1. Use of unsealed byproduct material for uptake, dilution, and excretion studies for which a written directive is not required
2. Training for uptake, dilution, and excretion studies
3. Use of unsealed byproduct material for imaging and localization studies for which a written directive is not required
4. Permissible molybdenum-99, strontium- 82, and strontium-85 concentrations
5. Training for imaging and localization studies

IV. Unsealed Byproduct Material—Written Directive Required

1. Use of unsealed byproduct material for which a written directive is required
2. Safety instruction
3. Safety precautions
4. Training for use of unsealed byproduct material for which a written directive is required
5. Training for the oral administration of sodium iodide I-131 requiring a written directive in quantities less than or equal to 1.22 gigabecquerels (33 millicuries)
6. Training for the oral administration of sodium iodide I-131 requiring a written directive in quantities greater than 1.22 gigabecquerels (33 millicuries)

V. Manual Brachytherapy

1. Use of sources for manual brachytherapy
2. Surveys after source implant and removal
3. Brachytherapy sources accountability
4. Safety instruction
5. Safety precautions
6. Calibration measurements of brachytherapy sources
7. Decay of strontium-90 sources for ophthalmic treatments
8. Therapy-related computer systems
9. Training for use of manual brachytherapy sources

VI. Sealed Sources for Diagnosis

1. Use of sealed sources for diagnosis
2. Training for use of sealed sources for diagnosis

VII. Photon Emitting Remote Afterloader Units, Teletherapy Units, and Gamma Stereotactic Radiosurgery Unit

1. Use of a sealed source in a remote afterloader unit, teletherapy unit, or gamma stereotactic radiosurgery unit
2. Surveys of patients and human research subjects treated with a remote afterloader unit
3. Installation, maintenance, adjustment, and repair
4. Safety procedures and instructions for remote afterloader units, teletherapy units, and gamma stereotactic radiosurgery units
5. Safety precautions for remote afterloader units, teletherapy units, and gamma stereotactic radiosurgery units
6. Dosimetry equipment
    a. Full calibration measurements on teletherapy units
    b. Full calibration measurements on remote afterloader units

c. Full calibration measurements on gamma stereotactic radiosurgery units
7. Radiation surveys
   a. Criteria
   b. Discussion
   c. Leak Test
   d. Model Leak Test Procedures
   e. Procedure for Performing Leak Testing and Analysis
   f. Instrument Specifications and Model Survey Instrument and Air Sampler Calibration Program
   g. Radiation Monitoring Instrument Specifications
8. Five-year inspection for teletherapy and gamma stereotactic radiosurgery units
9. Therapy-related computer systems
10. Training for use of remote afterloader units, teletherapy units, and gamma stereotactic radiosurgery units

VIII. Other Medical Uses of Byproduct Material or Radiation From Byproduct Material

IX. Records

1. Records of authority and responsibilities for radiation protection programs
2. Records of written directives
3. Records for procedures for administrations requiring a written directive
4. Records of calibrations of instruments used to measure the activity of unsealed byproduct material
5. Records of radiation survey instrument calibrations
6. Records of dosages of unsealed byproduct material for medical use
7. Records of leaks tests and inventory of sealed sources and brachytherapy sources
8. Records of the release of individuals containing unsealed byproduct material or implants containing byproduct material
9. Records of mobile medical services
10. Records of decay-in-storage
11. Records of 5-year inspection for teletherapy and gamma stereotactic radiosurgery units

X. Reports

1. Report and notification of a medical event
2. Report of a leaking source

XI. Agreement States

1. Definition
2. List of Agreement States
3. NRC's materials licensees
4. How to File
   a. Paper Application
   b. Electronic Application
5. Where to File
6. License Fees
7. Contents Of An Application
8. License Action Type
   a. New License
   b. Amendment to License
   c. Renewal of License
9. Applicant's Name And Mailing Address
10. Amendments And Renewals To A License
11. Termination of Activities
    a. Notify NRC, in writing, within 60 days of
    b. Discussion

c. Acceptable License Termination Screening Values of Common Radionuclides for Building Surface Contamination
d. Response from Applicant
e. Reference
f. NUREG (US Nuclear Regulatory Commission Regulation)

XII. United States Nuclear Regulatory Commission Form 313

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 27

Title: NRC Regulations, Packaging and Transportation of Radioactive Material, Part III (90 minutes)

Keywords: Radioactive Material, Regulations, License, Definitions, Transportation, Transport, Employee protection, Exemptions, Packages, Standards, Activity Limits, Classification, Marking, Labelling, Placarding, Consignor's Responsibilities, Storage, Safety, Test Procedures, Certificate

Objectives:
- Review Historical
- Review Regulatory Sources and Organizations
- Discuss Purpose and Scope
- Explain Requirement for License and Definitions
- Discuss Transportation of Licensed Material
- Describe Exemptions
- Discuss Classification of packages
- Discuss Application for package approval and Package approval standards
- Define Activity Limits and Classification
- Discuss general standards for all packages
- Review Transport of other goods
- Illustrate Marking Labelling and Placarding
- Describe Consignor's Responsibilities
- Discuss Transport and Storage in Transit
- Explain Basic Safety Concepts: materials and packages
- Review Selection of Optimal Package Type
- Discuss Test Procedures
- Discuss Approval and Administrative Requirements
- Describe Certificate of Competent Authority

Content:

I. Historical

II. Regulatory Sources and Organizations
1. Organizations
2. NRC Agreement States (1997)
3. Federal Regulations
4. International Regulations

III. Purpose and Scope
1. Communications and records
2. Interpretations
3. Requirement for license
4. Definitions
    a. A 1
    b. A 2
    c. Carrier
    d. Certificate holder
    e. Certificate of Compliance (CoC)
    f. Close reflection by water
    g. Consignment
    h. Containment

i. Conveyance
j. Criticality Safety Index (CSI)
k. Deuterium
l. DOT
m. Exclusive use
n. Fissile material
o. Graphite
p. Licensed material
q. Low Specific Activity (LSA) material
r. Low toxicity alpha emitters
s. Maximum normal operating pressure
t. Natural thorium
u. Normal form radioactive material
v. Optimum interspersed hydrogenous moderation
w. Package
x. Packaging
y. Special form radioactive material
z. Specific activity of a radionuclide
aa. Spent nuclear fuel or Spent fuel
bb. State
cc. Surface Contaminated Object (SCO)
dd. Transport index (TI)
ee. Type A quantity
ff. Type B quantity
gg. Unirradiated uranium
hh. Uranium
ii. Vehicle shall
jj. Vessel shall

5. Transportation of Licensed material
   a. Modes of transportation
6. Deliberate misconduct
7. Employee protection

IV. Exemptions

1. Specific exemptions
2. Exemption of physicians
3. Exemption for low-level materials
4. Exemption from classification as fissile material

V. Classification of Packages

1. Classification as excepted package
   a. Activity Limits for Excepted Packages

VI. Application for Package Approval

1. Contents of application
2. Package description
3. Package evaluation
4. Quality assurance
5. Renewal of a certificate of compliance or quality assurance program approval
6. Requirement for additional information

VII. Package Approval Standards

1. Demonstration of compliance
2. General standards for all packages
3. Lifting and tie-down standards for all packages
4. External radiation standards for all packages

5. Additional requirements for Type B packages
6. General requirements for fissile material packages
7. Standards for arrays of fissile material packages
8. Special requirements for Type B packages containing more than 105A2
9. Special requirement for plutonium shipments

VIII. Activity Limits and Classification

1. Excerpts from the List of Un Numbers Proper Shipping Names and Descriptions
2. Basic Radionuclide Values for Unknown Radionuclides or Mixtures

IX. Transport of Other Goods

1. Other Dangerous Properties of Contents
2. Requirements and Controls For Contamination and for Leaking Packages
3. Categories
   a. I-White
   b. II-Yellow
   c. III-Yellow in accordance with the conditions specified
   d. Categories of Packages Overpacks and Freight Containers

X. Marking Labelling and Placarding

1. Marking
   a. Un Marking for Packages and Overpacks
2. Labelling
   a. Hazard Symbol
   b. Class Name
   c. Color Classification
   d. Hazard Class
   e. Category I-White label
   f. Category II-Yellow label
   g. Category III-Yellow label
3. Placarding
   a. Package markings and associated hazard
   b. UN Numbers and proper shipping names

XI. Consignor's Responsibilities

1. Particulars of consignment
2. The UN class number "7"
3. Chemical description is acceptable for chemical form
4. Consignor's certification or declaration
5. Information for carriers
6. Notification of competent authorities
7. Possession of certificates and instructions

XII. Transport and Storage in Transit

1. Segregation during transport and storage in transit
2. Stowage during transport and storage in transit
3. Transport Index Limits for Freight Containers and Conveyances not Under Exclusive Use
4. CSI Limits for Freight Containers and Conveyances Containing Fissile Material
5. Additional requirements relating to transport by rail and by road
6. Additional requirements relating to transport by air

XIII. Basic Safety Concepts: materials and packages

1. Basic safety concepts
2. Inherent safety
3. Passive safety
4. Active safety

XIV. Selection of Optimal Package Type

XV. Test Procedures

1. Demonstration of compliance
2. Leaching Test for LSA-III Material and Low Dispersible Radioactive Material
3. Tests for Special Form Radioactive Material
   a. General
   b. Test methods
   c. Leaching and volumetric leakage assessment methods
4. Tests for Low Dispersible Ispersible Radioactive Material
5. Tests for Packages
   a. Testing the integrity of the containment system and shielding and assessing criticality safety
   b. Test for packagings designed to contain uranium hexafluoride
   c. Tests for demonstrating ability to withstand normal conditions of transport
6. Additional Tests for Type A packages designed for liquids and gases
7. Tests for demonstrating ability to withstand accident conditions of transport
8. Enhanced water immersion test for Type B(U) and Type B(M) packages containing more than 105 A2 and Type C packages
9. Tests for Type C packages

XVI. Approval and Administrative Requirements

1. Approval of Special Form Radioactive Material and Low Dispersible Radioactive Material
2. Approval of Material Excepted from Fissile Classification

XVII. Certificate of Competent Authority

1. Type a Packages
2. Marking Type A Packages
3. Labeling Type A Packages
4. Inspecting Package before Shipment
5. Security Seals
6. Minimum Separation between Packages and people
7. Shipping Paper Preparation and Retention
8. Shipper's Certification
9. Shipping Paper Accessibility
10. Emergency Response Information
11. Accident Notification Requirements
12. Excepted Packages
13. Appendix A, B, C, D and F

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 28

Title: Physics of Positrons and Production and PET Traces, Parts I and II (90 minutes)

Keywords: Positrons, Proton-rich, Annihilation radiation, Radioisotopes, Radiotracers, PET, Radiopharmaceuticals, 18F-FDG, C-11, N-13, O-15, F-18, Reimbursement Issues, Clinical Utility, Cyclotron Manufacturing Process, Synthesis, Black box, Quality Control, Physicochemical Test, Biological Test, USP Specifications

Objectives:
- Review Introduction of the Development of New PET Tracers
- Discuss Principles PET and Applications of PET tracers
- Explain Development of PET Radiotracers and Radioisotopes for PET
- Discuss the physics of positron
- Discuss the properties of positrons
- Discuss the physics of electron capture
- Discuss the application of PET Imaging
- Discuss 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.
- Review the cyclotron process of manufacturing various PET Radiopharmaceuticals
- Review C-11, N-13, O15, F-18
- Discuss the synthesis process for manufacturing PET Radiopharmaceuticals

Contents:

Part I

I. Principles
1. Principles of PET 1
2. Principles of PET 2
3. Principles of PET 3

II. Applications of PET tracers

III. Development of PET Radiotracers

IV. Radioisotopes for PET
1. C-11 Chemistry
2. F-18 Chemistry

V. Important PET Radiotracer

VI. Process of Cooperation

Part II

VII. Positrons
1. Properties of positrons
2. Nuclear transformation
3. Positron emission

4. Positrons and matter
5. Annihilation radiation
6. Positron decay equation
7. Positron emitters
8. Electron capture
9. Electron Capture Transformation
10. Electron Capture Decay Equation
11. Radionuclides decay
12. What is PET?
13. Value PET

VIII. PET radiopharmaceuticals

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

IX. Cyclotron manufacturing process

1. Hot cells
2. Synthesis molecules
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 18-F
   a. FDG - nucleophilic substitution
   b. DOPA - Electrophilic substitution
7. Radiochemistry with 11-C
   a. C-11 Methylation

X. Synthesis of 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 devices
4. Quality Control of PET Radiopharmaceuticals
   a. Physicochemical test
   b. Biological test

XI. USP Specifications for Routine PET Radiopharmaceutical

1. F18- fluorodeoxyglucose
2. 6-F18-L-Fluorodopa
3. N13-Ammonia

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 29

Title: CardioGen Generators (120 minutes)

Keywords: Rubidium-82, 82Sr/82Rb Generator, Production of 82Sr, CardioGen-82, FDA Drug Safety Communication, Infusion System, Chloride Injection, Drug Handling, Testing Protocol, Safety Information, Dosimetry, Radiation Dose, Drug Interactions, Pharmacology, Nonclinical Toxicology, Dose Calibrator, Quality control, Patient Preparation, Protocols, Tracer, Stress Testing, Side Effects, Safety Data Sheet, Hazard, First-aid measures, Transport information, Advantages, Limitations

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
- 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. Introduction

II. Rubidium-82

1. Rubidium-82
   a. Physical Data
   b. History
   c. Nuclear Properties
   d. Production
2. 82Sr/82Rb Generator
3. Production of 82Sr
4. Production Routes for 82Sr
5. Control of Product Radiopurity
6. Target Issues – RbCl
   a. Advantage and Disadvantage
7. Target Issues – Rb metal
   a. Advantage and Disadvantage
8. Facilities
9. Sr-82 Process Flow Chart
10. Sr-82 Product Specifications
    a. Radionuclidic Purity
    b. Specific Activity

c. Activity Concentration
d. Stable Elements

11. Decay scheme of 82Sr to 82Rb
12. Decay scheme of 82Rb to stable 82Kr
13. Relevant nuclear properties
    a. Photon emission of the daughter radionuclide

III. CardioGen-82 (Rubidium Rb 82 Generator)

1. The Generator: how does it work?
2. CardioGen-82® (Rubidium Rb 82 Generator)
3. Bracco Diagnostics Inc.
   a. Radiopharmaceuticals
   b. CardioGen-82
4. 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
5. CardioGen-82, Characteristics
   a. Uses For Cardiogen-82 Generator
   b. Use in Positron Emission Tomography (PET)
      - Myocardial blood flow tracers with PET
      - History
6. Tools for Risk Stratification
7. The Cardiac Imaging Market is Transitioning
   a. From SPECT to PET
   b. From Cardiac catheterization to CT angiography
8. PET Perfusion Imaging
9. Transitioning the perfusion market
10. CardioGen-82's high sensitivity and specificity can improve diagnostic accuracy
11. PET MPI provides benefits for a diverse patient population
12. PET MPI for thriving practice
    a. Convenience
    b. Efficiency
    c. Certainty
    d. A Non-Invasive
13. Occupational Safety Data
14. Commonly used brand name(s)
15. Chemical Characteristics
16. Physical Characteristics
17. External Radiation
18. Strontium Sr 82 decays to Rubidium Rb 82
19. 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

VI. Eluate Testing Protocol

1. Rubidium Eluate Level Testing
2. Strontium Eluate Level Testing
   a. Calculation
   b. Examples
3. Cardiogen-82 Expiration
4. Important Safety Information
   a. Perform generator eluate tests
   b. Alert Limits

VII. Radiation Dosimetry

1. About Absorbed Radiation Dose Coefficient
2. Calculation
3. Dosage Forms and Strengths
4. 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
5. Drug Interactions
6. Use in Specific Populations
   a. Pregnancy
   b. Nursing Mothers
   c. Pediatric Use
   d. Geriatric Use
   e. Renal Impairment
   f. Hepatic Impairment
7. Cardiogen-82 - Clinical Pharmacology
   a. Mechanism of Action
   b. Pharmacodynamics
   c. Pharmacokinetics
8. Nonclinical Toxicology
   a. Carcinogenesis, Mutagenesis, Impairment of Fertility

VIII. Dose Calibrator

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

IX. CardioGen-82 QC Procedures

1. QC Preparation
2. 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

X. 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

XI. 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

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 30

Title: Photon and Particle Interaction in Matter (60 minutes)

Keywords: Ionization, Atom, Excitation, Photons, Neutrino, Low Linear Energy Transfer (LET), Alpha Particles, Beta Particles, Bremsstralung Radiation, Braking, X-rays, Gamma Rays

Objectives:
- Review the basic model of a neutral atom
- Discuss excitation and ionization principles
- Distinguish between particulate radiation from electromagnetic radiation
- Discuss High and Low LET radiation
- Review the properties of alpha and beta particles
- Review the properties of Bremsstralung radiation
- Review the properties of positrons
- Review the properties of thermal neutrons
- Review the properties of gamma rays
- Discuss various methods for interacting with matter
- Discuss Coherent scatting
- Discuss Photoelectric Effect
- Discuss Compton Scattering
- Discuss Pair Production
- Discuss Triplet Production
- Discuss Photodisintegration

Content

I. Neutral Atom
1. Basic Model of a Neutral Atom
2. Ionization vs. Excitation
3. Ionizing radiation
4. Particulate vs. Electromagnetic Radiations
5. Electromagnetic spectrum
6. High vs. Low Energy Radiation
7. High vs. Low Linear Energy Transfer (LET)

II. Alpha Particles

III. Beta Particles

IV. Bremsstralung (or Braking) Radiation
1. Positrons
2. Neutrons

V. X-rays and Gamma Rays
1. Radiation
2. Photons
3. Neutrino
4. Charged particle radiation
5. Photons interaction with matter
6. Energy interactions
7. Coherent or Classical Scattering

8. Photoelectric absorption
9. Compton Scattering
10. Pair production
11. Triplet production
12. Photodisintegration

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 31

Title: Cellular Anatomy and Physiology (60 minutes)

Keywords: Organic and inorganic chemistry, Cellular Anatomy and Physiology, Cellular Reproduction, Mitosis, Meiosis, Mutations, Carbohydrates, Lipids, Nucleic Acids, Proteins, DNA and RNA, Enzymes

Objectives:

- Discuss the basics of organic and inorganic chemistry
- Review Cellular Anatomy and Physiology
- Describe Cellular Reproduction
- Define Mitosis, Meiosis and Mutations

Content:

I. Organic and Inorganic Chemistry

1. Biochemistry
2. Macromolecules
3. Four Major Categories of Compounds
    a. Carbohydrates (Breads and Starch)
    b. Lipids (Fats)
    c. Nucleic Acids (DNA and RNA)
    d. Proteins (Meat and Nuts)
4. Carbohydrates “Carbs”
    a. Function of Carbohydrates
    b. Simple Sugar: Glucose
    c. Table Sugar
    d. Starch: Complex Sugar
5. Lipids – Fats, Oils and Waxes
    a. Function of Lipids
    b. Formation of Lipids
    c. Saturated and Unsaturated fats
    d. Cholesterol

7. Nucleic Acids
    a. DNA
    b. Nucleotides
    c. Complementary bases
    d. RNA
    e. In the Nucleus
8. Proteins
    a. Function of Proteins
    b. Amino Acids
    c. Denaturation
    d. Enzymes
    e. Lock and Key Model

II. Cellular Anatomy and Physiology

1. Cell structure
2. Introduction to Cellular Anatomy
3. Composite Cell
4. The Cell Organelles

5. Cell Membrane
6. Cytoplasm
7. Endoplasmic Reticulum
8. Ribosomes
9. Golgi Apparatus
10. Mitochondria
11. Lysosomes
12. Peroxisomes
13. Microfilaments and microtubules
14. Centrosome
15. Cilia and flagella
16. Vesicles
17. Nucleus, nuclear envelope
18. Nucleolus
19. Chromatin

III. Cellular Reproduction

1. Mitosis
   a. Interphase
   b. Prophase
   c. Prometaphase
   d. Metaphase
   e. Anaphase
   f. Telophase
   g. Cytokinesis
2. Meiosis
   a. In Males
   b. In Females
3. Mutation
   a. Gregor Mendel
   b. Genotype
   c. Alleles
   d. Celera Genomics
   e. Scientific Breakthroughs

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 32

Title: 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, Bergonie and Tribondeau Law, Response Curves, Dose Response Relationship, Linear Nonthreshold Dose Response, Target Theory and Cell Survival Curves, Cell Death

Objectives:

- Discuss Direct and Indirect Effects of Radiation Exposure
- Describe Biochemical Damage from Ionizing Radiation
- Review Cell Cycle
- Explain the Law of Bergonie and Tribondeau and Radiolysis of Water
- Define Dose Response Relationship
- Explain Target Theory and Cell Survival Curves
- Analyze the Types of Dose Response Curves and Cell death

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

III. Cell Cycle

IV. Bergonie and Tribondeau Law

1. Radiosensitivity
2. Direct Effects
3. Chromosomal Damage
4. Indirect Action
5. 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

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 33

Title: 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, Effects of radiation on specific tissues and organs, 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. Biological Effects of Radiation
   a. Types Effects (Radiation Sickness, Cancer, Genetic Effects)
   b. Direct and Indirect Action
   c. Short and Long Term Effects
   d. A High Dose
   e. Data on Radiation Exposure to Humans
   f. 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 Cells
    a. Radiation dose
    b. Stem cell sensitivity
4. Structural changes
5. Chromosomal aberration
    a. Types of Chromosomal Aberrations
    b. Factors that Influence the Repair of Chromosomal Aberrations
    c. 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. Effects of Medical Intervention on the Acute Radiation Syndrome.
4. Consequences of Acute Radiation
5. Acute Exposure
6. Dose Response Curve
7. Radiation Doses and Expected Effects
8. Commonly Encountered Radiation Doses

9. Radiation Effects on Embryo/Fetus
10. Cell Sensitivity
11. Response Stage
12. Bone Marrow Syndrome
    a. Signs and Symptoms of Bone Marrow
13. Gastrointestinal Syndrome
    a. Signs and Symptoms of Gastrointestinal
14. Central Nervous System Syndrome
    Signs and Symptoms of Central Nervous System
15. Elements of acute radiation syndrome
    a. Gastrointestinal
    b. Hematopoietic
    c. Vascular

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 34

Title: Effects of Long-Term Exposure to Radiation (60 minutes)

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

Objectives:
- Discuss epidemiology and limitations on epidemiologic studies
- Describe population used as sources, Hiroshima-Nagasaki atomic bombings and Radiation induced malignancies
- Explain different risk models
- Define the dose rate effects, the genetic effects of radiation, the effects of radiation to the fetus and life span shortening
- Review stochastic and non-stochastic effects, 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
   a. Retrospective studies
   b. Prospective studies
4. Hiroshima-Nagasaki atomic bombings and radiation induced malignancies
5. 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

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. Expression of Radiosensitivity
   a. Absolute risk
   b. Relative risk
4. Somatic Effects

IV. Genetic Effects of Radiation

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

V. Effects on the Embryo

1. Triad of effects of radiation on the embryo
   a. Growth retardation
   b. Embryonic, fetal or neonatal death
   c. Congenital malformation
2. 10 Day Rule

VI. Linear No-Threshold Hypothesis (LNT)

VII. Life Span Shortening

VIII. Stochastic and Non-stochastic Effects

IX. Hormesis

Module III: “Introduction to PET/MR”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 35

Title: Radiation Protection of Personnel Part I, II and III (90 minutes)

Keywords: Radiation Protection Progra, Dosimetry, Landauer Dosimeter, Dosimetry Reports, Radiation Safety, Dose Limiting, A-L-A-R-A , Radiation Protection, Shielding, Inverse Square Law, Decrease Radiation Exposure, Radioactive Waste Disposal, Radioactive Spills, Radiation Exposure to the Fetus, to the Staff, to the Patients, to the Families and the General Public, Nuclear Medicine Technology

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
- Discuss Responsibilities of Badge Users
- Review the Society of Nuclear Medicine Performance and Responsibility Guidelines for NMT

Content:
Part I

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
2. Regulation of Radiation Usage
    a. Nuclear Regulatory Commission (NRC)
    b. Agreement State
    c. Radiation Safety Program
3. Radiation protection procedures
    a. External Radiation Protection
    b. Internal Radiation Protection
    c. Survey Procedures or Monitoring
    d. Radiation Spills
    e. Waste Disposal Guidelines
4. Units of Radiation Exposure
    a. Roentgen (R)
    b. Rad (radiation absorbed dose)
    c. Rem (roentgen equivalent man)
5. Radiation protection standards
    a. Dose Limit
    b. Principle of “ALARA”
6. General Handling Precautions
    a. Protective Clothing

b. The Work Place
c. Manipulations of Radioactive Materials

III. External Radiation Protection

1. The Three Basic Rules
   a. Time
   b. Distance
   c. Shielding

IV. Internal Radiation Protection

1. Mode of Entry into Body
   a. Inhalation
   b. Ingestion
   c. Absorption
   d. Injection
2. Routes of Intake, Transfers and Excretion
3. Tissue Damage and Health Effects

V. Radioactive Waste Disposal

1. Disposal
   a. Different types of wastes
2. Precautions on Waste Disposal
   a. Waste Minimization
   b. Segregation by Half-Life
   c. Prohibited Items
3. Precautions for Radioactive Spills
   a. Major Spills
   b. Minor Spills
   c. Key to Success

VI. Survey Procedures or Monitoring

1. Precautions on Dosimetry
   a. Radiation Badges
   b. Individuals Requiring Radiation Safety Training
2. Annual Radiation Dose Limits
3. Radiation Warning Signs
4. Record Retention
5. Criteria for Personnel Monitoring
6. Survey Meter Quality Assurance
7. Medical Events
   a. Administrative Criteria
   b. Dose Criteria
   c. Reporting Medical
8. Differences of PET

VII. Minimization of Radiation Exposure to…

1. Staff
   a. Sources of exposure for staff
   b. Time, distance and shielding
      - Inverse Square Law
   c. Laboratory technique
   d. Administrative and procedural controles
2. Patients
   a. Reducing PET/CT Patient Does
   b. Corrective Actions
3. Families and the General Public

a. Regulatory Requirements
b. “Patient Release” Guidelines
c. Annual Dose Limit to Non-Radiation Workers

VIII. Principles of PET/CT Shielding Calculations

1. Occupational Exposure Protection of the Worker
2. F-18 FDG PET
   a. Studies
   b. Exposure factors
   c. Dose Factors
3. PET Isotope Data
4. Exposure
5. Shielding
   a. Bench top shield
   b. Vial shields
   c. Syringe shields
   d. Structural shielding
6. Shielding Material and Transmission
7. PET Clinic Layout
   a. Typical PET room
   b. Calculation for Room Above an Uptake Room
   c. PET Clinic Shielding

IX. Radiation Exposure to the Fetus

1. Prevention of Unintentional Fetal Exposure
2. Fetal Doses
3. The Pregnant or Potentially Pregnant Radiation Worker
   a. Occupational dose limit
   b. Notification of employer about pregnancy
   c. Mutual Responsibilities
4. Methods to Reduce Occupational Exposure for the Pregnant Worker

X. Internet Resources

Part II

XI. Responsibilities of Badge Users

1. Landauer dosimeter

Part III

XII. Society of Nuclear Medicine Performance and Responsibility Guidelines for NMT

1. Revision 2003
2. Nuclear Medicine Technology
3. Patient Care
4. Nuclear Instrumentation—Quality Controle
5. Diagnostic Procedures
6. Radiopharmaceuticals
7. Radionuclide Therapy
8. Radiation Safety
9. References

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module I: Content Pertaining to a RAM Licenses

Lecture 36

Title: Radiation Safety in PET Imaging, Parts I, II and III (90 minutes)

Keywords: PET Physics, Key Variables, Exposure Factors, Radiation Protection, Worker Awareness, Records and Events, 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, Protection Programs, Principle of "ALARA", Dose Limits, Record Retention, Personnel Monitoring, Survey Meter Quality Assurance, Medical Events, Differences of PET/CT, Rate Constants, PET Shielding, Physical Half-Life, Minimization of Radiation Exposure to Staff, Minimization of Radiation Exposure to Patients, Minimization of Radiation Exposure to Families and the General Public, Non-Radiation Workers, Shielding Calculations, Minimization of Radiation Exposure to the Fetus

Objectives:

- Discuss the key variables associated with dose exposure in a PET facility; the basic elements of the radiation protection program and general safety measures; the actions taken in decontamination of accidental radiation exposure and the proper waste disposal procedure in a PET facility
- Explain the basic physics concepts pertinent to PET radiation safety; factors related to dose exposure and reducing exposure for each factor
- Describe the parameters in each ALARA level and the action(s) associated with exceeding each parameter;
- Define "medical event" and summarize the required actions related to a recordable event
- Review the specifics regarding a declared pregnancy
- Describe the information about the safety precautions and procedures
- Describe the compliance information for the operation of the PET/CT systems
- Illustrate the location and the uses of the emergency stops and information regarding laser light safety

Content:

Part I

I. PET Physics

1. High Energy Gammas
2. Exposure Rate Constant
3. Positrons
4. Half-value Layer
5. Key Variables
   a. Distance
   b. Time
   c. Shielding

II. Exposure Factors

1. Imaging Device
2. Study Protocol
3. Workload
4. Dose Preparation
5. Facility Design

III. Radiation Protection

1. NRC Program Components
2. Amendments
3. Signs
4. Safety Measures
5. Area and Facility Monitoring
    a. A Geiger-Mueller survey meter
6. Material Receipt and Accountability
7. Radioactive Decontamination
8. Waste

IV. Worker Awareness

1. Worker Responsibility
2. ALARA
    a. Three ALARA levels
3. Personal Radiation Detection and Measurement
4. Dosimeter Types
    a. Film badges (RDF)
    b. Fhermo luminescence dosimeters (TLD)
    c. Optically stimulated luminescence (OSL)

V. Records and Events

1. Records
2. Medical Events
3. Recordable Events
4. Reports
5. Additional Reports

Part II

VI. Safety Definitions and Symbols Used

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

VII. General Safety Guidelines

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

VIII. 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

IX. 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

X. Weighted CT Dose Index (CTDIw)
1. Dose Length Product
2. Accumulated Exam DLP

XI. Emergency Stop Buttons

XII. Warning Signs and Labels
1. Caution, High Voltage
2. Electric Shock Hazard
3. LS Table Assembly Label

XIII. Safety Labels and Rating Plates
1. Radiation Emission Warning
2. Pinch Hazard Label
3. Shock Hazard
4. Do Not Touch

XIV. Laser Safety
1. Warning

XV. Gamma Radiation
XVI. Prevention of Harmful Cumulative Dose
XVII. Data Safety
XVIII. Safe Operation Guidelines
XIX. Compliance and Regulatory Information
XX. Operator's Safety

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

Part III
XXII. Radiation Protection Programs
1. PET/CT Regulators
2. Helpful Organizations

XXIII. Principle of "ALARA"

XXIV. Annual Radiation Dose Limits
1. Rad. Workers
2. Occasion. Exposed
3. Gen. Public
4. Minor Trainees
5. Fetus

XXV. Radiation Warning Signs
1. Cyclotron
2. "Hot" Lab
3. PET/CT Scanner

XXVI. Record Retention
1. 3 years
   a. Shipping and Receiving
   b. Area Surveys and Trash Surveys

c. Public Dose Limit Compliance
2. Lifetime
   a. Personnel Dosimetry

XXVII. Criteria for Personnel Monitoring

XXVIII. Survey Meter Quality Assurance

XXIX. Medical Events
1. Administrative Criteria
2. Dose Criteria
3. Reporting Medical Events

XXX. Differences of PET/CT
1. Differences of PET
2. Higher Exposure Rate Constants
3. Higher Dose Rate From Patients
4. PET Shielding: Tenth Value Layers
5. Shorter Physical Half-Life
6. Shorter Half-Life: Lower Dose

XXXI. Minimization of Radiation Exposure to Staff
1. PET/CT: Sources of Exposure to Staff
2. Doses wich People Get
3. Measures to Reduce Personnel Dose
   a. Time, Distance and Shielding
   b. Laboratory Technique
   c. Administrative and Procedural Controls

XXXII. Minimization of Radiation Exposure to Patients
1. Reducing PET/CT Patient Dose
   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. Avoiding “Medical Events”
3. Corrective Actions

XXXIII. 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
4. Principles of PET/CT Shielding Calculations

XXXIV. Minimization of Radiation Exposure to the Fetus
1. Prevention of Unintentional Fetal Exposure
2. Fetal Doses (rads)
3. If One of Your Staff Becomes Pregnant

XXXV. Internet Resources

Module I: “Content Pertaining to a RAM Licenses”: You must score an 80% or greater in order to receive SNMMI TS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 37

Title: Introduction to CT: The Fundamentals (45 minutes)

Keywords: Computed Tomography, Tomographic principles, History, Scanner Generations, Multidetector CT (MDCT), Digital Image, Scanning, CT Components, CT Operations

Objectives:
- Describe the events leading to the discovery of computed tomography
- Explain the design of CT scanner generations
- Identify the location and function of major CT components
- List the most common uses of computed tomography in medical imaging
- Discuss the basic processes related to digital image processing

Content:

I. Discovery of Computed Tomography
1. Basic CT Definitions and terminology
2. Tomographic principles
3. Tomographic Planes
4. CT Roots
5. Founder Godfrey Hounsfield
6. First Scans

II. Design of CT Scanner Generations
1. First Generation
2. CT Comparison
3. Second Generation
4. Third Generation
5. Fourth Generation
6. Fifth Generation
7. Sixth Generation
8. Dual Source CT
9. Seventh Generation

III. Modern CT scanner
1. How CT Scanners Work
2. Beam Geometry
3. Fan Beam
4. Cone Beam
5. Multidetector CT (MDCT)
6. MDCT Technology

IV. Digital Image
1. Scanning
   a. Sequential Scanning
   b. Spiral or Helical Scanning
2. Visual Differentiation of Tissues

V. CT Components and Operations
1. Console

2. Gantry
3. Table
4. Radiographic Tube
5. Generators
6. Slip rings
7. Filters
8. Collimators
9. Detectors
10. Detectors Arrays
11. Data Acquisition Systems
12. Array Processors
13. Monitors and Archival devices

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 38

Title: CT Instrumentation (45 minutes)

Keywords: Computed Tomography, CT Components, Scanner Configurations, Helical Scanner, Axial Scanning, Multidetector Computed Tomography (MDCT), Digital Imaging

Objectives:
- Explain the CT Scanner Computer System
- Trace the sequence of events in CT scanning from the application of the electrical current to the radiographic tube to image display
- Discuss how to adjust the operator controls that affect the image quality
- Discuss the key elements of a digital CT image

Content:

I. Major CT Scanner Components
1. Patient Table
2. X,Y, Z axes
3. Gantry
4. X-ray Tube
5. Generator
6. Detectors
7. Collimators

II. Scanner Configurations
1. Historical Development of the Helical Scanner
2. Conventional Axial Scanning
3. Multidetector Computed Tomography (MDCT)
4. Volumetric Data Acquisition
5. Slip Rings
6. Operator Console and Data Acquisition
7. Pitch
8. Scan Field of View (SFOV)
9. Display Field of View (DFOV)
10. Annotation
11. Scout
12. Region of Interest (ROI)
13. CT/Hounsfield Numbers
14. Window Width (WW)
15. Window Level (WL)
16. WW/WL Example
17. Computer

III. Digital Imaging
1. Pixel
2. Matrix
3. Voxel
4. Digital Image Characteristics in CT
   a. Sampling and Aliasing
   b. Spatial Resolution
   c. Contrast Resolution

d. Temporal Resolution
e. Noise
f. Partial Volume Averaging

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 39

Title: CT Physics and Instrumentation (60 minutes)

Keywords: Bremsstrahlung Radiation, X-Rays, Voltage Variation, CT scanner Design, Rotation Speed, Kernels, Shaded Surface Displays, Scout, Scan Geometry, Mosaic Detectors

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
- Discuss the principle parts of a CT scanner and the function of each CT scanner component
- Discuss 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
- Discuss CT image quality issues
- List the origin of CT image artifacts and describe their prevention
- Discuss 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 importance of CT quality control
- Review GE‟s Discovery Light-Speed CT Scanner configuration

Content:

I. Introduction

1. Physics of X-rays
   a. Bremsstrahlung Radiation
   b. Characteristic X-rays
2. X-ray Tube design
3. Voltage Variation
4. Energies required
5. Tweaking kVp for Scanning
   a. Beam Hardening
   b. Advantages and disadvantages of using a higher kVp
6. Current Variation
   a. Current Variation in CT
   b. Advantages and Disadvantages of Current Variation
7. X-ray Filter
   a. Filters on a CT scanner

II. Principles of Computed Tomography (CT)

1. Definition
2. CT Scanner Design
   a. Gantry Composition
   b. X-Ray Detectors
   c. Collimation
   d. Rotation Speed
   e. Pitch
   f. Increments

III. Image Data Acquisition

IV. CT Image Reconstruction

1. Values of CT Image Reconstruction
2. Hounsfield Units
3. Tissue Hounsfield Unit values
4. CT Reconstruction Algorithm's
    a. Filtered back-projection (FBP)
    b. Iterative algorithms
5. Reconstruction Kernels
    a. Example of Kernels in Reconstruction
6. Advantages and Disadvantages of CT image reconstruction
7. Post Processing Filtering

V. CT Display

1. Limitations of CT display
2. Examples of CT window selection
3. Display of Volumetric Image Data
4. Maximum intensity projection (MIP)
5. The creation of shaded surface displays (SSDs)

VI. Image Quality

1. Contrast Resolution
    a. High-Contrast Resolution
    b. Low-Contrast Resolution
2. Image Noise
3. CT Protocols
4. Diagnostic CT

VII. Artifacts

1. Streaks
2. Rings and bands
3. Shading

VIII. Radiation Safety and Quality control

1. Definition
2. Why do we need QC?

IX. LightSpeed16

1. Hardware components
2. Scan Geometry
3. Mosaic Detector
4. Detector Configurations
5. System Highlights
6. Axial Signal Collection
7. Axial Configurations
8. Axial Interfacing
9. Axial Intervals
10. Axial Interval with Skip
11. Tilt Correction
12. Helical Pitch
13. Helical Configurations
14. Helical Interface
15. Slice Prospective
16. Slice Profiles
17. Benefits

X. References

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 40

Title: Computed Tomography Instrumentation and Operation (60 minutes)

Keywords: Coordinate System, Gantry, Detectors, ADC, High Voltage Generator, Gantry Control, DAC, Scan Controller, Host Computer, Console, Array Processors

Objectives:

- Discuss the key components of a basic CT scanner
- Discuss the components found within the housing unit of the Gantry
- Discuss the coordinate system of a CT scanner
- Discuss the scannable ranges of a CT system
- Discuss the patient couch weight limits
- Discuss the different focal spot sizes
- Discuss how the tube voltage would have an impact on the CT image
- Discuss various CT Detector scintillation crystals

Content:

I. CT Main System

1. Imaging System
2. Computer System
3. Display, Recording, Storage Systems
4. Data Acquisition System

II. Components of a Basic CT Scanner

1. Gantry
2. Detectors
3. S/H
4. Analog to Digital Converters (ADC)
5. Array Processors
6. Storage
7. X-Ray Tube
8. High Voltage Generators
9. Host Computer
10. Gantry Control
11. DAC
12. Scan Controller
13. Console

III. Scaner

1. Gantry
2. Patient Couch

IV. Components of the Gantry

1. Gantry Houses
   a. X-Ray Tube
   b. Generator (Low Voltage Design)
   c. Collimators
   d. Detectors
2. Gantry Characteristics

a. Aperture
    - Coordinate System
    - Isocenter
b. Tilt Range

V. Patient Couch Weight Limits

VI. Imaging System

1. Functions
2. Imaging System Components
    a. X-Ray Tube
    b. High Voltage Generator (HVG)
    c. Collimators
    d. Filter
        - Filtration material
    e. Detectors
    f. Detector Electronics
3. X-Rat Tube and X-ray Production
    a. Cathode
    b. Thermionic Emission
    c. Focal Spot
    d. Anode
    e. Heat Units calkulation
    f. Technique Compensation
        - mA
        - kVp
        - Time
    g. X-ray emission
    h. Tube Current Change
    i. Tube voltage (kVp) Change
    j. kVp in CT

VII. Detector Types

1. Scintillation
    a. Crystals
        - Sodium Iodide
        - Calcium Fluoride
        - Bismuth Germanate
    b. Photocathodes
        - Calcium Tungstate
        - Ceramic
2. Gas Ionization
3. Efficiency of Detectors - QDE

VIII. Computer System

1. Functions
2. Minicomputers
3. Hardware and Software
4. Computer Processing in CT
5. CT Operating System
    a. Unix
    b. Windows
6. Host Computer

IX. Data Acquisition System (DAS)

X. Display, Recording, Storage Systems

1. Image Display
2. Image Recording Systems (Laser Printers)
    a. Solid state laser Printers
    b. Gas laser Printers
    c. Hard Copy
3. Image Storage Media

XI. Communication

XII. Overread Network

XIII. CT Room Layout

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 41

Title: CT Data Acquisition (60 minutes)

Keywords: Axial Scanning, Helical Scanning, Cine, Data Acquisition Systems (DAS), ADC, DAC, Amplifiers, Binary Encoding, Fourier Transforms, Aliasing Artifacts, Acquire images

Objectives:
- Discuss the methods of acquiring computed tomography images
- Explain the functions of the data acquisition system (DAS)
- Describe the process of data acquisition
- Identify the factors that influence data acquisition
- List the selectable scan factors used to acquire images

Content:

I. Methods of Data Acquisition
1. Axial
   a. Axil Scanning
2. Spiral
   a. Helical/Spiral Technology
   b. Helical/Spiral Scanning
3. Cine

II. Data Acquisition processes
1. Lambert-Beer Law
2. CT Hounsfield Numbers
3. Data Acquisition System (DAS)
4. Analog to Digital Converters (ADC)
5. Digital to Analog Converters (DAC)
6. Amplifier/Log Amplifier
7. Transmitted Beam Measurements
8. Binary Data Encoding
   a. Binary System
9. Fourier Transformations
10. Data Transmissions
11. Aliasing Artifacts
12. Ring Artifacts
13. Convolutions, Back Projections snd Iterative Algorithm
14. Analytic Reconstructions
15. Kernels
16. Interpolations

III. Digital Acquisition System Performance
1. CT Tube
2. Detectors
   a. Gas Ionization Detectors
   b. Scintillation Detectors
   c. Detector Properties
3. Data Acquisition
4. Filters

5. Collimators
    a. Pre patient Collimators
    b. Post Patient Collimators

IV. Selectable Scan Factors

1. Display Field of View
2. Matrix
3. Slice Thickness
4. Spacing
5. Reconstruction Intervals

V. Scan factors used to acquire images

1. mAs
2. kVp
3. Kernels
4. Bypass Filters
5. Scan Time
6. Rotational Arcs
7. Rotation Times
8. Regions of Interest
9. Magnifications
10. Focal Spot Size
11. Tube Geometry
12. Dose Modulation
13. Pitch

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 42

Title: CT Image Processing and Reconstruction (60 minutes)

Keywords: CT Reconstruction, Linear Interpolation, Filtered Back Projections, Z-Axis Filtering, Interlaced Sampling, Smoothing, Windowing, Rendering, 3-D Reconstructions, Image Processing, Postprocessing Techniques, Gray-scale Manipulation, Image Display, Manipulation, Recording, Archiving, Technologist Workstation, Workstation Applications

Objectives:

- Describe the CT reconstruction steps
- Discuss Image Enhancement, and post processing techniques
- Discuss the tools used to view a CT Scan
- Discuss various workstation applications used with specialized CT studies
- Describe the methods of recording and archiving CT data

Content:

I. CT Reconstruction Steps

1. Image Processing
   a. Mini and Microprocessors
      - Array Processors
   b. Backprojections
   c. Linear Interpolation
   d. Filtered Backprojection
   e. Longitudinal Interpolation with Z-Axis Filtering
   f. Interlaced Sampling
   g. Practice Question
2. Reconstruction
   a. Retrospective Reconstruction
   b. Reformatting

II. Specific Postprocessing Techniques

1. Maximum and Minimum Intensity Pixels
2. Image Smoothing
3. Edge Enhancement
4. Gray-scale Manipulation
   a. Window Width
   b. Window Level
   c. WW/WL Equation
   d. WW/WL Equation
5. Shaded Surface Rendering
6. Multiplanar Reconstruction
   a. Curved Multiplanar Reconstruction
7. Volume Rendering
   a. 3-D Reconstruction
8. Virtual Reality
9. Practice Question

III. Tools used to view a CT Scan

1. Cathode Ray Tube

2. Liquid Crystal Display
3. Image Pan
4. Zoom
5. Image Scrolling
6. Swivel
7. Roll
8. Rotate
9. Measurement
10. Magnify
11. Viewing Modes
    a. 2-D and 3-D
    b. Slab
    c. Planar
    d. Cine

IV. Technologist Workstation

1. Directory or Patient List
2. Film/Print
3. Delete
4. Archive Button
5. Query
6. Send/Network
7. Copy/CD
8. Online Help

V. Workstation Applications

1. Ejection Fraction
2. Calcium Scoring
3. Stereotaxis
4. Radiation Oncology Treatment Planning
5. Fusion
6. Neurology
7. Vessel Analysis
8. Vessel Tracking

VI. Recording and Archiving

1. Laser Camera
2. Archiving
3. PACS
   a. Digital Imaging and Communications in Medicine (DICOM)
4. Practice Question

VII. Conclusion

VIII. Bibliography

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 43

Title: CT Image Quality (60 minutes)

Keywords: Image Quality, Resolution, Linearity, Uniformity, Image Quality Factors, Selectable Factors, Preset Options, Artifacts, Quality Control Program, Testing, Phantom Setup

Objectives:
- Discuss factors that affect image quality in CT
- Explain the methodology used to define image quality
- Identify CT image artifacts
- List factors that influence artifacts
- Identify the tests associated with a QC program

Content:

I. Image Quality
1. Evaluating Image Quality
2. Contrast Resolution
3. Linearity
4. Noise
5. Uniformity
6. Resolution
    a. Spatial
    b. Temporal

II. Factors Influencing Image Quality
1. Focal Spot Size
2. Beam Geometry
3. Image Receptor
4. Subject Contrast
5. Viewing Conditions
6. Selectable Factors
    a. mA and Scan Time
    b. Scan Field of View (SFOV)
    c. Display Field of View (DFOV)
    d. Slice Thickness and Spacing
    e. Filters
    f. kVp
7. Preset Options

III. Artifacts
1. Beam Hardening Artifacts
2. Partial Volume Averaging Artifacts
3. Motion Artifacts
4. Metal Artifacts
5. Equipment Artifacts
6. Ring Artifacts
7. Cone Beam Artifacts
8. Edge Gradient Artifacts
9. Out of Field Artifacts

IV. Quality Control Program in CT

1. Principles of Quality Control Testing
2. Phantom Setup
3. CT Number Calibration Test
4. Standard Deviation of the CT Number in Water
5. High-contrast Resolution
6. Low-contrast Resolution
7. Distance-measuring Device Accuracy
8. Video Monitor Distortion
9. CT Number Flatness
10. Hard Copy Output
11. Localization Device Accuracy
12. CT Couch Indexing
13. CT Couch Backlash
14. Light Field Accuracy
15. Slice Width
16. Radiation Leakage and Scatter

V. Measurements by Physicists

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 44

Title: CT Quality Control Procedures (60 minutes)

Keywords: Quality Control, Procedures, Tests, CT Dosimetry, Image Quality, Spatial Resolution, Contrast Resolution, Noise, Artifact, Beam Subject, Transmissivity, Dose, Slice Thickness, Scatter, Display Resolution, Reconstruction Algorithm, Point Spread Function (PSF), Contrast Transfer Function (CTF), Contrast Response Function (CRF), Modulation Traffic Function (MTF), Ring Artifact, Scan rotation time, Tube current, Peak tube voltage, Slice thickness, Table increment, Pitch, Linear Attenuation coefficient, Attenuation, Field-of- View (FOV), Matrix, Magnification, Widow

Objectives:
- Discuss what is Quality Control
- Discuss why we need Quality Control
- Explain the principles of Quality Control
- Discuss the Quality Control procedures performed on a CT Scanner
- Discuss Image Quality

Content:

I. Quality Control
1. Definition
2. Why do we need QC?
3. Principles of QC
   a. Periodic QC procedures
      - Daily
      - Monthly
      - Annually
   b. Prompt Interpretation
   c. Good Record Keeping
4. Tests
   a. Average CT Number in Water
   b. Standard Deviation of CT
   c. High Contrast Resolution
   d. Low Contrast Resolution
   e. Accuracy of Distance Measuring Devices
5. CT Dosimetry
6. Measuring CT Doses
7. Single Dose Descriptor

II. CT Image Quality
1. Image Quality Parameters
   a. Spatial Resolution
   b. Contrast Resolution
   c. Image Noise
   d. Artifacts
2. Factors Influencing CT Image Quality
   a. Beam Subject
   b. Characteristics Transmissivity
   c. Dose
   d. Slice Thickness

e. Scatter
f. Display Resolution
g. Reconstruction Algorithm

3. Spatial Resolution
   a. Resolvable Object Size and Limiting Resolution
   b. Geometric Factors affecting Spatial Resolution
   c. Geometric Unsharpness and CT
   d. Non Geometric Factors affecting Spatial Resolution
   e. Reconstruction Algorithms
4. Hi-Resolution CT Techniqu
5. Contrast Resolution
   a. CT Image Noise
   b. Noise Level
   c. Noise Measurement in CT
   d. Photon Flux to Detectors
   e. Slice Thickness
   f. CT Image Quality Equation Form
6. Measurements of Image Quality
   a. Point Spread Function (PSF)
      - Qualifying Blurring
      - Full Width at Half Maximum (FWHM)
   b. Line Spread Function (LSF)
   c. Contrast Transfer Function or Contrast Response Function (CTF or CRF)
      - CT Phantom
      - CT Spatial vs. Contrast Resolution
      - Contrast & Detail
      - Contrast Detail Diagrams
   d. Modulation Traffic Function (MTF)
      - Component
      - CT Number Calculations
      - Linearity
      - CatPhan
      - Cross-field Uniformity
7. CT Artifacts
   a. Definition
   b. Sources
      - Motion
      - Metal and high-contrast sharp edges
      - Beam hardening
      - Partial volume averaging
      - Sampling
      - Detectors
   c. Abrupt High Contrast Changes
   d. Ring Artifact in 3rd Generation
8. Image Quality Tests
   a. CT Number Calibration Test
   b. CT Number Standard Deviation Test

III. Patient Dose

1. Definition
2. Causes
   a. Scan rotation time
   b. Tube current
   c. Peak tube voltage
   d. Slice thickness

    e. Table increment
    f. Pitch
    g. Anatomical coverage desired
3. Linear Attenuation coefficient
    a. Amount of Attenuation
        - Atomic Number
        - Density of Electrons
        - Thickness
        - Photon Energy
4. Single-row Detectors Scanners
5. Multi-row Detector Scanners
6. Reconstruction Interval
7. Field-of- View (FOV)
    a. Scan FOV
    b. Reconstruction FOV
8. Matrix
9. Magnification
10. Widow Width and Window Level

IV. Conclusion

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 45

Title: Artifacts in CT (30 minutes)

Keywords: Artifacts, Streaks, Shading, Bands, Rings, Patients, Motion, Beam Hardening, Metal Artifacts, Out of Field Artifact, Equipment, Partial Volume Effect, Aliasing, Noise, Air-Contrast Interface, Rising, Tube Arcing, Line in Topogram, Staircase, Image Quality, Water Phantom, Region of Interest (ROI), Spiral Artifacts

Objectives:

- Discuss Appearance of Artifacts
- Describe Patients Induced Artifacts
- Describe Equipment Induced Artifacts
- Discuss Image Quality
- Illustrate Noise in CT, Linearity, Cross-Field Uniformity, Image Artifacts
- Explain the Methods of artefacts correction

Content:

I. Appearance of Artifacts

1. Streaks
2. Shading
3. Bands
4. Rings

II. Patients Induced Artifacts

1. Motion
   a. Types
      - Voluntary Motion
      - Involuntary Motion
   b. Remedy
2. Beam Hardening
   a. Types
      - Skull–Petrous Pyramids
      - Upper Chest and Shoulders
      - Hips
   b. Remedy
3. Metal Artifacts and Remedy
4. Out of Field Artifact and Remedy

III. Equipment Induced Artifacts

1. Partial Volume Effect and Remedy
2. Aliasing and Remedy
3. Photon Starvation (Noise) and Remedy
4. Air-Contrast Interface and Remedy
5. Rising and Remedy
6. Tube Arcing and Remedy
7. Line in Topogram and Remedy
8. Staircase and Remedy

IV. Image Quality

1. Noise in CT
   a. Noise Level
      - Mas
      - Scan Time
      - KVP
      - Slice Thickness
      - Object Size
      - Algorithmity
   b. Noise and Uniformity Measurement Techniques
   c. Water Phantom and Region of Interest (ROI)
   d. Object Size Noise
2. Linearity
3. Cross-Field Uniformity
4. Image Artifacts
   a. Types
      - Streaks
      - Rising
      - CT Distortion
   b. Sources
      - Patients
      - I imaging Process
      - Equipment
   c. Types and Causes of Artifacts
5. Motion Artifact-Voluntary & Involuntary Correction
   a. Immobilization
   b. Proper Explanation of Procedures
   c. Short Scan Time
   d. Motion Prediction
   e. Software
6. Metal Artifacts
   a. Avoidance of Metal Artifacts
7. Beam Hardening Artifacts - Coupling Artifact
8. Partial Volumer Artifact
   a. Minimiizing
   b. Correcting
   c. Noise – Photon Starvation
9. Out of Field Artifact
10. Equipment Induced Artifacts
11. Rising Artifacts - III Generation
    a. Correction
12. Aliasing Artifacts
    a. Correction
13. Tube Arcing
14. Spiral Artifacts
    a. Windmill
    b. Motion
    c. Staircase
    d. Shading

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 46

Title: CT Radiation Dose Calculations (60 minutes)

Keywords: Dose, Volume Computed Tomography Dose Index (CTDIvol), Patient Dose, Size Specific Dose Estimate (SSDE), Dose Length Product (DLP), Scan Mode, Table Feed, Detector Configuration, Pitch, Exposure Time, Tube, Beam Shaping Filter, Dose Modulation, Automatic Exposure Control (AEC), Image Quality, Noise Reduction, Dose Display, Phantom, Radiation Dose Structured Reports (RDSRs)

Objectives:

- Discuss what is Dose
- Determine differences between Volume Computed Tomography Dose Index (CTDIvol) and Patient Dose
- Review Acquisition Parameter Settings
- Define Dose Modulation and Reduction
- Discuss Dose Display

Content:

I. Dose

1. Volume Computed Tomography Dose Index (CTDIvol)
2. Patient Dose
3. How is CTDIvol related to patient dose?
4. Size Specific Dose Estimate (SSDE)
5. Dose Length Product (DLP)
6. Useful Concepts/Terms

II. Acquisition Parameter Settings

1. Scan Mode
    a. Dynamic Scan Mode
2. Table Feed/Increment
3. Detector Configuration
4. Pitch
5. Exposure Time per Rotation
6. Tube Current
7. Tube Potential
8. Tube Current Time Product
9. Effective Tube Current Time Product
10. Field of Measurement
11. Beam Shaping Filter

III. Dose Modulation and Reduction

1. Automatic Exposure Control (AEC)
2. Image Quality Reference Parameter
3. Tube Current Modulation
    a. Angular
    b. Longitudinal
    c. Angular and Longitudinal
    d. ECG-Based
    e. Organ-Based

4. Automatic Tube Potential Selection
5. Iterative Reconstruction
6. Noise Reduction Using Other Post Processing Software

IV. Dose Display

1. Display of Planned CTDIvol
2. Post Study Data Page
   a. CTDIvol
   b. DLP
   c. CTDI Phantom
3. Summing Dose Report Values
4. Dose Notification Levels
5. Dose Alert Levels
6. Radiation Dose Structured Reports (RDSRs)
7. Sample Doses

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 47

Title: Measuring Patient Dose From Computed Tomography (CT) Scanner (60 minutes)

Keywords: Computerized Tomography, X Rays, CT Scan, Computed Tomography (CT), Basic Principle of CT, Data Acquisition (DAS), Spiral or Helical Scanning, Helical CT Scanning, CT Gantry, CT Scanner Geometry, CT Scanner Components, Ionization Chamber, Absorbed Dose, Measurement Patient Dose, Computed Tomography Dose Index (CTDI), Dose Length Product (DLP), Effective Dose, Radiation Units, Radiological Protection, Dosimetry in CT, CT dose index, CTDI in air, Thermoluminescent Dosimeters (TLDs), CTDI in Acrylic Phantoms, CTDI in Perspex Phantoms, Multiple Scan Average Dose (MSAD), Reduction of Patient Dose, Size Specific Dose Estimate (SSDE), Contact Shields

Objectives:

- Discuss what is CT and basic principle of CT
- Review CT Scanner Geometry
- Describe dose distribution within the patient
- Review measurement of patient dose
- Define Dosimetry Quantity in CT
- Describe CT Dose Index (CTDI), Thermoluminescent Dosimeters (TLDs), Dosimetry - CTDI in Acrylic Phantoms
- Explain Multiple Scan Average Dose (MSAD)
- Illustrate Dose Length Product and Reduction of Patient Dose

Content:

I. Computerized Tomography

1. Definition of Tomography
   a. Tomography imaging
2. Background
3. X Rays
4. X Ray Tube Principles
5. Understanding the Image
   a. Conventional X-ray Images
   b. Attenuation
6. Understanding Basic factors
   a. Attenuation
7. Image Densities
8. Convectional X-ray and CT

II. CT Scan

1. Prototype CT Scaner
2. Present CT Scaner
3. Computed tomography
4. Basic principles
   a. Slice / Cut
   b. Matrix
   c. Poxel
   d. Voxel
   e. Digital Image
   f. CT numbers
   g. Visual image & Gray Scale

5. Phases of CT imaging
    a. Scanning the patient
    b. Data Acquisition (DAS)
    c. Image reconstruction
    d. Image Display
    e. Image archival (recording)
6. The Data Acquisition System
    a. Gantry
    b. X-ray tube
    c. X-ray detectors (sensors)
7. CT generations are based on
    a. Beam geometry
    b. X-ray tube trajectory (shift)
    c. Number of detectors
8. Tomographic acquisition
9. Reasons for Using CT
    a. Advantages of the spiral (Volume) CT scanner
    b. Hounsfield units
    c. CT Numbers or Hounsfield Units
    d. CT Numbers
10. Spiral or Helical Scanning
    a. Helical CT Scanning
    b. Helical (spiral) Scan Principle
    c. Helical CT Scanners
    d. Helical (spiral) CT
    e. Pitch
11. Modern CT scanner
    a. CT Gantry
    b. External and Internal structure

III. CT Scanner Geometry

1. CT Scanner Components
2. Principle of operation
3. Gantry
4. CT Tubes
5. Detectors
6. Table
7. Image Display
8. FOV
9. Image manipulation
10. Windowing
11. Image manipulation

IV. Ionization Chamber

1. Absorbed Dose
2. Dose Distribution within the Patient
    a. Radiation Dose for a single slice
3. Measurement Patient Dose
4. Computed Tomography Dose Index (CTDI)
    a. Weighted CTDI
    b. Volume CTDI
5. Dose Length Product (DLP)
6. Effective Dose
7. Radiation Units
    a. Absorbed dose in CT
    b. Radiation risk in CT

V. Radiological Protection and Dosimetry in CT

1. Radiation Dosimetry
2. Dosimetry Quantity in CT
3. CT dose index
   a. CTDI100
   b. CTDIw
   c. CTDIvol
4. Dosimetry - CTDI in air
   a. Pencil Ionization Chamber Method Of Measuring CT
   b. CT Phantom & Ionization Chamber
   c. Measurement of CTDI
5. Thermoluminescent Dosimeters (TLDs)
6. Dosimetry - CTDI in Acrylic Phantoms
7. Dosimetry - CTDI in Perspex Phantoms

VI. Multiple Scan Average Dose (MSAD)

1. MSAD
2. CTDI and MSAD
   a. Factors affecting absorbed dose: Z-axis
3. CTDI/MSAD method

VII. Reduction of Patient Dose

1. CTDIvol and Patient Dose
2. Factors Affecting Patient Dose
   a. KVp
   b. mAs
   c. Pitch
   d. Collimation
   e. Bed Index
   f. Beam Geometry
   g. Detector Setup
   h. Other: repeats, shielding, alignment, patient size...etc..
3. The effect of KV on Dose
4. Pitch and Dose
5. Size Specific Dose Estimate (SSDE)
6. Dose Length Product
7. Summary of CT Dose Quantities
8. Reduction of Patient Dose
   a. Contact Shields

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 48

Title: 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

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 49

Title: Basic Instrumentation of SPECT/CT: CT component (90 minutes)

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

c. Voltage Variation
d. KVP in CT
e. Advantages and Disadvantages of Voltage Variation
f. Current Variation
g. Advantages and Disadvantages of Current Variation
h. Current Variatio
i. MA of Tube Current
j. S –Time of Exposure
k. Focal Spot
l. X-ray Filter
m. Filtration Material
n. Filtration Change

II. Principles of Computed Tomography

1. CT Scanner Design - CT System
   a. Computer work station
   b. Image processing computers
   c. Electronic cabinets
   d. Gantry
   e. Patient imaging table
2. Computed Tomography Instrumentation and Operation
   a. Gantry and Gantry Control
   b. CT Detectors
   c. The X-ray Tube
   d. High Voltage Generator (HVG)
   e. DAS
   f. Console
   g. Host Computer
   h. Array Processor
   i. ADC
   j. Sample/Hold Unit (S/H)
   k. Storage
   l. Scan Controller
3. Collimation
   a. Advantages of thinner collimation
   b. Compromises of thinner collimation
4. Rotation Speed
5. Pitch
6. Incensement
7. Multislice Helical CT Systems
8. Image Data Acquisition
   a. Data Acquisition System (DAS)
9. CT Image Reconstruction
10. CT Display
11. Control Console
    a. Set scan parameters
    b. Set scan mode
    c. IRS (Image reconstruction System)
    d. Review and archive images
    e. Post-processing
12. Coordinate System
13. Isocenter
14. Patient Orientation
    a. Head First
    b. Feet First
    c. Patient Couch

15. Scannable Range
16. Scan FOV
    a. DFOV – Displayed Field of View

III. Scanning Methods

1. Surview
   a. AP
   b. Lat
   c. Surview
   d. Scanogram
   e. Topogram
2. Conventional CT
   a. Axial
   b. Start/stop
3. Volumetric CT
   a. Helical or spiral CT
   b. Continuous acquisition

IV. Topogram Regular Scan

1. Topogram (Scout)
   a. AP Scout
   b. LAT Scout
2. CT Data Acquisition

V. Fundamentals of Multislice CT

1. Axial Scan
   a. Spiral
   b. Axial CT
2. Conventional and Spiral/Helical CT
   a. Advantage of Spiral Imaging Over Conventional - Speed
   b. Digital Projection
3. Axial CT
4. Volume CT
   a. Pitch
   b. Advantages of Volume C
5. Multislice Effectiveness
   a. Dual Slice Detector Optimized for 2 Slice Acquisition
   b. Quad Detector Technology
   c. Variable Wide Area Detector
   d. Quad Technology
   e. Slip Ring Twchnology
   f. Singl Slice and Multi Slice CT
6. Spiral CT
   a. Display of Volumetric Image Data
   b. Image Quality
   c. High and Low Contrast
   d. Image Noise
7. Low–Dose CT for SPECT Attenuation Correction
   a. Attenuation
8. Integrated SPECT/CT Protocols
   a. CT Protocols
9. Diagnostic CT
   a. Abdomen CT
   b. Chest CT
   c. Neck CT
10. Contrast Media

a. CT Contrast Agents
b. Administration

11. Advantages and Limitations of CT
12. Goals of CT
13. Density Information
    a. Hounsfield scale
14. Windows Settings
15. CT Images Quality
16. Isotropic Imaging
17. Post Processing Options
18. Pixel Size
    a. Reconstruction
    b. Pixel and Voxel
    c. Vocal Size Depends
19. Image Display
    a. Computed Gray Scale and CT Numbers
    b. CT Image
    c. CT Number
    d. Image Recording Systems (Laser Printers)
    e. Heard Copy
    f. Image Storage Media
    g. Communication

VI. CT Quality Control

1. General QC Tests: Image Quality
    a. Noise and Field Uniformity
    b. CT Number Linearity
    c. Low Contrast Detectability
    d. Spatial Resolution
    e. Display and Hard Copy Image Quality
2. General QC Tests: Dosimetry
    a. CTDI
    b. Patient Dosimetry
3. Alignment Laser Accuracy
4. Table Incrementation Accuracy and Collimation (Axial Scan)
5. Table Incrementation Scanned Volume Helical Pitch Accuracy
6. KVP Accuracy
7. Hale-Value Layer
8. Exposure Reproducibility and Linearity
9. Radiation Profile Width
10. Slice Sensitivity Profile
11. Image Quality Measures
    a. Noise and Field Uniformity
    b. CT Number Linearity
    c. Low Contrast Detectability
    d. Spatial Resolution
    e. Reconstruction times
    f. Scout view accuracy
12. Phantoms and Test Tools
13. Display and Heard Copy Image Quality
14. Dosimetry Measurement: CTDI
15. CT Equipment Quality Control Program
16. Acceptance Testing
    a. Considerations for Acceptance Tests
    b. Essential Tests
    c. Optional Tests

d. Alternative Tests
17. Annual ACR Requirements
18. Monthly to Semi-annual Tests Per AAPM
19. Continuous Quality Control
    a. Continuous Quality Control Tests
    b. Daily Tests AAPM
    c. AIDS to Daily QC
20. AUTOQA Lite Overview
21. CT Radiation Safety

VII. Basic SPECT/CT Technology

VIII. General overview of SPECT/CT System Architecture

IX. Overview of basic SPECT/CT Protocols

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

XI. Advantages of SPECT/CT

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

XIII. Diagnostic quality CT Studies

XIV. CT Internal Radiation Dose Dosimetry

XV. Estimated Radiation Dose from a SPECT/CT Procedure

XVI. SPECT/CT Radiopharmaceuticals

XVII. Comparing today's SPECT/CT systems
1. SPECT/CT

XVIII. Conclusion

Module II: "Content pertaining to CT": You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 50

Title: Electronics of SPECT Detectors (30 minutes)

Keywords: SPECT, PET, Imaging, Emission Tomography, Data Corrections, Image Analysis, Attenuation Problem, Uniformity Corrections, Radionuclide Bone Imaging, Randoms Correction, Scatter Correction

Objectives:
- Discuss Basic Principles of SPECT and PET Imaging
- Describe Performance Characteristics in Emission Tomography
- Explain Data Corrections and Image Analysis
- Review Recent Developments in Radionuclide Bone Imaging

Content:

I. Introduction

II. Basic Principles of SPECT Imaging

III. Basic Principles of PET Imaging

IV. Performance Characteristics in Emission Tomography
1. General aspects of performance characteristics in emission tomography
2. Physical properties of some of the detector materials used in emission tomography

V. Data Corrections and Image Analysis
1. The Attenuation Problem
2. Uniformity Corrections and Detector Normalisation
3. Randoms Correction (PET)
4. Scatter Correction

VI. Recent Developments in Radionuclide Bone Imaging

VII. References

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course
Module II: Content pertaining to CT

Lecture 51
Title: SPECT Quality Control (120 minutes)

Keywords: Gamma camera, Scintillation camera, Anger camera, Quality Contol (QC), Quality Assurance (QA), Image, Binary digits (Bits), Collimator, Photomultiplier Tubes (PMT's), Definition, Test Equipment, Visual Inspection, Background level measurement, Photopeak, Window setting, Sensitivity, Rate Performance, Resolution, Linearity, Detector Head Tilt, Centre of Rotation (COR), Detector, Uniformity, Phantom Studies, Attenuation Correction, Shielding, System Alignment, Correction Tables, Documentation, Record Keeping, Action Thresholds

Objectives:
- Discuss what is it a Quality Control (QC) and Gamma Camera QC
- Give some guidelines for troubleshooting and problem solving
- Describe Image Types, Fundamental component and Characteristics of Gamma Camera General Definitions
- 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)
1. Definition
2. Quality Assurance (QA) and Quolity Control (QC)

III. Image Types
1. Analog and Digital Images
2. Digital Advantage
   a. Functions of digital image
3. Analog Images
4. Human Digits
5. Comparing Human and Computer Digits
   a. Ten different digits
   b. Binary digits (Bits)
6. Writing Numbers in Bits
7. Range of Values for Numbers in Binary Form
8. Pixel Bit Depth
9. Eight-bit Pixel Depth
10. Effect of Bit Depth on the Image
11. 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
12. Image Matrix Size for the Different Imaging Modalities
13. Numerical Size of a Digital Image
14. Image Compression
    a. Lossless compression

IV. Gamma Camera

1. Definition
2. Fundamental components
   a. Sodium iodide crystal
   b. Array of photomultiplier tubes
   c. Collimator
   d. Computer
3. Scintillation Camera Function
4. Collimator
   a. Micro-cast Technology
   b. Micro-linear Technology
   c. Collimator Quality
5. Types of Collimator
   a. Parallel hole collimator
   b. Slanthole collimators
   c. Converging and Diverging Collimators
   d. Fanbeam collimators
   e. Pinhole collimators
6. Scintillation
   a. Scintillation Counter
7. Photomultiplier Tubes (PMT's)
   a. Pre-Amplifier
   b. Position logic circuit
8. Computer
   a. Analog to digital converter (ADC)
9. Gamma Camera Characteristics

V. General Definitions

1. Absolute linearity
2. Central Field of View (CFO)
3. Detector
4. Differential linearity
5. Differential uniformity
6. Digital resolution
7. Energy resolution
8. Energy window
9. Foldover
10. Full width at half maximum (FWHM)
11. Full width at tenth maximum (FWTM)
12. Integral uniformity
13. Input count rate
14. Intrinsic
15. Linear interpolation
16. Observed count rate
17. Photopeak
18. Pixel
19. Scatter
20. Sensitivity
21. Spatial Linearity
22. Spatial resolution
23. Spectrum
24. Standard deviation
25. System
26. Test pattern
27. 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
10. Image Alignment in Y for Multihead SPECT Systems
    a. Exemple: Dual head SPECT system — misalignment in Y
11. 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 Frequent Tests
    a. Resolution Phantoms
    b. Center of Rotation (COR) Test
5. Summary of SPECT QC Tests

XVI. Documentation, Record Keeping and Action Thresholds

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 52

Title: 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
1. Artifact groups
   a. camera dependent artifacts
   b. radiopharmaceutical dependent artifacts
   c. patient-related artifacts

III. Instrument and computer-related artifacts in nuclear medicine
1. Artifacts associated with instrumentation errors
   a. Flood field non-uniformity
   b. Center-of-rotation (COR) error
   c. Camera head tilt
   d. Detector-to-patient distance
2. 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
3. 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
    4. Artefacts arising from sources/phantoms
        a. Fillable flood sources
            - Air bubble
            - Adherence of activity to the container at the filling site (algae)
    5. Cobalt sheet sources
        a. New 57Co sheet source
        b. Intrinsic uniformity — geometry of point source and detector — source too close to detector
    6. Spatial Resolution and Linearity
        a. Intrinsic spatial resolution influence of digital matrix size
    7. 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
    8. 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

1. 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
2. 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

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

15. Extraosseus Uptake on Bone Scintigraphy
16. Cardiac
17. Image Display
18. Image Interpretation and Reporting
19. Attenuation Correction and Artifacts: Artifacts of Soft Tissue Attenuation
20. Artifacts of Subdiaphragmatic Radiotracer Activity
21. Artifacts of Patient Motion
22. Artifacts of Misregistration
23. Effects of Normal Apical Thinning

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 53

Title: CT Safety and Protection (45 minutes)

Keywords: Patient Safety, Measuring Patient Dose, Dose Indices, Reducing Radiation Dose, mA Modulation, Pitch, Collimation, Gating, Detector, Occupational Exposure, Contrast, Power Injectors, Venipuncture, Extravasation, PICC Lines, Port a Cath, Perm a Cath, Pre scan Procedures, Metformin, Patient Consent, IV Lines, Post Scan Procedures, Ethics, Restraints, Pediatrics, Pregnant, Emergency

Objectives:

- Describe and use methods to measure patient dose
- Discuss the role of the computed tomography technologist in reducing radiation dose, including technical factor selection, positioning and shielding
- Explain the basics of occupational exposure in computed tomography
- Discuss special considerations for pediatric patients
- Describe ethical considerations, including the overuse of CT, appropriate imaging of pediatric patients and how protocols can affect scanning.
- Use the basics of patient care to ensure patient safety, including protocols, venipuncture, contrast administration and informed consent
- Explain pre procedure and post procedure instructions
- Demonstrate emergency procedures

Content:

I. Patient Safety

II. Measuring Patient Dose

III. CT Dose Indices

IV. Reducing Radiation Dose

1. Patient Education
2. Physicians Education
3. Positioning
4. Shielding
5. Technical Factors

V. mA Modulation

VI. Pitch

VII. Collimation

VIII. Gating

IX. Detector Configuration

X. Occupational Exposure

XI. CT Order

XII. Contrast
1. Contrast Contraindications

XIII. Power Injectors

XIV. Venipuncture
1. Venipuncture procedures

XV. Extravasation

XVI. Central Access Devices
1. PICC Lines
2. Port a Cath
3. Perm a Cath

XVII. Prescan Procedures
1. Metformin
2. Patient Consent

XVIII. IV Lines

XIX. Post Scan Instructions

XX. Ethics

XXI. Restraints

XXII. Pediatrics

XXIII. Pregnant Patients

XXIV. Emergency Equipment

XXV. Emergency Situations

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 54

Title: Methods for Reducing the Radiation Exposure in a PET/CT Lab: CT Component (90 minutes)

Keywords: CT, Scanners rotation, Unit, Dosimetry, Computed Tomography Dose Index, CTDI, Muliple Scan Average Dose, MSAD, Dose Metrics, Weighting Factors, Beam Geometry, Bed Index, Reeducation of Dose, Patient Dose, Dose Reduction, Methods, Shielding, Children, Protocol, Immobilization Devices, Sedating, Equipment, Medications, Intra-Procedure, Post-Procedure

Objectives:

- Identify various types of CT scanner rotations
- Define traditional and international units of radiation exposure
- Discuss CT Dosimetry measurements
- Discuss CT beam geometry
- Explain factors effecting patient dose from a CT scanner
- Discuss dose reduction methods with a CT scanner
- Discuss the importance of proper patient positioning
- Identify key CT acquisition parameters effects on radiation exposure
- Discuss various types of patient shielding devices
- List effective radiation dose values from a CT scan
- Identify alternative methods for dose reduction
- Discuss the parent's role in reducing a child's radiation exposure
- Discuss standardized CT protocol development
- List child immobilization devices used to control patient motion
- Discuss methods for sedating a child
- List required equipment needed to sedate a child
- Discuss sedation medication effects
- List common sedation medications
- Describe Intra-procedural and Post-procedural monitoring

Content:

I. Different types of CT scanners rotation

1. Axial CT
2. Volume CT
   a. Volume Scanning Pitch
   b. Advantages of Volume CT
3. Multislice CT
   a. Multislice Fundamentals
   b. Multislice Effectiveness
   c. Quad Detector Technology

II. Units of radiation exposure

1. Traditional
2. International

III. Dosimetry measurements

1. Principle of Operation of Ionization Chambers
2. CT Dosimetry
3. Method to Measure Patient Dose
   a. CTDI
   b. MSAD

4. Pencil Ionization Chamber Method of Measuring CT Dose
5. CTDI/MSAD Measurement Methods
6. CT Dose Metrics
7. Weighting Factors

IV. CT Beam Geometry

1. Muliple Scan Average Dose (MSAD)
2. Bed Index (BI)
3. Computed Tomography Dose Index (CTDI)
4. CTDI and MSAD
5. CTDI and MSAD Affect
6. MSAD and BI

V. Reeducation of Dose

1. Factors Affecting Patient Dose
2. Dose Reduction Methods with a CT scanner
    a. Patients Positioning
    b. Positioning and Dose Modulation
    c. Tube Position for Scouts
3. CT Acquisition Parameters Effects on Radiation Exposure
    a. KV
    b. FOV and Filters
    c. Pitch
    d. Image Noise
    e. Rotation Time
    f. Dose Modulation
    g. Patients Alignment
4. Shielding
    a. Contact Shields
    b. Gonadal Shields
    c. Bismuth Shields
        - Bismuth Breast Shielding
        - Breast Shielding in Practice
        - Breast Shielding Protocol
        - Other Bismuth Applications
5. Recommendations
6. Effective Radiation Dose Values
7. Alternative Methods for Dose Reduction to Children
    a. CT scans on Children
    b. Dealing with the Problem
    c. Why Increased Dose to the Children
    d. Parental Tips to Limit CT Radiation Exposure to Children
8. CT Scan Overuse may up Cancer Risk
9. Why Increased Dose
10. Organ Doses in CT
11. Observations

VI. CT Protocol Development

1. How to Develop CT Protocols for Children
2. Technologist Role
3. Manufacturers Role
4. Physician Role

VII. Child Immobilization Devices used to Control Patient Motion

1. Successful CT Studies of Children
2. Parent Role

3. Immobilization Devices
    a. Tam-em board
    b. Pigg-O-Stat
    c. Sandbags
    d. Tape and Bandage
    e. Compression Bands and Head Clamps
    f. Weighted Angle Blocks as Head Clamps
    g. Mummifying or Wrapping With Sheets or Towels
4. Minimal Repeats
5. Gonadal Protection

VIII. Methods for Sedating a Child

1. Pre-exam Preparation
2. Children Preparation
3. Consent
4. Pre-Sentation Evaluation
    a. History/Physical
    b. Immediate Pre-Sentation Assessment
5. Patient Preparation
6. Monitoring and Training of Personnel
7. Equipment
    a. Emergency code cart
    b. Oxygen delivery system
    c. Monitoring equipment
    d. Defibrillator readily available
    e. Drug antagonist readily available
8. Medications
    a. Three distinct effects
        - Sedation
        - Analgesia
        - Amnesia
    b. Barbiturates
    c. Benzodiazepines
    d. Narcotics
    e. Ketamine
    f. Ketorolac
    g. Propofol
    h. Chloral Hydrate
    i. Reversal Agents
        - Naloxone
        - Flumazenil

IX. Intra-Procedure Monitoring

X. Post Procedure Monitoring/Discharge

XI. Patient Education/Legal Guardian

XII. Summary

XIII. References

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module II: Content pertaining to CT

Lecture 55

Title: Methods for Reducing the Radiation Exposure in a PET/CT Lab: PET Component (60 minutes)

Keywords: Radiation Protection, PET/CT Lab, Radiation Protection, Diagnostics, Hazard, Hazard, Building Requirements, Background Equivalent Radiation Time (BERT), Equivalent Doseand (EqD), Effective Dose (EfD), Organization, Dose Limiting System

Objectives:

- List the various sources of radiation exposure found in a PET/CT Lab
- Identify ways to reduce the radiation exposures from a PET/CT Lab department layout
- Explore safe practice considerations when designing a PET/CT Lab
- Discuss the key team members in planning a PET/CT Lab
- List methods for restricting access to controlled and uncontrolled areas in a PET/CT Lab
- Explain potential areas of exposures found in the PET hot lab
- Discuss the Room Layout in designing a PET/CT Lab
- Discuss the Interview, Consultation, and Office layout design for the PET/CT Lab
- Discuss the Waiting and Uptake Room layout design plans for a PET/CT Lab
- Discuss the Scanning Room layout design for a PET/CT Lab
- Discuss the Post Scan or Recovery Room for a PET/CT Lab
- Explain shielding exposure limiting considerations for a PET/CT Lab
- Discuss Dose Reduction Strategies for the staff
- Describe the requirements of a good Radiation Safety Program
- Discuss the categories of hazards and weighting factors within a PET/CT Lab
- Explore the biological effects of radiation exposures
- Define ALARA
- Define Background Equivalent Radiation Time (BERT)
- List sources of natural background radiations
- Identify the various organizations involved in regulating radiation exposures

Content:

I. Radiation Protection of the Staff in a PET/CT Lab

1. Sources of Radiation Exposure
2. Layout of a PET/CT Department
3. Work Practice Considerations
4. General Environment and Layout of a PET/CT Lab
   a. Interview room/consultation room/office
   b. Waiting room
   c. Uptake rooms
   d. Scanning rooms
   e. Post-scan patient changing room
5. Shielding Considerations
   a. Data for shielding calculations
6. Dose Reduction Strategies for Staff
7. Good Radiation Protection Program
8. A few points are worthy of special mention.
9. X-ray Aprons

II. Clinical demands for PET/CT diagnostics

1. Sources of radiation exposure

a. Internal dose from radiopharmaceuticals (PET)
b. External from X-rays (CT)

2. Effective Patient Dose and Image Quality for Hybrid PET/CT Imaging
3. Annual Radiation Dose Limits
4. PET Hot Lab Hazards
   a. Categorization of Hazards
      - Weighting Factors According to Radionuclide
      - Weighting Factors According to Type of Operation
      - Administration of 11 GBq F-18 (FDG)
      - Patient examination, 400 MBq Tc-99m
      - Patients waiting
      - Premises not Frequented by Patients (Typically Results of Hazard Calculations)
   b. Building Requirements
      - Design
      - Ventilation
      - Fume Hood
      - Sinks
      - Washing Facilities
      - Shielding

III. Effective Radiation Protection Principles

1. Biologic Effects
2. Benefits vs. Risk
3. Diagnostic Efficacy
4. Achievement of Diagnostic Efficacy
5. ALARA
   - Responsibility for Maintaining ALARA
6. Patient Education
7. Background Equivalent Radiation Time (BERT)

IV. Types of Radiation

1. Ionizing amd Non-ionizing Radiation
2. Particulate Radiation
3. Equivalent Doseand (EqD) and Effective Dose (EfD)
4. Sources of Radiation
   a. Terrestrial Radiation
   b. Cosmic Radiation
   c. Internal Radiation
   d. Manmade (Artificial) Radiation

V. Organizations Involved in Regulating Radiation Exposure

1. International Commission on Radiological Protection (ICRP)
2. Nuclear Regulatory Commission (NRC)
3. National Council on Radiation Protection and Measurements (NCRP)
4. Environmental Protection Agency (EPA)
5. Food and Drug Administration (FDA)
6. Occupational Safety and Health Administration (OSHA)
7. Radiation Safety Committee (RSC) and Radiation Safety Officer (RSO)

VI. Effective Dose Limiting System

1. Non-stochastic and Stochastic effects
2. Early and Late Non-Stochastic effects
3. ALARA Concept
4. Radiation Protection
5. Risk

6. Effective Dose Limiting System
7. NCRP Recommendations
8. Occupational Dose Limits

Module II: “Content pertaining to CT”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 56

Title: MR Fundamentals (90 minutes)

Keywords: Magnetic resonance (MR) imaging, Advantages, MR Scanners, Magnet Types, Magnetic Field Strength, MR Safety, Planes, History, Clinical Application, Innovation, Examination, Requirements, Physics, The Faraday Law, Electromagnetism, Magnetic Induction, Vectors, Hydrogen Atoms, Field Applied, Field Strength, Magnetic Fields, Precession, Larmor Equation, Radiofrequency, Resonance, Superconducting Magnet, Coordinate System, Relaxation, Computers, Integrated Modalities

Objectives:
- List the advantages of using magnetic resonance (MR) imaging
- Discuss the history of MR imaging
- Name the researchers and pioneers in MR imaging
- Explain how an image is acquired using MR
- Describe how the MR signal is produced and detected
- Discuss the future of MR imaging

Content:

I. Introduction

II. Advantages of MR

III. MR vs. CT

IV. MR Scanners

V. Magnet Types
1. Permanent Magnet
2. Resistive Magnet
3. Superconducting Magnet

VI. Magnetic Field Strength

VII. MR Safety

VIII. Planes
1. Coronal
2. Sagittal
3. Axial

IX. MR Defined — Evolution

X. History of MR Imaging

XI. MR History — Clinical Application

XII. MR Innovation

XIII. MR Examination

XIV. MR Requirements

XV. MR Physics

XVI. The Faraday Law

XVII. Electromagnetism and MR

XVIII. Magnetic Induction

XIX. Vectors

XX. Hydrogen Atoms

XXI. No External Field Applied

XXII. External Field Applied

XXIII. Increasing Field Strength

XXIV. Net Magnetization Vector

XXV. Magnetic Fields

XXVI. Precession

1. Precessional Frequency
2. In-phase Precession
3. Out-of-phase Precession

XXVII. Larmor Equation

XXVIII. Larmor Frequency and Magnetic Field Strength

XXIX. Radiofrequency

XXX. Resonance

1. Generating MR Signal
    a. Longitudinal Direction
    b. Transverse Magnetization
2. RF Excitation Pulse
3. RF Energy Absorption

XXXI. Superconducting Magnet

XXXII. Coordinate System

XXXIII. Relaxation

1. Types of Relaxation
    a. Longitudinal Relaxation (T1 Relaxation)
    b. Transverse Relaxation (T2 Relaxation)
2. Relaxation Process
3. Free Induction Decay (FID)
4. T1-weighted Contrast
5. T2-weighted Contras

6. Excitation
7. T1 and T2 Relaxation

XXXIV. Computers in MR Imaging

XXXV. Advances in MR

XXXVI. Integrated Modalities

XXXVII. MR-safe Pacemakers

XXXVIII. Conclusion

XXXIX. Annex

1. Bibliography
2. Acknowledgements
3. MR Parameters: Actions and Associated Trade-offs
4. Optimizing Image Quality
5. MRI Fundamentals Glossary

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 57

Title: Radiofrequency and Gradients (90 minutes)

Keywords: Gradients, RF Systems, Gradient Composition, Gradient Coils, RF Coils, RF Shielding, Gradient-echo Pulse Sequences, Safety

Objectives:
- Explain the functionality of the radiofrequency (RF) system in magnetic resonance (MR) imaging.
- Explain the functionality of the gradient system in MR imaging.
- Discuss how gradients alter magnetic fields.
- Describe the role of coils when applying gradients.

Content:

I. Introduction

II. Gradients and RF Systems

III. Gradient Composition

IV. Magnetic Isocenter

V. Gradient Coils and Amplifiers

VI. Applying Gradients

VII. Hardware — Gradient Coils

VIII. Example

IX. Gradient Axes

X. Partial Gradients

XI. Oblique Angle

XII. Gradients

XIII. Pulse Sequence

XIV. Slice-select Gradient

XV. Phase Encoding

XVI. Phase Shift

XVII. Frequency Encoding

XVIII. Frequency-encoding Gradient

XIX. Balanced Gradient System

XX. Gradient Strength

XXI. Gradient Rise Time and Slew Rate

XXII. Duty Cycle

XXIII. Eddy Current
1. Eddy Current Compensation

XXIV. Safety
1. Acoustic Noise

XXV. RF Systems

XXVI. Body Coil

XXVII. RF Production

XXVIII. Faraday Law of Induction

XXIX. Electromagnetic Spectrum

XXX. RF Production Steps

XXXI. Sampling

XXXII. Fourier Transform Algorithm

XXXIII. Facts About K-space

XXXIV. Filling K-space

XXXV. RF Transmitters

XXXVI. RF Coils
1. Volume Coil
2. Quadrature Coils
    a. Circular-polarized design
    b. Linear Polarized Design
3. Surface Coils
4. Phased-array Coils
5. Multiple Coils

XXXVII. RF Shielding

XXXVIII. Magnetic Field Strength

XXXIX. Angular Momentum

XL. Precession

XLI. Active Nuclei

XLII. Resonance

XLIII. Magnetism

XLIV. Net Magnetization Vector (NMV)

XLV. The MR Signal

XLVI. Gradient-echo Pulse Sequences

1. Coherent Gradient-Echo Pulse Sequences
2. Rewinder Gradient
3. Incoherent Gradient Sequence
4. Gradient Spoiling

XLVII. Using Gradients

XLVIII. T1 Recovery

XLIX. T2 Decay

L. Proton Density

LI. RF Safety

1. Tissue Heating
2. Specific Absorption Rate (SAR)
3. Burns

LII. Conclusion

LIII. Annex

1. Bibliography
2. Acknowledgements
3. MR Parameters: Actions and Associated Trade-offs
4. Optimizing Image Quality
5. MRI Fundamentals Glossary

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 58

Title: Image Quality (90 minutes)

Keywords: Image Quality, Intrinsic parameters, Extrinsic parameters, Signal-to-noise ratio, Contrast-to-noise ratio, Artifacts, Hardware, Field Strength (B0), Coil configuration (B1), Positioning, Voxel Size, Slice Thickness, Field of View, Matrix , Sampling, Pulse Sequences, Image contrast, Temporal Resolution, Repetition time, Echo time, Inversion time, Flip angle, Motion Compensation, MR image formation

Objectives:

- List the imaging parameters that determine image contrast
- Describe how imaging parameters determine spatial resolution on magnetic resonance (MR) images
- Name the imaging parameters involved in MR image formation
- Explain parameters and imaging options to obtain diagnostic MR images with minimal image artifacts

Content:

I. Introduction to MR Image Quality
   a. Intrinsic and Extrinsic Parameters
   b. MR Parameters and Options
   c. Which Image Is Better?

II. Definitions
   1. Signal-to-noise ratio
   2. Contrast-to-noise ratio

III. MR Artifacts
   1. Physics Artifacts
   2. Sampling Artifacts
   3. Instrumentation Artifacts
   4. Technical Error Artifacts
   5. Beneficial Artifacts
   6. Nonbeneficial Artifacts
   7. Susceptibility Artifact

IV. Scan Parameters
   1. Hardware
      a. Field Strength (B0)
         - Field Strength and Noise
         - Susceptibility Artifact
      b. Coil configuration (B1)
         - RF Coils
      c. Positioning
   2. Voxel Size
      a. Voxel Characteristics
      b. Pixel Size
      c. Isotropic Voxel
      d. Partial Volume Averaging

e. Non-Isotropic Voxels
f. Slice Thickness
g. Field of View
    - Field of View and Aliasing
h. Matrix

3. Sampling
    a. Number of Signals Averaged
    b. Bandwidth
    c. 2-D vs. 3-D
4. Pulse Sequences
    a. Time and Quality
    b. Pulse Sequences and Quality
    c. Temporal Resolution
    d. Repetition Time
    e. Echo Time
    f. Quality and T1
    g. Flip Angle Effects
    h. Flip Angle and Noise
    i. Contrast Enhancement
5. Flow Motion Compensation
    a. Spatial presaturation
    b. Gradient moment nulling
    c. Respiratory Compensation (breath-hold techniques)
        - respiratory triggering and respiratory compensation
        - respiratory-ordered phase encoding

V. Conclusion

VI. Annex

1. Bibliography
2. MR Parameters: Actions and Associated Trade-offs
3. Optimizing Image Quality
4. MRI Fundamentals Glossary

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 59

Title: Image Production Parameters (90 minutes)

Keywords: MR Imaging, Intrinsic Parameters, T1 relaxation, T2 relaxation, Proton density, Extrinsic Parameters, Repetition time (TR), Echo time (TE), Inversion time, Flip angle, T1 Weighting, T2 Weighting, Proton-Density Weighting, Proton-Density Scans, Image Weighting Parameters, Image Contrast Comparisons, Pulse Sequences, Spin-Echo Pulse Sequences, Spin-Echo Sequence Steps, Fast Spin-Echo Sequences, Gradient, Recovery Sequences, Image Quality Comparison, Balancing Parameters

Objectives:

- Explain intrinsic parameters that affect image quality, such as proton density, T1 relaxation and T2 relaxation
- Explain extrinsic parameters that affect image quality, such as repetition time (TR), echo time (TE), inversion time and flip angle
- Define the use of gradient and radiofrequency (RF) pulses in acquiring MR images
- Described image contrast appearance according to image weighting

Content:

I. MR Advantages and Parameters

II. Intrinsic Parameters

1. T1 relaxation
2. T2 relaxation
3. Proton density

III. Extrinsic Parameters

1. Repetition time (TR)
2. Echo time (TE)
3. Inversion time
4. Flip angle
5. Signal and Flip Angle

IV. Manipulating Extrinsic Parameters

1. T1 Weighting in MR Imaging
   a. T1 Relaxation Time
   b. T1 Contrast Curve
   c. T1 Brain Images
   d. Contrast vs. T1 and TR
2. T2 Weighting in MR Imaging
   a. T2 Relaxation Time
   b. T2 Contrast Curve
   c. T2-weighted Images

V. TE Values and T2 Weighting

1. Contrast vs. T2 and TE
2. Summary of T1 and T2 Relaxation
3. Combined Effects of T1 and T2 Relaxation
4. T2* Weighting
5. Longitudinal Magnetization
6. Spin-Echo vs. Gradient-Echo

7. Shimming
8. Comparing T2 and T2* Images

VI. Proton-Density Weighting in MR Imaging
1. Proton-Density Weighting
2. Proton-Density Imaging
3. Hydrogen Content in Tissues
4. Uses of Proton-Density Scans

VII. Image Weighting Parameters
1. T1-weighted scan uses a short TE and a short TR
2. T2-weighted scan uses a long TE and a long TR
3. Proton-density scan uses a short TE and a long TR

VIII. Image Contrast Comparisons

IX. Introduction to Pulse Sequences
1. Saturation
2. T1-weighted Images and Saturation
3. Partial Saturation Sequence

X. Conventional Spin-Echo Pulse Sequences
1. Spin-Echo Pulse Sequences
2. Relaxation
3. Review of Spin-Echo Sequence Steps
   a. Flip the net magnetization vector
   b. Remove RF Pulse
   c. Free Induction Decay
   d. Rephase With 180-degree Pulse
   a. Spins Return to In-Phase
4. Spin-Echo
5. Parameter of Tau
6. Advantages of Spin-Echo
7. Disadvantages of Spin-Echo

XI. Fast Spin-Echo Sequences
1. Gradient-Echo Pulse Sequences
2. Magnetic Field Gradients
3. Advantages of Gradient Echo

XII. Inversion Recovery Sequences
1. Fast Spin-Echo Inversion Recovery
2. Inversion Time
3. Short Tau Inversion Recovery
4. Fluid-Attenuated Inversion Recovery

XIII. Image Quality Comparison
XIV. Balancing Parameters
XV. Conclusion

XVI. Annex
1. Bibliography
2. Acknowledgements
3. MR Parameters: Actions and Associated Trade-offs
4. Optimizing Image Quality
5. MRI Fundamentals Glossary

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 60

Title: Equipment and Instrumentation (60 minutes)

Keywords: Equipment, MR gantry, Patient Table, Operator's console, Computer, Magnetism, Magnetic Field Strength, Specific Absorption Rate (SAR), Chemical Shift, Dielectric Effect, Magnetic Susceptibility, Magnet Configurations, Shielding, Future

Objectives:

- Identify the major hardware components in magnetic resonance (MR) imaging
- Understand magnetism and magnetic properties
- Define gauss and tesla
- Describe the three basic types of magnets
- Discuss the differences in low-, mid-, high- and ultra-high field systems
- Explain the functionality of the shim system in MR imaging

Content:

I. Equipment

1. MR gantry
    a. Coordinates
    b. MR Unit Length
    c. Laser Positioning Lights
    d. Patient Table
2. Operator's console
3. Computer

II. Magnetism

1. Diamagnetic Substances
2. Paramagnetic Substances
3. Superparamagnetic Substances
4. Ferromagnetic Substances

III. Magnetic Field Strength

1. The unit of measure for magnetic field strength
    a. Gauss
    b. Tesla
2. Five categories of field strength
    a. Ultra-high field magnets
    b. High-field magnets
    c. Midfield magnetic
    d. Low-field strength
    e. Ultra-low field
3. Specific Absorption Rate (SAR)
4. Chemical Shift
5. Dielectric Effect
6. Magnetic Susceptibility
7. High-Field vs. Low-Field

IV. Magnet Configurations

1. Permanent Magnet

2. Electromagnet
    a. Resistive Electromagnet
    b. Superconducting Electromagnet
3. Magnetic Field
4. Resistive Magnet
5. Cryogens
6. Superconducting Magnet
7. High-Field Open MR
8. Fringe Fields

V. Shielding

1. Passive Shielding
2. Active Shielding
3. Magnetic Field

VI. The Future

VII. Conclusion

VIII. Annex

1. References
2. Bibliography
3. Acknowledgements
4. MR Parameters: Actions and Associated Trade-offs
5. Optimizing Image Quality
6. MRI Fundamentals Glossary

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 61

Title: Pulse Sequences (90 minutes)

Keywords: Image Quality, Image Balancing, Basic MR Imaging Principles, Longitudinal and Transverse Magnetization, Slice Selection, Number of Signals Averaged (NSA), Spin density, Relaxation, Repetition time, Echo time, Inversion time, Flip angle, Gradient, Echo, Pulse sequence

Objectives:

- List parameters related to tissue characteristics that affect image quality, such as spin density and T1 and T2 relaxation
- Identify other parameters that affect image quality, such as repetition time, echo time, inversion time and flip angle
- Apply pulse sequence principles to magnetic resonance (MR) imaging
- Explain the concepts of image formation in MR imaging
- Describe image contrast appearance according to image weighting

Content:

I. Image Balancing Act

II. Basic MR Imaging Principles

1. Hydrogen Atoms
2. Magnetic Field Effect
3. Net Magnetization Vector
4. Precession in the Magnetic Field
5. The Larmor Equation
6. The Gyromagnetic Ratio
7. Calculating Precessional Frequency

III. Longitudinal and Transverse Magnetization

1. Faraday Law of Induction
2. T1 and T2 Relaxation Times
3. Image Contrast
4. Pulse Sequences
5. Repetition Time (TR)
6. Echo Time (TE)

IV. Scan Timing Parameter Chart

V. Pulse Sequence Diagram

VI. Slice Selection

1. Gradients
2. Phase and Frequency Encoding
3. Phase-encoding Gradient
4. Frequency-encoding Gradient
5. Matrix Size
6. K-space
7. Spiral Filling
    a. Centric Filling
    b. Zero Filling

VII. Number of Signals Averaged (NSA)

VIII. Gradient Slew Rate

IX. Field of View

X. Echo Spacing

XI. Receive Bandwidth

XII. Single- or Dual-Echo Conventional Spin-echo

1. Calculating Spin-Echo Scan Time

XIII. Fast Spin-Echo

1. Fast Spin-Echo and K-space
2. Calculating Fast Spin-Echo Scan Time
3. Fast Spin-Echo Pulse Sequences
4. Fast Spin-Echo Tradeoffs
5. Fast Spin-Echo Sequence

XIV. Gradient-Echo Pulse Sequences

1. Gradient-Echo and Spin-Echo Pulse Diagrams
2. Gradient-Echo Pulse Sequences
3. Inversion Recovery
4. Calculating Gradient-Echo Scan Time
5. Advantages of Gradient-Echo pulse Sequences

XV. Gradient-Echo T2-Weighting

XVI. Echo Planar Imaging

1. Calculating EPI Scan Time

XVII. EPI vs. Fast Spin-Echo Imaging

XVIII. Increased Resolution

XIX. White Matter Sensitivity

XX. Faster Imaging Applications

XXI. Ultrafast EPI

XXII. EPI Sequences for Stroke

XXIII. Diffusion-weighted Imaging

XXIV. Dynamic Studies

XXV. Pulse Sequence Comparison

XXVI. Magnetic Susceptibility Artifacts

XXVII. Geometric Distortion

XXVIII. Conclusion

XXIX. Annex

1. Bibliography
2. Acknowledgements
3. MR Parameters: Actions and Associated Trade-offs
4. Optimizing Image Quality
5. MRI Fundamentals Glossary

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 62

Title: Safety Essentials, MR Safety, part 1 (90 minutes)

Keywords: Safety, Magnetic Classification of Objects, Field Strength, Static Magnetic Field, Electromagnetic Spectrum, RF Radiation Exposure, Specific Absorption Rate (SAR), Thermal Increases, Thermal Burns, Gradient, Safety Zones, Safety Classifications of Personnel, Safety Screening, Contraindications and Precautions, Patient Preparation, Patient Monitoring, Patient Emergencies, Equipment or Environmental Emergencies, Ancillary Equipment, Cryogen Gas Monitoring

Objectives:

- Discuss the elements of safety that help ensure a magnetic resonance (MR) imaging facility operates safely
- Demonstrate proper screening and preparation of patients for MR imaging
- Explain how to monitor patients during procedures
- Describe when and how to quench the magnet and handle other emergencies in the MR environment

Content:

I. Importance of Safety

II. MR Safety Incidents

III. MR Safety Considerations

IV. Magnetic Classification of Objects

1. Diamagnetic Substances
   a. Diamagnetic Objects
2. Paramagnetic Substances
   a. Paramagnetic Materials
3. Superparamagnetic Substances
4. Ferromagnetic Substances
   a. Ferromagnetic Objects

V. Field Strength Measurement

VI. Field Strengths and Safety

1. 5-Gauss Warning
2. Static Magnetic Field
3. Fringe Field
4. Shielding
   a. Active shielding
   b. Passive shielding

VII. Translational Force

VIII. Rotational Force

IX. Screening and Testing Objects

X. Summary for Static Magnetic Field

XI. Electromagnetic Spectrum

XII. RF Radiation Exposure

XIII. Specific Absorption Rate (SAR)
1. How a Scanner Estimates SAR

XIV. Heating

XV. Thermal Increases

XVI. Preventing Thermal Burns
1. Implanted Medical Devices
   a. Medical Devices and Overheating
2. Jewelry, Body Piercings and Tattoos

XVII. Gradient Magnetic Fields
1. Nerve Stimulation
2. Acoustic Noise
3. Peripheral Nerve or Muscle Stimulation
4. Magnetohemodynamic Effect

XVIII. Safety Zones
1. Zone I
2. Zone II
3. Zone III
4. Zone IV

XIX. Safety Classifications of Personnel

XX. Safety Screening
1. Patient and Personnel Safety Screening
2. Patient Screening — Referring Physician
3. Pre-examination Screening
4. Patient and Examination Identification
5. Final Patient Screening
6. Safety Questionnaire

XXI. Contraindications and Precautions
1. Intracranial Vascular Clips
2. Pacemakers and Other Implanted Devices
3. Implanted Devices and Field Strength
4. Intraocular Ferrous Foreign Bodies

XXII. Patient Preparation
1. Objects With Metal
2. Contrast Media and Pregnancy

XXIII. Patient Monitoring
1. Verbal Monitoring
2. Monitoring Unconscious or Sedated Patients

XXIV. Patient Emergencies

XXV. Equipment or Environmental Emergencies

XXVI. Ancillary Equipment

XXVII. Cryogen Gas Monitoring

1. Quenching the Magnet
2. Controlled Quench
3. Uncontrolled Quench
4. During a Quench
5. Cryogen Gas Release
6. Quench Response

XXVIII. Conclusion

XXIX. Annex

1. Bibliography
2. Acknowledgements
3. MR Parameters: Actions and Associated Trade-offs
4. Optimizing Image Quality
5. MRI Fundamentals Glossary

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 63

Title: MRI Safety Policies & Procedures, MR Safety, part 2 (90 minutes)

Keywords: MRI, Basic Components, Safety, Terminology, Site Access Restrictions. Safety Considerations, Firefighters, Police, Emergency Response Protocol, Fire Extinguisher, Fire Alarm, Fire Prevention Plan, Cryogen, Screenings, Gun Shot Wounds, Oxygen Cylinders, Implants, Foreign Body, Cardiac Implantations, Cardiac Pacemaker/ICD, Vascular Stents, Filters, Coils, Brain Stimulators, Shunt Process, Implantable Devices, Pregnant MRI Healthcare, Breast Feeding Patients, IV Contrast Agents, Oral Contrast, Gadolinium, eGFR, levels of "Stat" Ordered exams, Rooms Cleaning, Latex Allergies, Patient Monitoring, Code, Nursing Responsibilities, Safety Officer Responsibilities, Medical Director ResponsibilitiesWanding, Ear Plugs, Ferrous Object

Objectives:

- Examine the possible risks, associated with the MR Suite including but not limited to static, time-varying magnetic fields and RF Pulses
- Identify policies and procedures to be in compliance with the most up to date MR safety information provided by the Joint Commission and the ACR
- Discuss and be able to implement MRI safety for staff and patients
- Identify MR personnel and their responsibilities
- Describe how radiation and MRI are used in the healthcare setting
- List and explain the hazards of radiation and MRI
- Describe safeguards for healthcare staff who work with radiation or radioactive patients
- Detail safeguards for healthcare staff and patients involved in MRI

Content:

I. Introduction

1. What is MRI?
2. Basic Components of MRI
3. MRI Safety Manual Acronyms

II. MRI Safety Manual General Policy

1. MRI Safety Terminology

III. Site Access Restrictions

1. Site Access for Zones I
2. Site Access for Zone II
3. Site Access for Zone III
4. Site Access for Zone IV
5. MRI Functional Zone Diagram: Example of a Standard ACR Zone

IV. EAR PLUGS and other TIME VARYING GRADIENT MAGNETIC FIELD-RELATED ISSUES

1. Auditory Considerations
2. Induced Voltage Considerations
3. Thermal Considerations

V. Firefighters, Police & Safety Considerations

VI. Emergency Response Protocol

1. Rescue

2. Alarm
3. Confine
4. Extinguish

VII. Fire Extinguisher Protocol

VIII. Fire Alarm Activation Procedures

IX. MRI Emergency Procedures

X. Fire Prevention Plan

XI. Cryogen Related Issues

XII. MRI Personnel Screenings

1. Non-MR Personnel
2. Level 1 MR Personnel
3. LEVEL 2 MR Personnel
4. MRI Personnel & Non MRI Personnel

XIII. Family Members Safety/Screening

XIV. Device/Object Screening

XV. Gun Shot Wounds

XVI. General Outpatients MRI Screening

XVII. Inpatients MRI Screening

XVIII. Unresponsive Patients in MRI

XIX. Oxygen Cylinders

XX. Penile Implants

XXI. Foreign Body in Orbits

1. Policy
2. Procedure

XXII. Ordering & Scheduling Foreign Body X-ray of Orbits

XXIII. Cardiac Implantations

1. Cardiac Valves
2. Coronary Artery Stents
3. Cardiac Leads

XXIV. Cardiac Pacemaker/ICD

XXV. Vascular Stents, Filters & Coils

1. Embolization Coils
2. Stents & Filters
3. Aneurysm Clips

XXVI. Brain Stimulators

1. Cyberonics Vagal Nerve Stimulator

2. Medtronic Deep Brain Stimulator
3. Neuropace RNS Therapy

XXVII. Programmable Shunt Process

1. Common Shunt Processes

XXVIII. Implantable Devices

1. Common Device List
   a. MEDTRONIC INTERSTIM bladder control
   b. 8637 MEDTRONIC SYNCHROMED II Baclofen Pain Pump
   c. 8626, 8627 MEDTRONIC SYNCHOMED EL Baclofen Pain Pump
2. Orthodontic Dental Devices
   a. Prior to appointment
   b. Immediately prior to appointment
   c. During MRI
3. Trans-Dermal Medication Patches and Wound Dressings
   a. Trans-Dermal Medication Patches
   b. Wound Dressings
4. Miscellaneous Devices
   a. Bivona Trach
   b. Tissue Expander/Breast Expander
   c. Cardiac Loop Recorder Implantable Cardiac Monitor
   d. Perifix Polyamide Catheter
   e. Reveal XT 9529 DX 9528
   f. Reveal LINQ
   g. Scleral Buckle
   h. Swanz-Ganz Catheters
   i. Temperature Foley Catheters
   j. X-Stop Vertebrae Implant
5. Miscellaneous Surgical Objects
   a. List of surgical objects safe on 1.5 & 3T

XXIX. Pregnant MRI Healthcare Providers & Pregnant Patients

1. Pregnant Health Care Employees
2. Pregnant Patients 1.5 and 3T
3. Possible Pregnant Patients and NON Contrast
4. Pregnant Companions

XXX. Administration of Contrast to Breast Feeding Patients

XXXI. IV and Oral Contrast Agents

1. IV Contrast Agents
2. Oral Contrast

XXXII. Gadolinium and eGFR Screening

1. Outpatients
2. Inpatients
3. Patients on Dialysis
4. Exceptions Regarding Contrast Usage in Patients
5. Off Label Usage
6. Documentation of Contrast Usage

XXXIII. Multiple Gadolinium Injections in a 24 Hour Period

1. Time in between contrast injections
2. Types of contrast given
3. Patients Renal Function

XXXIV. MRI Emergency Department and STAT Requested Exams

1. levels of "Stat" Ordered exams
    a. Life-Threatening
    b. Urgent
2. MRI Requests
    a. Life Threatening
    b. Urgent
    c. Routine
    d. Time Dependent
3. Stat MRI Procedure for Stroke Evaluation
4. Overnight MRI Cases

XXXV. Magnet Room Cleaning

XXXVI. Latex Allergies in MRI

XXXVII. Patient Monitoring

1. Monitoring By Nursing Staff: Critical Care Patients
2. Monitoring By MRI Staff for Thermal Injury

XXXVIII. Code Procedure/Code Chart

XXXIX. Quench or Emergency Situation

XL. MRI Nursing Responsibilities

XLI. Ferrous Object in MR Scan Room

1. If the object is inside the patient or in the imaging field
2. If the object is pinning a patient or staff member
3. If the object is solitary and not creating a life threatening situation

XLII. MRI Safety Officer Responsibilities

XLIII. MRI Medical Director Responsibilities

XLIV. MRI Safety/Wanding

XLV. Ear Plugs During an MRI Exam

Module III: "Content pertaining to MR Safety": You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 64

Title: MR Safety, part 3 (90 minutes)

Keywords: Magnetic Resonance Imaging (MRI), Types of MR formats, MRI Scanner, Equipment Screening, OLD Terminology, Current Terminology, Access Restriction And Zoning, Types of Radiationm Health Effects, Types of Magnetic Fields, Effects Of Static Magnetic Field (Bo), Effects of Time-varying Magnetic Field (dB/dt), Effects of Radiofrequency Fields, MRI Labeling, Warning Sign, RF safety, Infection Control, Bio Effects Of Contrast Media, Emergency Buttons, Scan Room, Employees Safety, Magnet

Objectives:
- Brief review of Magnetic Resonance Imaging (MRI)
- Discuss Equipment Screening, MRI Safety Label old and Current Terminology
- Review Access Restriction And Zoning
- Review Types of Radiation
- Define Health Effects
- Determine Effects Of Static Magnetic Field (Bo), Effects of Time-varying Magnetic Field (dB/dt) and Effects of Radiofrequency Fields
- Understand MRI Labeling & Warning Sign
- Discuss RF safety
- Explain Infection Control
- Determine Bio Effects Of Contrast Media
- Understand Emergency Buttons

Content:

I. Introduction

II. Magnetic Resonance Imaging (MRI)
1. Types of MR formats
   a. Bore Format
   b. Open Style
   c. Stand Up
2. MRI Scanner
   a. MRI Scanner Properties
   b. MRI Scanner Static magnetic field
3. How MRI work?
   a. Superconducting Magnet

III. Equipment Screening
1. MRI Safety Label OLD Terminology
   a. MR Safe
   b. MR Compatible
2. MRI Safety Label Current Terminology
   a. MR Safe
      - Miscellaneous Implants and Devices
      - Vascular Access Ports, Infusion Pumps*, and Catheters
      - Coils, stents, filters and vascular grafts
      - Orthopedic Implants, Materials, and Devices
      - ECG (EKG) Electrodes

b. MR Conditional
   - Conditional 1 (Heart Valves and Annuloplasty Rings)
   - Conditional 1 (Dental Implants, Devices, and Materials)
   - Conditional 2 (Filters, stents, clips, cardiac occludes)
   - Conditional 3 (Transdermal patches or other metallic comp)
   - Conditional 4 (Halo vest or cervical fixation device)
   - Conditional 5 (Vendor or the manufacturer for further information)
   - Conditional 6 (MRI-Related Heating)
   - Conditional 6 (Artifact)
   - Conditional 7 (Important Note)
   - Conditional 8 (MRI-Related Heating)
   - Conditional 8 (Artifact)

c. MR Unsafe
   - Biopsy Needles, Markers, and Devices
   - Breast Tissue Expanders and Implants
   - Insulin Pumps
   - Neuro stimulation (Neuromodulation) Systems:
   - Cardiac Pacemakers, Implantable Cardioverter Defibrillators (ICDs), and Cardiac Monitors

3. Use of Terminology
   a. Terminology Applied to Implants and Devices
      - Field Strength
4. Terminology Regarding the List of Safe MRI

IV. Access Restriction And Zoning

1. Zone I
2. Zone II
   a. Security and Safety
3. Zone III
   a. Ferromagnetic Detector System
4. Zone IV

V. Types Of Radiation

1. Ionizing Radiation
2. Non-ionizing Radiation

VI. Health Effects

1. Types of Magnetic Fields
   a. High static magnetic field
   b. Gradient magnetic field
   c. Radio frequency electromagnetic wav
2. Effects Of Static Magnetic Field (Bo)
   a. Field Strength
   b. Projectile Effect
   c. Torsion and Translation Forces
   d. Attraction of ferromagnetic material towards the magnet
   e. Safety Measures
      - Poor screening
      - Potential Projectiles
   f. Magnetic Field Hazards
      - Displacement and Heating of Surgical Implants
      - Stents and Aneurysm Clips
   g. Biological changes
      - Cell Functions
      - Growth and healing of bone

- Thrombolysis
- Nerve Function
- Cardiovascular Effects
- Temperature
- Magnetophosphenes

h. Exeples
i. Static Field Bio effects Summary

3. Effects of Time-varying Magnetic Field (dB/dt)
   a. Gradient Safety Concerns
      - Biological effects: Peripheral Nerve Stimulation
      - Acoustic Noise
4. Effects of Radiofrequency Fields
   a. Magnetic Field Hazards
      - Body Piercing Jewelry
      - Transdermal Patches
      - Tattoos
      - Pregnancy
      - Summary of MRI Hazards

VII. MRI Labeling & Warning Sign

1. Only MRI IV
2. Special MRI Equipment

VIII. RF Safety

1. Specific Absorption Rate (SAR)
2. Radio Frequency Safety Concerns
3. FDA SAR Limits
4. FDA Temperature Limits
5. Avoid Unwanted RF Antennas

IX. Infection Control

X. Bio Effects Of Contrast Media

XI. Emergency – Scan Room

1. Emergency Buttons
   a. Emergency Stop / Shut Off
   b. Quench or Emergency Run Down
2. Employees Safety
3. Remember, the magnet is ALWAYS on!
4. MRI Labeling & Warning Sign
5. Remember this mnemonic

XII. References

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 65

Title: Introduction to PET/MR Artifacts (60 minutes)

Keywords: Aliasing, Artifact (error), Patient Related, Motion Artefacts, Magnetic Susceptibility, Metal Artefacts, Chemical Shift Artefacts, Black Line, Partial Volume, Zebra Stripes, Entry Slice Artefacts, Magic Angle Artefacts, Zipper artifact, Noise, Bo Inhomogeneity, Gradient, Flow Artifact, Image Distortion, Integrating PET/MR System, Motion Correction, Implanted Material Artifacts, PET/MRI Respiratory motion Artifact

Objectives:

- Discuss what is Aliasing
- Review what is Artifact (error)
- Explain MRI Artifact
- Understand MRI Motion Artifact
- Discuss Integrating PET/MR System
- Understand what MR can do for PET and what PET can do for MR
- Review PET/MR Motion Correction
- Review PET/MR Implante Material Artifacts
- Review PET/MRI Respiratory Motion Artifact

Content:

I. Aliasing

1. Definition
2. How to avoid Aliasing?

II. Artifact (error)

1. Definition
2. Sources of Artifacts
   a. Hardware Issues
   b. Software problems
   c. Physiological phenomena
   d. Physics limitations

III. MRI Artifact

1. Patient Related
   a. Motion Artefacts
   b. Magnetic Susceptibility Artefacts
      - Diamagnetic
      - Paramagnetic materials
      - Superparamagnetic
      - Ferromagnetic materials
   c. Metal Artefacts
   d. Chemical Shift Artefacts
   e. Black Line Artefacts
   f. Partial Volume Artefacts
   g. Zebra Stripes
      - Moire fringes
      - Zero-fill artifact
      - Spike in k-space

h. Entry Slice Artefacts
i. Magic Angle Artefacts

2. Zipper artifact MRI
3. DC Offset and Quadrature Ghost
4. RF Noise
5. Bo Inhomogeneity
6. Gradient
7. Flow Artifact
8. Image Distortion in Clinical PET/MRI
9. PET/MR Imaging artifacts

IV. MRI Motion Artifact

1. Motion Respiratory Motion Artifact
2. Signal Averaging
3. Respiratory Triggering/Gating
4. Gradient moment nulling
5. Fat Suppression Methods
6. Cardiac Motion

V. Integrating PET/MR System

1. PET effects on the MR
2. MR effects on the PET
3. What MR can do for PET
4. What PET can do for MR
5. Ways in Which MRI Can affect PET
6. Ways in Which PET Can affect MRI
7. MR and PET Can Help Each Other

VI. PET/MR Motion Correction

VII. PET/MR Implanted Material Artifacts

1. Different appearances of artifacts

VIII. Effect of MRI-based PET AC

1. Whole body [18 F]-FDG PET/MRI study with truncation artifact
2. Coronal [18 F]-FDG PET/MRI of a Dementia Patient

IX. PET/MRI Respiratory motion Artifact

1. Partial volume effects (PVE) affect PET data quantification
2. Pitfalls in hybrid positron emission tomography/MRI

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 66

Title: PET/MR Instrumentation (60 minutes)

Keywords: Instrumentation, PET, CT, PET/CT, PET/MRI, MRI, Optical imaging, Multimodality Imaging, Molecular Imaging

Objectives:
- Explain Advances using PET Detector Technology
- Understand the Fundamentals of MRI
- List what advantages does CT scan offer over other imaging modalities
- Identify Optical molecular imaging technologies
- Explain difference between MRI and PET

Content:

I. PET

II. Advances in PET Detector Technology
1. Scintillation Materials Used in Nuclear Medicine Instrumentation

III. Advances in PET Reconstruction Algorithms

IV. TOF PET

V. CT and PET/CT

VI. Optical Imaging

VII. MRI
1. Fundamentals of MRI
2. Beyond Anatomic MRI - Toward Functional Imaging
3. Toward Higher Field Strengths
4. Whole-body MRI

VIII. Multimodality Imaging PET/MRI
1. We Have PET/CT - Do We Need PET/MRI?
2. Technical Aspects
3. Applications: from Combining Function with Anatomy to Multifunctional Imaging

IX. Conclusion

X. References

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 67

Title: PET/MRI Attenuation Correction (90 minutes)

Keywords: Magnetic resonance imaging (MRI), Positron emission tomography (PET), Attenuation Correction, Hybrid Imaging, PET/MRI Scanner, Biograph scanner, Reconstruction, Quality Control, Template-based, Atlas-based, Direct segmentation, Bone-representing sequences, Aliasing, temporal aliasing, Spatial aliasing, Wraparound, FOV

Objectives:

- Discuss what is Hybrid Imaging
- Review the basic instrumentation fundamentals of PET/MR
- Identify Hybrid PET/MR Challenges
- Review Attenuation correction with PET/MR imaging
- Discuss Quality Control of PET/MR

Content:

I. Introduction

1. Background for PET/MRI

II. Hybrid Imaging

1. What is Hybrid Imaging?
2. Hybrid PET/MRI Scanner
3. PET/MR Advantages
4. PET effects on the MR
5. MR effects on the PET
6. How does MRI/PET work?

III. Basic instrumentation fundamentals of PET/MR

1. Biograph scanner
2. PET/MR Integrated solution
3. Combine MRI and PET imaging in an integrated system
4. Three concepts for integration of PET and MRI
5. PET Detectors
6. PET/MR Design Challenges
    a. Limited space for the PET detector
    b. PET detector must not use magnetic materials
    c. PET detector must not emit in MR frequency
    d. MR-compatible PET shielding materials
    e. MR gradient field-eddy currents
    f. MR materials
7. RF Induced Distortions in the PET Data
8. How to Combine MRI with a PMT Based PET?
9. Light Fiber Based PET/MRI Systems
10. Field Cycled MRI-PET
11. Other Potential Approaches for a Combined PET/MR
12. Novel Detectors for PET/MRI
13. Typical Topology of an Integrate PET/MRI
14. APD Based PET/MRI Systems
    a. Avalanche photodiode (APD)

15. Small Animal Studies with PET/MRI
16. Hybrid PET/MR Advantage and Challenges

IV. Quantitative image reconstruction in PET-MRI

1. Attenuation
2. Requirements for attenuation correction
3. Hybrid PET/MR Challenges
4. Attenuation and PET/MR imaging
5. Two different ways for Attenuation correction
    a. Pre-correct the measured emission data with the attenuation factors
    b. Incorporate the knowledge on the μ-map directly into the iterative reconstruction
6. MRI-based attenuation correction
7. Challenges in Implementation
8. Performance of methods for attenuation correction in PET-MRI
    a. MRI (Segmentation)
    b. MRI (Atlas)
    c. MRI (UTE)
    d. PET (Emission)
    e. PET (Transmission)
9. Attenuation correction based on data from PET
    a. Transmission based attenuation correction
    b. PET detector element related issues
10. Attenuation Correction for PET/MRI
11. Other methods attenuation correction
    a. Template-based
    b. Atlas-based
    c. Direct segmentation approaches
    d. Methods based on special bone-representing sequences

V. System construction

1. Sequential construct
2. Insert construct
3. Integrated construct

VI. Quality Control of PET/MR

VII. Conclusion

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 68

Title: Image Distortion in Clinical Imaging (90 minutes)

Keywords: Attenuation Correction (AC), Artifacts, PET/CT, PET/MRI, CT-based Attenuation Correction (CTAC), Hybrid PET/MR, Protocols, Whole-Body PET/MRI, Patient Preparation, Partial-volume effect (PVE), Image quality.

Objectives:
- Discuss the risk and artifact using PET/MRI in diagnostic imaging
- Explain the presence and causes of potential artifacts in PET/MRI
- Understand the Dual-modality imaging and attenuation effect
- Define what is the source of image distortion and image bias in hybrid PET/CT and PET/MR
- Discuss how to minimize the attenuation effect in clinical PET/MR imaging

Content:

I. Introduction

II. Attenuation Correction (AC)
1. Artifacts
2. Attenuation-corrected and Non-attenuation-corrected Data

III. PET/CT Imaging
1. Advantages PET/CT over separate PET and CT scans
2. Examples for mis-registration in different regions of whole-body PET/CT scans

IV. CT-based Attenuation Correction (CTAC)
1. Bilinear scaling transform used to convert CT image values to PET attenuation coefficients

V. PET/CT Artifact
1. CT AC Artifact From Port
2. Orthopedic Device Causing AC Artifact
3. Dental Hardware AC Artifact
4. Source of image distortion and image bias in hybrid PET/CT and PET/MR

VI. Technical Aspects and Differences between PET and MRI Relevant for Optimizing Protocols in Integrated PET/MRI

VII. Workflow and Scan Protocol Considerations for Integrated Whole-Body PET/MRI
1. Patient Preparation Before Examination
2. In-Bed Patient Preparation
3. Optimization of PET/MRI Protocols
4. Diagrams

VIII. PET/MR Artifact
1. MRI-guided attenuation correction in PET/MRI
2. MRI-guided image reconstruction in PET/MRI
3. MRI-guided partial-volume correction in PET/MRI
   a. Partial-volume effect (PVE)
4. MRI-guided motion compensation in PET/MRI

a. Non-rigid registration of independently reconstructed images
b. Initial estimation of motion information from gated PET or MR/CT images
c. Simultaneous estimation of motion parameters and images

IX. Clinical workflow and protocols

X. Feasibility studies and PET image quality in PET/MRI versus PET/CT

XI. Hybrid PET/MR Pitfalls and artifacts

1. Truncation artifacts
2. Potential new artifacts by MR-AC: truncation
3. Solution
4. Inhomogeneity
5. Fold-over artifacts
6. Pulsation artifacts
7. Possible solutions
8. Eddy currents and standing wave
9. Motion artifacts
10. Susceptibility artifacts
11. Geometric distortion
12. Motion artifacts
13. Motion correction
14. Bone
15. Metallic Implants
16. Metals
17. PET images and profiles through lung lesion
18. Transformation of attenuation coefficients
19. Soft Tissue
20. Contrast Agent
21. PET/MRI Misregistration
22. Non-recognition of Lung Compartment
23. Attenuation Correction in PET/MRI
24. Software-based algorithms
25. AC-specific sequences

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 69
Title: PET/MR QC Standards (90 minutes)

Keywords: Quality Control (QC), Expected quality, Perceived quality, Actual quality, Quality Assurance (QA), Quality Assessment, QC tests, MRI, Image artifacts, Spatial resolution, Magnetic Field Inhomogeneity, MAGE quality MRI, Spatial accuracy, PET Scanner, PET/MRI, National Electrical Manufacturers Association (NEMA), Digital Imaging and Communications in Medicine (DICOM), Medical imaging & technology alliance (MITA), Phantom, Siemens mMR

Objectives:
- Understand the typical elements of a QC program for MRI, and PET equipment
- Anticipate the QC challenges created by new imaging technology advances

Content:

I. Quality Control
1. QC Goal
2. "META" QC: What is the Quality of your Quality Control?
3. Need for Quality Management in Diagnostic Imaging and in Radiology
4. The purpose of a quality management program
5. Levels of quality of patient care & diagnostic images
    a. Expected quality
    b. Perceived quality
    c. Actual quality
6. Quality Assurance (QA)
7. Quality Assessment
8. Quality Control (QC)
9. Types of QC tests
    a. Acceptance testing
    b. Routine performance evaluations
    c. Error correction tests
10. Continuous Quality Improvement
11. Quality Assurance MRI

II. Quality Control MRI
1. MRI Quality control testing frequency
2. Image artifacts
3. Spatial resolution
    a. Contrast-to-noise ratio (CNR)
    b. SNR
    c. Readout bandwidth (BW)
4. Magnetic Field Inhomogeneity
5. Mage quality MRI
    a. ACR MRI Large Phantom
6. Spatial accuracy
    a. Large FOV Phantom

III. Quality Control in PET Scanner
1. Spatial Resolution
2. Detector size
3. Sensitivity
4. Noise Equivalent Count Rate
5. Scatter Fraction

6. Contrast
7. Daily Quality Control Tests
   a. Sinogram (uniformity) check
8. Weekly Quality Control Tests
   a. System Calibration
   b. Normalization
9. NEMA phantoms for PET performance tests
10. Performance data of different PET scanners
11. PET Scanner Quality Control Frequency

IV. Image Distortion in Clinical PET/MRI

V. Current design of PET/MR system

1. General Electric (GE)
2. Ingenuity TF PET/MRI
3. Siemens 3T Biograph mMR

VI. National Electrical Manufacturers Association (NEMA)

1. NEMA standards Digital Imaging and Communications in Medicine (DICOM)
2. NEMA standards Medical imaging & technology alliance (MITA)
3. Technical PET performance of commercially available systems
4. PET/MRI quality control and NEMA standards

VII. NEMA image quality phantom measurements and attenuation correction in integrated PET/MR hybrid imaging

1. Phantom measurement setup
2. PET phantom preparation and data acquisition
3. NEMA image quality parameters
4. Contrast recovery and background variability
5. NEMA IQ measurement with MR-based AC
6. Optimization of PET reconstruction parameters of 3D OP-OSEM

VIII. Qualitative and Quantitative Evaluation of Blob Based Time-of-Flight PET Image Reconstruction in Hybrid Brain PET/MR Imaging

1. Phantom Studies
2. Image Reconstruction
3. Comparison with Hoffman Phantom

IX. Performance Measurements of the Siemens mMR Integrated Whole-Body PET/MR Scanner

1. Siemens MR scanner
2. PET Spatial Resolution (Case Study)
3. PET Scatter Fraction, Count Losses, and Randoms (Case Study)
4. PET Sensitivity (Case Study)
5. PET Accuracy (Case Study)
6. PET Image Quality (Case Study)
7. PET System Stability (Case Study)
8. MR Image Quality (Case Study)
9. MR Image Quality (Case Study)
10. MR Magnetic Field Homogeneity (Case Study)
11. MR Radiofrequency Field Homogeneity (Case Study)
12. MR Radiofrequency Interference (Case Study)
13. In Vivo Studies (Case Study)

X. Systematic Evaluation of Phantom Fluids for Simultaneous PET/MR Hybrid Imaging

1. 18F-FDG PET Imaging
2. MR Imaging

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 70

Title: PET/MR System Designs (90 minutes)

Keywords: PET/MR system designs, Side-by-side, PET-insert, Integrated PET/MRI, Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), Challenges, MRI compatible PET detectors, Sequential Systems, Simultaneous Systems, SIGNA, Biograph mMR, Siemens' technologies, Scanner Designs

Objectives:

- Discuss system design of hybrid PET/MR
- List the compatibility issues of PET/MR issue and how to manage it
- Provide the information regarding the improvement of hybrid system in future
- Explains the necessity for PET attenuation correction required new methods based on MR data

Content:

I. Introduction

II. Multimodality imaging with PET-CT and PET-MRI

III. PET/MR system designs

1. Side-by-side
2. PET-insert
3. Integrated PET/MRI
    a. Sequential systems
    b. Insert systems
    c. Integrated systems

IV. Physics of Magnetic Resonance Imaging (MRI)

1. Scanner construction and operation
    a. Magnet
        - Permanent magnet
        - Resistive electromagnet
        - Superconducting electromagnet
    b. Shims
    c. Gradients
    d. Radio frequency system
2. Nuclear spin
3. Application of external magnetic field
4. Application of electromagnetic radiation
5. T1 and T2 relaxation

V. Physics of Positron Emission Tomography (PET)

1. PET Detectors
    a. Coincidence Detection
    b. How it works: Timing coincidence
    c. How it works: Scintillation
    d. Scintillation Crystals
2. Typical PET Scanner Detector Ring
3. Anatomy: PET gantry

4. Prototypical PET Detector
5. PET Block Detector Design
6. PET Detector Requirement

VI. Development of PET/MR

1. Motivation for PET/MR
2. Brief history of PET/MR development
3. Challenges in the integration of PET and MRI
   a. MRI compatible PET detectors
   b. PET impacting MR
   c. MR impacting PET
   d. Attenuation Correction
4. MRI compatible PET detectors
   a. Light Fiber Based PET/MRI Systems
      - First approach to acquire PET data inside an MRI scanner (1997)
      - West Virginia University, USA – Optical Fibers
   b. Avalanche Photodiode Arrays
      - University of Tuebingen, Germany
      - Advantages
      - Challenges
   c. Solid-state photodetectors (SSPD)
   d. APD based detectors
   e. SiPM based detectors
   f. Silicon Photo Multipliers (SiPM, Geigermode-APD)
5. Strategies for PET/MR
   a. Use of MR-friendly materials
   b. Reducing magnetic fields seen by photomultiplier tubes
   c. Using PET detectors that are insensitive to magnetic fields
   d. Reducing PET signal interference with MR
   e. Attenuation correction

VII. Sequential Systems

1. PET and MR standard systems with software fusion
2. PET/MR systems with PET and MR gantries in different rooms
3. PET/MR systems with separate gantries in the one room
4. MRI characteristics of the Philips Achieva 3T-X MRI system
5. PET characteristics of the Philips Ingenuity TF system.

VIII. Simultaneous Systems

1. Turbocharge your diagnostic capabilities
2. The SIGNA* PET/MR features GE's digital MR compatible silicon photomultiplier detector (SiPM) technology
3. Surpass traditional norms of quantitative reliability
   a. Silent Scan
   b. Magnet
   c. MR RF Coils
   d. Surpass
   e. OpTix Optical RF
   f. Gradients
   g. Sharp IR
   h. PET Detector
4. Reimagine the benchmarks for clinical flexibility and patient comfort
5. High Resolution in-Room Operator Control (iROC)
6. Sleek dual-sided controls
7. IntelliTouch Patient Positioning
8. Sophisticated LED accent lights

IX. Biograph mMR

1. One streamlined exam boosts your productivity
2. Shorter exams and low radiation exposure
3. Significant reduction of costs
4. Be at the frontier of diagnostics and research with Biograph mMR
5. Spatial alignment
6. Minimizing the effects of motion
7. Temporal co-registration
   a. Overview Technical Details
8. Siemens' technologies
9. MR-compatible PET detectors
10. Tim
11. Gradient System
12. RF Technology

X. Pros and Cons of the Scanner Designs

1. Field of view
2. Scanning time
3. Time-of-flight PET
4. Motion
5. Attenuation correction
6. Complexity and amount of new engineering

XI. The Future

1. New technologies
2. New designs
3. What is the clinical future of PET/MR?
4. Next Generation PET/MRI Systems
5. Further Integration of PET with MR RF-Coil

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 71

Title: PET/MR Workflow (60 minutes)

Keywords: Whole-Body MRI, PET/CT, Hybrid Imaging, Workflow in Imaging, Patient Preparation, Gadolinium, Impaired Renal Function, Pregnant Patients, 18F-FDG, Nephrogenic systemic fibrosis (NSF), GBCA, Biograph mMR, Simultaneous acquisition timeline, Sequential acquisition timeline, Oncology, Protocols, PET/MR Neuroimaging, Partial Volume Effects Correction, Dementia, Neurodegeneration, Epilepsy, Cardiac Imaging, Musculoskeletal, Pediatric Oncology

Objectives:
- Describe Whole-Body MRI
- Explain General Aspects of Workflow in Imaging
- Explain Options for Time Savings in Hybrid Imaging
- Define Workflow and Logistic Considerations
- Patient Preparation for PET MR scan
- Describe Patient Screening Prior to PET/MRI

Content:

I. Introduction

II. General Aspects of Workflow in Imaging
1. Whole-Body MR
2. PET/CT

III. Options for Time Savings in Hybrid Imaging

IV. Workflow and Logistic Considerations

V. Patient Preparation Before Examination

VI. Patient Preparation for PET MR scan
1. General Instructions
2. Patient Screening Prior to PET/MR
3. Creatinine Testing Prior to Gadolinium Administration
4. Gadolinium in Patients with Impaired Renal Function
    a. Nephrogenic systemic fibrosis (NSF)
    b. GBCA stratify into three levels of apparent NSF-related risk
    c. Risk classification for contrast agents containing gadolinium
5. Gadolinium in Patients with Impaired Renal Function
6. PET/MR in Pregnant Patients
7. Gadolinium in Pregnant Patients
8. Standard tracer for 18F-FDG

VII. In-Bed Patient Preparation

VIII. PET/MRI and Workflow
1. Imaging workflow for Biograph mMR
2. Sequential vs Whole body acquisition
3. Sequential vs Simultaneous acquisition

4. Simultaneous acquisition timeline
5. Sequential acquisition timeline

IX. General Protocol Aspects and Whole-Body PET/MR Imaging

1. Sequential PET/CT–MR Imaging
2. Simultaneous PET/MR Imaging
3. Current Literature

X. Workflow Proposals And Concepts

1. Oncology
2. Basic Protocols
3. Organ-Based Protocols
4. Basic Whole-Body Protocols
5. Advanced Whole-Body Protocols
6. PET/MR Neuroimaging
7. Partial Volume Effects Correction
8. Dementia / Neurodegeneration
9. Epilepsy
10. PET/MR Cardiac Imaging
11. Musculoskeletal
12. Pediatric Oncology

XI. Data Visualization, Analysis, and Reporting

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 72

Title: PET/MR Site Planning (90 minutes)

Keywords: Hybrid PET/MR, Safety issues when installing PET/MR, Room Layout Planning For MRI, Room Layout Planning For PET, Cyclotron and Radiopharmacy, Magnet Room, Equipment Room, Control Room, Positron PET scanner, Room Layout Planning For Hybrid PET/MR, SIGNA PET/MR, Magnetic Fringe Field, Electrical Current, Non-MR System Equipment Sensitivity, Suite Temperature and Humidity, Radiation Survey, Gamma Ray Protection, Magnetic Shielded Room Requirements, The Radio Frequency (RF) Definitions, Grounding, Hybrid PET/MR Zones, Hot-lab considerations

Objectives:
- Discuss Hybrid PET/MR and Safety issues when installing PET/MR, take a look on MR and PET Room layout individually then hybrid PET/MR
- Explain Room Layout Planning For Hybrid PET/MR
- Describe Access Restriction and Zoning, Hybrid PET/MR Zones
- Define Dedicated shielding requirements for simultaneous hybrid system
- Review Radiation safety & Hot-lab considerations

Content:

I. Hybrid PET/MR

II. Safety Issues when Installing PET/MR
   1. Effects on facilities
      a. Construction
      b. Precautions
      c. Radiation Protection
      d. Reporting Omissions and Errors
      e. Responsible
   2. Room Layout Planning For MRI
      a. Magnet Room
      b. Magnetic Shielding
      c. Equipment Room
      d. Control Room
      e. Preferred Room Layout Example of Philips system
   3. Room Layout Planning For PET
      a. Cyclotron and Radiopharmacy
      b. Planning Models (Location, Unit Layout, Ambulant Patient Waiting, Anesthesia and Sedation, Teaching and Research)
      c. Hot Lab / Dispensary and Radioactive Waste Store
      d. Uptake Room
      e. Hot Laboratory
      f. Clinical Support Areas
      g. Site selection
      h. Requirements for the Positron PET scanner facility

III. Room Layout Planning For Hybrid PET/MR
   1. SIGNA PET/MR Room layout
   2. Site Pre-Installation Tasks
      a. Dates and General Site Requirements

   b. Site Planning
   c. Equipment Compatibility and Network Connections
   d. Network Connection Tasks
   e. Miscellaneous Tasks
3. General System Level
   a. Upgrade Requirements
   b. System Components and Accessories
4. Suite Minimum Room Size Requirements
   a. Minimum Room Dimensions
   b. Minimum Magnet Service Area
   c. Minimum Magnet Ceiling Height
5. Suite Acoustic Specifications
6. Structure-Borne Vibration Control Specifications
7. Suite Magnetic Field Specifications
   a. Magnetic Fringe Field
   b. Interference from Changing Magnetic Fields
   c. Magnet Moving Metal Sensitivity Line Plot
8. Electrical Current
9. Non-MR System Equipment Sensitivity to Magnetic Fields
   a. Magnetic Proximity Limits
10. Multiple System Requirements
   a. Multiple Magnets
   b. Shared Equipment Rooms
11. Suite Temperature and Humidity
12. Magnetic Room
   a. Structural Requirements
   b. Environmental Steel Limits
   c. Shielding Requirements and Radiation Sources (Shielding Requirements, Radioactive Phantoms, Specifications and Dose Rates)
   d. Phantoms and PET Spheres
13. Radiation Survey
   a. Survey Data, Storage
   b. Other Sources of Radiation
14. Gamma Ray Protection
   a. Radiation Protection for Equipment
   b. Radiation Protection for Personnel
15. Magnetic Shielded Room Requirements
16. The Radio Frequency (RF) Definitions
   a. Broadband Interference
   b. Discrete Interference
   c. Electromagnetic Environment
   d. Plane Wave
   e. Penetration
   f. Shield
   g. Shielding Enclosure (Faraday Cage)
   h. Shielding Effectiveness (SE)
   i. Primary Ground
   j. Secondary Ground
   k. Customer Responsibilities
   l. Requirements RF Shieldin
17. Magnet Room Equipment Specifications
   a. Magnet
   b. Magnet and Rear Pedestal
   c. PET/MR Insert
18. Magnet Room Electrical and Grounding Requirements
   a. Electrical Line and Filter

b. Lighting
c. Grounding

19. Equipment Room
    a. Layout Example
    b. Typical Equipment Room Layout
20. Control Room
    a. Operator Work Space (OWS) Equipment Specifications

IV. Access Restriction and Zoning
1. Zone I
2. Zone II
    a. Security and Safety
3. Zone III
    a. Ferromagnetic Detector System
4. Zone IV

V. Hybrid PET/MR Zones
1. Zone I
2. Zone II
3. Zone III
4. Zone IV

VI. Dedicated shielding requirements for simultaneous hybrid system

VII. Radiation safety & Hot-lab considerations

Module III: “Content pertaining to MR Safety”: You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module III: Content pertaining to MR Safety

Lecture 73

Title: PET/MR Artefact (90 minutes)

Keywords: Aliasing ; Artifact ; MRI Artifact ; Motion Artifact ; Integrating PET/MR System; Motion Correction; PET/MR Implanted Material Artifacts; PET/MRI Respiratory motion Artifact

Objectives:
• Explain what is Aliasing
• Understand MRI Artifact
• Describe PET/MR Implanted Material Artifacts and Respiratory motion Artifact
• Describe What MR can do for PET and What PET can do for MR

Content:

I. Aliasing
1. Definition
2. Temporal aliasing
3. Spatial aliasing
4. Avoid Aliasing
    a. Increase FOV

II. Artifact (error)
1. Definition
2. Sources of Artifacts
    a. Hardware Issues
    b. Software problems
    c. Physiological phenomena
    d. Physics limitations
3. Artifact in Medical imaging

III. MRI Artifact
1. Patient Related
    a. Motion Artefacts
        • Respiratory Motion Artifact
        • Signal Averaging
        • Respiratory Triggering/Gating
        • Gradient moment nulling
        • Fat Suppression Methods
        • Cardiac Motion
        • Electrocardiographic Triggering/Gating
    b. Susceptibility Artefacts
    c. Metal Artefacts
        • Diamagnetic
        • Paramagnetic
        • Superparamagnetic
        • Ferromagnetic
    d. Chemical Shift Artefacts
    e. Black Line Artefacts
    f. Partial Volume Artefacts
    g. Zebra Stripes
        • Moire fringes

        - Zero-fill artifact
        - Spike in k-space
    h. Moire Fringes
    i. Entry Slice Artefacts
    j. Magic Angle Artefacts
2. DC Offset and Quadrature Ghost
3. RF Noise
4. Bo Inhomogeneity
5. Gradient
6. Flow Artifact

IV. Image Distortion in Clinical PET/MRI

1. Source of image distortion and image bias in hybrid PET/MRI
    a. Malfunctioning imaging system
    b. Indication and patient referral
    c. Motion
    d. Data Processing
    e. Observations
    f. Reporting
2. Observation
3. Solution

V. PET/MR Imaging artifacts

1. MRI-based attenuation correction (MRAC)
2. Integrating PET/MR System
    a. PET effects on the MR
    b. MR effects on the PET
    c. What MR can do for PET?
        - Attenuation Correction
        - Motion Correction
        - Patial volume effect
        - Arterial input function estimation
3. PET/MR Motion Correction
4. PET/MR Implanted Material Artifacts
5. Different appearances of artifacts
6. Effect of MRI-based PET AC
7. Whole body [18 F]-FDG PET/MRI study with truncation artifact
8. Coronal [18 F]-FDG PET/MRI of a Dementia Patient

VI. PET/MRI Respiratory motion Artifact

1. Partial volume effects (PVE) affect PET data quantification
2. The high resolution morphological MRI data can be used for PET PVE correction

VII. Pitfalls in hybrid positron emission tomography/MRI

1. Susceptibility Artefacts
2. What MR can do for PET
3. Ways in Which MRI Can affect PET
4. Interference effects of MRI on PET performance
5. Interference effects of PET on MRI

VIII. What PET can do for MR

IX. Ways in Which PET Can affect MR

X. MR and PET Can Help Each Other

Radiation Safety Review Course

Module IV: Content pertaining to X-Ray and Fluroscopy

Lecture 74

Title: X-ray and Fluoroscopy (120 minutes)

Keywords: Fluoroscopy, Radiography, Acquisition Modes, History, Fluoroscopic Imaging Chain, Equipment Configurations, Dose Metric, Modes of Operation, Radiation Protection, Interventional Procedures, International Commission on Radiological Protection (ICRP), fundamental principles for radiation protection, Dose Estimation, Radiation Management, Good practices, Radiation protection of medical staff

Objectives:

- Define Fluoroscopy and Describe use Fluoroscopy
- Review Historical Development
- Illustrate Fluoroscopic Imaging Chain
- Review Fluoroscopic Equipment Configurations
- Describe Fluoroscopy Dose Metric
- Explain Fluoroscopy Modes of Operation
- Discuss Radiation Protection and Fluoroscopy/IR
- List Fluoroscopically Guided Interventional Procedures
- Discuss Good practices in interventional fluoroscopy
- Discuss Radiation protection of medical staff in interventional fluoroscopy

Content:

I. Introduction

1. Definition
2. Fluoroscopy and Radiography

II. Fluoroscopy

1. The procedures wich use Fluoroscopy
   a. Barium X-rays
   b. Cardiac catheterization
   c. Electrophysiologic procedures
   d. Arthrography
   e. Placement of intravenous (IV) catheters
   f. Hysterosalpingogram
   g. Percutaneous vertebroplasty/kyphoplasty
2. Fluoroscopy is also used for
   a. Lumbar puncture
   b. Biopsies
   c. Locating foreign bodies
   d. Guided in jections into joints or the spine
   e. Fluoroscopy may be used alone, or with other diagnostic procedures
3. Acquisition Modes
   a. Cardic imaging system
   b. Vascular System
4. Fluoroscopy Vs Acquisition

III. Historical Development

IV. Fluoroscopic Imaging Chain

1. X-ray Generator
2. X-ray Tube
   a. Anode
   b. Cathode
   c. Envelope
   d. Housing
   e. The X-ray Circuil
   f. Electron energy
   g. Potential
   h. Kinetic
   i. Binding Energy
   j. Bremsstrahlung
      - Production Process
      - Spectrum
      - Focal Spot
      - Effect of KV
   k. Characteristics Radiation
      - Effect of KV
      - Production
      - Tungsten Spectrum
   l. Efficiency
   m. Efficacy (Output)
3. Collimator
   a. Collimator Effects
4. Filters
5. Patient Table and Pad
6. Grid
7. Image Intensifier
   a. Components
      - Input layer components (input window, substrate, input phosphor, and photocathode)
      - Output layer components (output window, output phosphor, anod)
   b. Configuration of equipment
      - Standard R and F
      - Remote control R and F
      - Fixed C-arm
      - Mobile C-arm
   c. Internal construction of an II x-ray tube
8. Optical Coupling
9. Television System
   a. Video camera and Monitor
   b. Determining resolution (vertical and horisontal)
   c. Charged coupled device (CCD sensors)
   d. Image quality
   e. Digital image processing
      - Greyscale processing
      - Spatial filtering
      - Temporal filtering
   f. Flat panel detector
   g. Digital subtraction angiography (DSA)
   h. Artefacts
   i. Dose to patient
      - Minimising patient dose
   j. Dose to staff
      - Stray radiation

- Minimising staff dose

10. Definitions
    a. Fluoroscopy
    b. Fluorography
    c. ITV system
    d. II x-ray tube
    e. Photocathode
    f. II electron optics
    g. II output
    h. Display of image
        - II TV camera
        - Charged coupled device (CCD sensors)
        - Flat panel detector
    i. Image quality
    j. Digital processing
    k. Dose
    l. Cross section of the II-TV system

V. Fluoroscopic Equipment Configurations

1. R/F Units with Under-Table X-ray Tube
2. Fixed C-arm Positioners
3. Mobile C-arms Positioners

VI. Fluoroscopy Dose Metric

1. Radiation quantities
2. Dose quantities and radiation units
3. Absorbed dose
4. Absorbed dose, D and KERMA (kinetic energy released in a material)
5. Radiation dose estimation
    a. Fluoroscopy time (FT, min)
    b. Total air kerma at the interventional reference point
    c. Air kerma area product
    d. Peak skin dose (PSD, Gy)
    e. Radiation dose limits
    f. Occupational health hazards and radiation safety concept
6. Radiation reduction in the Cath lab
    a. Reducing radiation dose
    b. Use collimation
    c. Patient/operator positioning
    d. X-ray angulation
        - Table Dose reduction technologie
    e. Substantial Radiation Dose Limits (SRDL)
7. Fluoroscopy vs Projection Radiography

VII. Fluoroscopy Modes of Operation

1. Typical entrance exposure rates to the patient

VIII. Radiation Protection and Fluoroscopy/IR

1. Badging – OUTSIDE the lead near the neck/collar
2. Lead aprons
3. Protective gloves
4. Leaded glasses

IX. Fluoroscopically Guided Interventional Procedures

1. The International Commission on Radiological Protection (ICRP), fundamental principles for radiation protection

a. Justification
b. Optimization of protection
c. Application of dose limits

2. Radiation Dose Estimation
3. Radiation Management in Interventional Procedures
    a. Before the Procedure
    b. Preprocedure Planning
    c. During the Procedure
        - Summary of Radiation Monitoring Dose Notification Thresholds
    d. After the Procedure

X. Good practices in interventional fluoroscopy

1. How can I know patient dose while using the C-arm in an operating theatre?
2. Should the X-ray tube be positioned closer to the patient or further away from the patient during fluoroscopy?
3. Does a patient's physique have an effect on radiation dose to the patient and staff?
4. How effective is a reduction in fluoroscopy time in reducing dose to the patient and staff?
5. Is there a difference between a single long fluoroscopy and several shorter fluoroscopies with same total doses?
6. How should I select the pulse frequency in pulsed fluoroscopy?
7. Does the use of shielding have an effect on a patient's radiosensitive organ dose?
8. Should termination of pregnancy be considered after a fluoroscopically guided procedure?
9. What is the magnitude of patient doses associated with fluoroscopically guided procedures?
10. Key points to remember for patient dose management in fluoroscopy

XI. Radiation protection of medical staff in interventional fluoroscopy

1. Relationship between staff dose and patient dose in fluoroscopy
2. Where should I stand in relation to the X-ray tube during a fluoroscopic procedure?
3. How effective are lead aprons in fluoroscopic work?
4. Should I use lead impregnated gloves in fluoroscopic work?
5. Do different views such as posteroanterior, lateral and oblique have an effect on patient dose?
6. Skin exposure variation in exposure rate (DAP rate) with projection
7. I do not use fluoroscopy very often. Is there a risk of developing cataract for me?
8. Do I need special radiation protection training for working with fluoroscopy machines?
9. Why is periodic quality control (QC) of fluoroscopic equipment necessary?
10. Should I use a protective screen, as I am not used to it and I find it a hindrance in my work?
11. How should I monitor my radiation exposure?
12. What is the magnitude of staff doses associated with fluoroscopically guided surgical procedures?
13. Key points to remember for staff dose management in fluoroscopy
14. What are the typical radiation doses associated with diagnostic and therapeutic interventional procedures?

Module IV: " Content pertaining to X-Ray and Fluroscopy": You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module IV: Content pertaining to X-Ray and Fluroscopy

Lecture 75

Title: Optimization Radiation Exposure (120 minutes)

Keywords: Radiation Exposure, Justification, Optimization, Clinical Audit, Medical Exposures, Sensitive Populations, High Skin Dose Examinations, Population Screening, Effective Dose, Receiver Operating Characteristic (ROC), Good Practice, Dose Optimization, Dose Estimation, CT Dose Parameters, Image Quality Parameters, Patient Protection, Public Protection, Pregnancy, Staff Protection, Reduction of Patient Exposure without Losing Diagnostic Information, General Radiology, Digital Radiology, Computed Tomography, Mummagraphy, Interventional Procedures Using X-rays, Pediatric Radiology, Dental Radiology, Radiopharmaceuticals, ALARA, UNSCEAR, ICRP, Scientific Background

Objectives:
- Define Justification
- Define Optimisation
- Discuss CT Radiation Dose Optimization and Estimation
- Determine General Radiation Protection Features for Radiological Equipment
- Illustrate Examples of Rules for Operational Safety (Local Rules)
- Discuss Optimization by Applying Methods For Reduction of Patient Exposure without Losing Diagnostic Information
- Review Dose Optimization in Nuclear Medicine
- Describe Optimisation of Protection for Medical Exposures
- Define Clinical Audit
- Discuss Scientific, Regulatory Background & Optimization

Content:

I. Introduction

1. Practitioner Responsibility
    a. Justification
    b. Optimization
    c. Clinical Audit

II. Justification

1. Definition
2. Levels of Justification of Medical Exposures
3. Referral Guidelines for Imaging
4. Classification the typical effective doses
5. Sensitive Populations
6. High Skin Dose Examinations
7. Population Screening
8. Informed Consent

III. Optimisation

1. Effective Dose
2. Receiver Operating Characteristic (ROC)
3. Equipment, Guidelines & Imaging Criteria
4. Good Practice
    a. Pregnant patient and foetus protection
    b. Adopting the exposure setting to patient size

c. Managing high local skin doses
d. Positioning of the patient
e. Limiting the radiation field
f. Protective shielding
g. Compression
h. Photon energy
i. Low-attenuating materials
j. Scatter rejection methods
k. Automatic exposure control,
l. AEC setting
m. Appropriate film optical density or background quantum noise level
n. Viewing conditions
o. Two Practical Examples

IV. CT Radiation Dose Optimization and Estimation

1. Image Quality Parameters and CT Dose
2. CT Dose Parameters
   a. Tube potential
   b. Tube current, pitch
   c. Weighted CT dose index (CTDIw)
   d. Volume CT dose index (CTDIvol)
   e. Dose-length product (DLP)
   f. Effective dose is a prerequisite
3. Strategies for CT Dose Optimization
   a. Body Size-Adapted CT Protocols
   b. Tube Current Modulation
   c. Tube Current Modulation
   d. ATCM based on Reference Image Quality
   e. Optimal Tube Voltage
      - Tube Voltage and Radiation Dose
      - Low Tube Voltage Scanning
      - Kilovoltage, Milliamperage, and Noise Index: Interrelationships
      - and Impact on Dose and Image Quality
      - Automatic Kilovoltage Selection
      - Practical Aspects of Low-Kilovolt Scanning
   f. Iterative Image Reconstruction
      - Statistical Iterative Reconstruction
      - Diagram of the steps of iterative reconstruction
      - CT Dose Reduction and Maintenance of Diagnostic Accuracy
   g. Scan Modes
      - Overbeaming and Overranging
      - Retrospectively ECG-Gated Spiral Scanning
      - High-Pitch Dual Source Spiral Scanning
      - Dual Energy Scanning
   h. Noise-Reducing Image Reconstruction Algorithms
   i. Miscellaneous Methods
4. Clinical Applications
   a. Pediatric CT
   b. Chest CT
   c. Head and Neck CT

V. General Radiation Protection Features for Radiological Equipment

1. Leakage radiation
2. Beam filtration
3. Beam size

4. Image receptors
5. Selection of materials for patient's couch, film cassette, etc.
6. Signals and marking
7. Exposure switches
8. Control of exposure duration
9. Exposure measurement
10. Scattered radiation for fixed fluoroscopy

VI. Examples of Rules for Operational Safety (Local Rules)

1. Patient and Public Protection
2. Pregnancy and X-ray Examinations
    a. Identification of pregnant patients
    b. Procedure when patient is pregnant
    c. Procedure after exposure of pregnant patients
3. Staff Protection
    a. Radiation monitoring badges
    b. Patient immobilization
    c. Lead apron testing
    d. Lead gloves or gauntlets
    e. Glasses

VII. Optimization by Applying Methods for Reduction of Patient Exposure without Losing Diagnostic Information

1. General Radiology
    a. Sensitivity of image receptors for radiography
    b. Image intensifier for fluoroscopy
    c. Beam quality (penetration)
    d. Antiscatter grids
    e. Collimation
    f. Organ shielding
    g. Focus to skin distance
    h. Reducing attenuation between the patient and image receptor
    i. Examination technique
    j. Film processing
2. Digital Radiology
3. Computed Tomography
4. Mummagraphy
5. Interventional Procedures Using X-rays
6. Pregnancy
7. Pediatric Radiology
8. Dental Radiology

VIII. Guidance Levels of Radiology (Typical Adult Patients)

IX. Dose Optimization in Nuclear Medicine

1. Radiopharmaceutical Selection
2. Injected Radioactivity
3. Collimator Selection and Imaging Time
4. Image Restoration

X. Optimisation of Protection for Medical Exposures

1. Diagnostic Procedures
    a. Approximate radiation dose to adults from diagnostic nuclear medicine procedures
2. Radiopharmaceuticals
    a. Receipt and use of unit patient doses
    b. Reconstitution of 'cold-kits'

3. Patient Identification and Procedure Confirmation
4. Radionuclide Therapy Procedures
    a. Medical supervision
    b. Pregnancy and avoidance of conception
    c. Design of treatment areas and wards
    d. Procedures for therapeutic radionuclides
    e. Preparation of therapeutic radiopharmaceuticals
    f. Patient information
        - Prior to Radiopharmaceutical Administration
        - After Radiopharmaceutical Administration

XI. Clinical Audit

1. Objectives
2. Coverage of Radiological Practices
3. Standards of Good Practice
4. Relationship with Other Quality Assessments & Regulatory Control
5. Methods and Practical Organization
6. Role of the Medical Physicist

XII. Scientific, Regulatory Background & Optimization

1. ALARA (As Low As Reasonably Achievable)
    a. Why implement an ALARA approach?
    b. How is ALARA integrated into national regulations?
2. UNSCEAR (United Nations' Scientific Committee on the Effects of Atomic Radiation)
3. ICRP (International Commission on Radiological Protection)
4. Principles of the radiological protection system
    a. Justification of practices
    b. Optimization of radiological protection (ALARA)
    c. Limiting individual exposure
5. Important questions & answers
    a. What is the link between the ICRP and the national regulations?
    b. What does justification mean?
    c. Who decides whether a planned exposure situation is justified or not?
    d. Can an unjustified practice be optimized?
    e. What is the difference between ALARA and optimization of radiation protection?
    f. What are the objectives pursued through optimization of radiation protection?
    g. What is the role of the whole body individual dose limit (effective dose)?
    h. Why has the ICRP set the dose limit for workers at 100 mSv over 5 years?
    i. Why has the ICRP set the dose limit for workers at 100 mSv over 5 years?
    j. Why did the ICRP 2007 recommendations, publication number 103 propose specific dose limits for the eye lens and skin (and, more especially, for the extremities) rather than contenting itself with a whole body dose limit?
    k. What is the relationship between dose limits and ALARA?
    l. What is a deterministic effect?
    m. What is a stochastic effect?
    n. Is there any scientific proof that stochastic effects can be caused by exposure to low doses?
    o. Is scientific knowledge in this field progressing?
    p. Is receiving a dose within a very short period of time the same as receiving the same dose accumulated over a long period?
    q. What are the differences between these different dose quanties and their significance?
    r. What is a collective dose?

Module IV: " Content pertaining to X-Ray and Fluroscopy": You must score an 80% or greater in order to receive SNMMITS Voice Credits.

Radiation Safety Review Course

Module IV: Content pertaining to X-Ray and Fluroscopy

Lecture 76

Title: Internal Radiotherapy (90 minutes)

Keywords: Radionuclides, Cancer, Radiotherapy, Radio-iodine, Radioiodine Therapy, Radiation Safety Considerations, Release Considerations, Benign Thyroid Disease, Thyroid Cancer, MIBG Therapy, Lipiodol Therapy, Brachytherapy

Objectives:
- Review Background
- List Optimal Radionuclides for Therapy
- Discuss Cancer Treatment
- Determine What is radiotherapy and Types of radiotherapy
- Discuss Types of Radiotherapy
- Review Radioactive iodine and Iodine-131
- Explain Radioiodine Therapy
- Discuss Radiation Safety Considerations
- Illustrate Other Radionuclide for Theraphy
- Explain Brachytherapy

Content:

I. Introduction

II. Background

III. Optimal Radionuclides for Therapy
1. Alpha-Emitting Radionuclides
2. Beta-Emitting Radionuclides
3. Auger Electron-Emitting Radionuclides

IV. Cancer Treatment
1. Surgical therapy
2. Radiotherapy
3. Chemotherapy

V. Radiotherapy
1. What is radiotherapy?
2. When radiotherapy is used?
3. How does radiotherapy work?
    a. Reasons for Radiotherapy
        - Curative Treatment
        - Palliative treatment

VI. Types of Radiotherapy
1. External Radiotherapy
    a. External Beam radiotherapy
    b. Intensity-Modulated Radiotherapy (IMRT)
    c. Stereotactic radiosurgery
    d. Stereotactic body radiation therapy (SBRT)
    e. Image-guided radiotherapy (IGRT)
    f. Intra-operative Radiotherapy (IORT)
    g. Electron Therapy or Electron Beam Therapy (EBT)

h. Proton Therapy or Proton Beam Therapy
i. Superficial Radiotherapy (SRT)

2. Internal Radiotherapy
   a. Radioisotope or Radionuclide
   b. Brachytherapy (internal implants)
   c. Selective internal radiation therapy (SIRT)

VII. Radio-iodine

1. Radioactive iodine for thyroid cancer
2. Isotopes of iodine
3. Radioiodines I-123, I-124, I-125, and I-131 in medicine and biology
4. Iodine-123 and iodine-125
5. Iodine-124
6. Iodine-131
   a. Radioactive decay
   b. Handling of Doses
   c. Follow authorized procedures when carrying out iodine therapy
   d. Emergency

VIII. Radioiodine Therapy

1. Radionuclide Therapy with I-131 Sodium Iodide
2. Patient & Dose Administrator Precautions, Administration Methods
   a. I-131 NaI Capsules
   b. I-131 NaI Solution
3. Precautions to be Observed with Low-Dose I-131 Therapy Outpatient
4. Patient Hygiene
5. Dose Administrator precautions for a patient receiving a low dose
6. Considerations related to pregnancy, nursing, and child-care
7. Nursing Guidelines
8. Other considerations for minimizing radiation dose and contamination
9. Precautions to be observed with High-Dose I-131

IX. Radiation Safety Considerations

1. Uninstalled Radionuclide Therapies
2. Radionuclides and Their Main Emissions
3. Radiation Protection Following Release of Patients
   a. Dose Limit, Dose Constraints and Persons at Risk
   b. General Considerations
      - External irradiation of other persons
      - Contamination of other persons

X. Specific Therapies and Release Considerations

1. Iodine-131 Used in Benign Thyroid Disease (Thyrotoxicosi, Grave's Disease and Toxic Goitre)
   a. Radionuclide, form and activity
   b. Excretion
   c. Post-discharge issues
   d. Advice to patients and families
      - External radiation
      - Contamination
      - Emergencies
2. IODINE-131 Used in Thyroid Cancer
   a. Radionuclide, form and activity
   b. Excretion
   c. Post-discharge issues
   d. Advice to patients and families

3. IODINE-131 MIBG Therapy
    a. Radionuclide, form and activity
    b. Excretion
4. Antibody Therapy
    a. Radionuclide and form
    b. Excretion
5. IODINE-131 Lipiodol Therapy
    a. Radionuclide, form and activity
    b. Post-discharge issues

XI. Factors affecting safety in radionuclide therapy

1. Storage of I-131
2. Dispensing
3. Radioactive Waste
4. Guidance level for maximum activity for patients in therapy on discharge from hospital
5. Death of Patients

XII. Other Radionuclide for Theraphy

1. Yttrium-90
2. Phosphorus-32
3. Rhenium-186
4. Erbium-169
5. Strontium-89
6. Samarium-153

XIII. Brachytherapy

1. Definiton
2. Medical uses
    a. Cervical cancer
    b. Prostate cancer
    c. Breast cancer
        - Interstitial breast brachytherapy
        - Intracavitary breast brachytherapy
        - Intraoperative radiation therapy (IORT)
        - Permanent Breast Seed Implantation
        - non-invasive breast brachytherapy using mammography for target localization and an HDR source
    d. Skin cancer
    e. Blood vessels
3. Side effects
    a. Acute
    b. Long-term
4. Types
    a. Source placement
    b. Dose rate
        - Low-dose rate (LDR)
        - Medium-dose rate (MDR)
        - High-dose rate (HDR)
        - HDR Treatment Process
        - Pulsed-dose rate (PDR)
5. Procedure
    a. Initial planning
    b. Insertion
    c. Creation of a virtual patient
    d. Optimizing the irradiation plan
6. Radiation sources