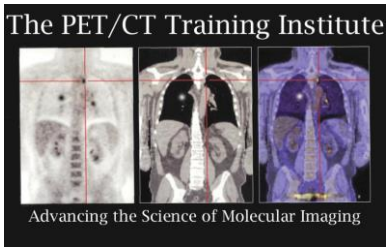

"PET MR REVIEW COURSE"

(75 hours)

SYLLABUS

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The PET/CT Training Institute, Inc.

Overview: This online self-study Learning Management System course will cover various topics of PET/MR. PET/MR combines two complementary advanced imaging technologies- positron emission tomography (PET) and magnetic resonance imaging (MRI) into a single scanner that can acquire PET and MRI data simultaneously. The simultaneous acquisition of PET and MR data enables new opportunities for physicians who need diagnostic imaging of patients with cancer, brain disorders, and heart disease, among other diseases and neurological issues.

This course will cover topics of PET/MR, ranging from technical developments to clinical applications. Technical developments will include understanding basic MR approaches to attenuation correction and motion correction. This course will provide a broad overview of clinical applications of both PET and MRI within the body and brain.

The intended advantage of this advanced level education for PET/MR Technologist is to allow only one technologist to perform the scanning procedures.

Audience: The target audience for this online course is primarily Imaging Technologist.

Contents

Module I: Introduction to PET

➢ Lecture 1: Terminology

Time: 30 minutes

Topic: Glossary of Molecular and PET Imaging Terms

Objective: Define and fully understand the Molecular and PERT imaging terms.

Imaging Terms: Listed in alphabetical order

A

- Alzheimer's disease
- Amino acid
- Aneurysm
- Angiography
- Annihilation
- Antibody
- Antigen
- Arrhythmia
- Atherosclerosis
- Atrophy
- Automated external defibrillator
- Automatic internal cardiac defibrillator
- Axillary lymph node dissection
- Axillary lymph nodes
- Axillary lymph nodes, dissection
- Axon

B

- Benign
- Beta-amyloid plaque
- Biological pathway
- Bioluminescent imaging
- Biomarker

Biopsy

Bipolar disorder

Blood brain barrier

Bone marrow

Bone scan

Bradycardia

Breast-specific gamma imaging

C

C-11-PIB

Carcinoembryonic antigen (CEA)

Cardiac Catheterization

Cardiac sarcoidosis

Cardiomyopathy

Cartilage

Cervix

Chemotherapy

Co-registration

Colorectal

Colorectal cancer

Computed tomography

Congenital

Congestive Heart failure

Contrast agent (contrast media or contrast material)

Coronary artery disease

Cryosurgery

D

Degenerative

Dementia

Diagnostic Imaging (Diagnostic scan)

Diastolic

Differential Diagnosis

Differentiated thyroid cancer

Diffuse

Ductal carcinoma in situ (DCIS)

Ducts

E

EGG stress test

Echo stress test

Echocardiography

Ejection fraction

Electrocardiography

Electrodessication and curettage

Electromagnetic radiation

Electron

Embolism

Endocrine

Enzyme

Epilepsy

Esophageal

Estrogen receptor-positive breast cancer

Estrogen, estrogen receptor

Exercise treadmill testing

F

FDG

Fluorescence imaging (Fluorescence molecular tomography (FMP))

Fluoroestradiol (FES)

Fluorothymidine (FLT)

Follicular thyroid cancer

Frontotemporal dementia

Frontotemporal disorders

Fusion Imaging

G

Gallbladder

Gamma camera

Gastric

Gastrointestinal tract (GI) tract

Glial cell

Gynecology

H

Heart attack

Heart failure

Hippocampus

Hodgkin's disease

Hurthle cell thyroid cancer

Hybrid imaging

Hypothyroidism

I

I-123 MIBG scintigraphy

I-131 Radiotherapy

Imaging agent (imaging probe, radiotracer)

Imaging biomarker

Imaging device

Imaging probe

Immunotherapy

Incidental cancers

Indium-111-octreotide

Intravenous(Iv)

Ionizing radiation

Isotope

L

Larynx

Lewy body dementia

Ligand

Lobules

Localize

Lumpectomy

Lymph

Lymph node biopsy

Lymph nodes

Lymph vessels

Lymphatic system

Lymphocyte

Lymphoma

Lymphoscintigraphy

M

Magnetic Resonance imaging (MRI)

Magnetic resonance spectroscopy (MRS)

Malignant

Mastectomy

Matrix metalloproteinase (MMP)

Mediastinoscopy

Melanin

Melanocytes

Melanoma

Metabolic

Metabolism

Metabolites

Metastasize

Micro- (PET, MR, CT, SPECT)

Microbubbles

Mild cognitive impairment (MCI)

Millisieverts (MSV)

Molecular imaging

Molecular markers

Molecular radiotherapy

Molecular ultrasound

Monocional antibody

Monocional antibody imaging

MR spectroscopy

Myelin

Myocardial infraction (MI)

Myocardial perfusion imaging

Myocardial perfusion scan (MPI)

Myocarditis

N

Nanometer

Nanoparticle

Nanotechnology

National oncologic PET regristry (NOPR)

Nerve

Nervous system

Neurodegenerative diseases

Neuroendocrine

Neuroimaging

Neuroimaging probes

Neuron

Neurotransmission

Neurotransmitter

Non-hodgkin lymphoma (NHL)

Non-invasively

Noninvasive

Nuclear cardiology

Nuclear functional study

Nuclear medicine / nuclear imaging

Nucleus

O

Obsessive-compulsive disorder

Opacity

Optical imaging

Ovary

P

Pancreas

Papillary thyroid cancer

Parkinson's disease

Peripheral artery disease (PAD)

PET

PET-CT

Pharmacodynamics

Pharmacogenetics

Pharmacokinetics

Pharmacological stress test

Pharynx

Photodynamic therapy

Photon

Pick's disease

Plaque

Plaque, beta-amyloid

Positron

Positron emission mammography (PEM)

Positron emission tomography (PET)

Post-traumatic stress disorder (PTSD)

Prostanscint scan (PSMA Study)

Prostate gland

Prostate-specific antigen (PSA)

Prostate-specific membrane antigen (PSMA) study

Prostatectomy

R

Radiation therapy

Radioactivity

Radioimmunoscintigraphy (RIS) (monoclonal antibody imaging)

Radioimmunotherapy

Radioiodine

Radioisotope

Radiopharmaceutical

Radiotracer

Re-staging

Rectum

Reporter-gene systems

Risk-stratification

S

Sarcoma

Schizophrenia

Sentinel lymph node

Sentinel node biopsy

SPECT

Spleen

Stage

Stress perfusion study

Stroke

Sudden cardiac death

Synapse

Systolic

T

Tachycardia

Technetium-99m-Sestamibi (MIBI)

Technetium-99m-sulfur-colloid

Thymus

Thyroid

Thyroid gland

Tomography, tomographic reconstruction

Transient ischemic attack

Translational medicine

Tumor

Tumor marker

U

Ultrasound

Urethra

Uterus

V

Ventricular remodeling

X

X-ray

Y

Yttrium-90 labeled octreotide.

Contents

➢ Lecture 2: Nuclear Decay Mathematics

Time: 90 minutes + video-lecture

Keywords: radionuclide, half-life, radiation, calibration

Objectives:

- 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
- Review dose volume calculations
- Calculate effective half-life
- Determine radiation dose versus time
- Compute radiation dose versus distance
- Calculate radiation intensity with shielding
- Convert units of activity, exposure, and absorption.

Content:

I. Post-calibration

II. Radioactive decay

1. Decay equation
2. Decay chart
3. Universal decay table
4. Questions
5. Formulas
6. Calculations
7. Calculator features

II. Pre-calibration Mathematics

1. Decay factor
2. Formula
3. Pre-calibration methods
4. Post calibration methods
5. Questions

III. Specific activity and specific concentration mathematics

1. Specific activity
2. Units of specific activity
3. Sample problems
4. Specific concentrations

IV. Dose volume determination mathematics

1. Define the principles.
2. Discuss how to calculate dose volumes.
3. Provide examples of how to calculate dose volumes with a calculator.
    a. Dose volumes
    b. Concentration
    c. Questions

V. Effective half-life mathematics

1. Discuss the principles
2. Review the methods for calculating effective half-life.
3. Provide examples to calculate.
    a. Effective half-life
    b. Formulas
    c. Sample questions

VI. Radiation dose versus time mathematics

1. Discuss the principles of radiation dose versus time.
2. Review how to calculate the total radiation dose based on time of exposure.
3. Provide examples of math problems.
    a. Radiation dose
    b. Time exposure
    c. Formula
    d. Samples questions

VII. Radiation dose versus distance mathematics

1. •Discuss the principles of the Inverse Square Law
2. Review how to calculate the radiation dose based on distance.
3. Provide examples of equations for solving for Inverse Square Law.
    a. Radiation dose
    b. Distance (inverse square law)
    c. Formulas
    d. Questions

VIII. Radiation dose versus shielding mathematics

1. Discuss the principles of radiation dose versus shielding materials.
2. Review how to solve mathematical problems using the half-value layer formula.
3. Provide examples of problems.
    a. Exposure rate
    b. Formula
    c. Questions
    d. Calculator examples

IX. Units conversion mathematics

1. Review how to convert between curie and Becquerel's
2. Discuss how to convert between rads and grays
3. Review how to convert between rems and sieverts
4. Provide examples to calculate
    a. Curies
    b. Bequerels
    c. Problems

d. Formulas
e. Rads
f. Grays
g. Equations
h. Rem
i. Sievert

Contents

➢ Lecture 3: Background Radiation

Time: 60 minutes

Keywords: radioactivity, radioisotopes, alpha rays, gamma rays, beta rays, gamma rays

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. Alpha rays
2. Beta rays
3. Gamma rays
4. Radioactive decay
5. Harmful radiation
6. Alpha decay
7. Gamma decay
8. Beta decay
9. Energy barrier
10. Half-life

II. Ionizing radiation

1. Natural background

2. Technology modified sources
3. Modified natural sources
4. Technology produced sources
5. Natural background radiation

III. Cosmic radiation

1. Protons
2. Alpha particles
3. Assorted atomic nuclei
4. Cosmogenic nuclides

➢ Lecture 4: Atomic Structure and Nuclear Stability (Part I)

Time: 60 minutes

Keywords: matter, mass, ionization, protons, atoms, neutrons, electrons, energy, ionic bonds

Objectives

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

Content:

I. Matter and energy

1. Chemical properties
2. Atomic model dilemma
3. Makeup of nucleus
4. Isotopes
5. Sub atomic particles
6. Chemical bonds
7. Electron shells
8. Atomic mass
9. Atomic number
10. Hydrogen
11. Electrons
12. X-rays

13. Physics
14. Unified field theory
15. Binding energy of electrons
16. Photo electric effect
17. Atomic structure
18. Neutrons
19. Nucleons
20. Excited state nuclides
21. Meta stable state
22. Mev binding energy
23. Kev binding energy
24. Tc99m
25. Nuclear cement
26. Radioactive nuclides
27. Unstable nuclides
28. Radioactive decay
29. Atomic model
30. Radium purified by the Curies
31. Refined atomic model
32. Laws of Conservation of Matter and Energy and electric charge
33. Alpha ion
34. Beta decay
35. Isobaric Transition
36. Law of Conservation of Mass
37. Carbon dating
38. Physical half-life
39. Beta positive decay
40. Electron capture
41. Decay identification
42. Isomeric transition
43. Isobaric transition
44. Electromagnetic spectrum

45. Internal conversion
46. Decay schemes

Contents

➢ Lecture 4: Atomic and Nuclear Structure (Part II)

Time: 60 minutes + video-lecture

Keywords: atoms, electrons, protons, neutrons, Isotopes, Isomers, isobars, cyclotrons

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
   2. Protons
   3. Electrons
   4. Neutrons

II. Atomic nomenclature
   1. Atomic number

2. Mass 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

1. Energy
2. Penetrating power
3. Joule
4. Electron-volt
5. One Mev
6. Macroscopic scale
7. 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 decay
8. Beta-plus decay
9. Electron capture decay
10. Isomeric transition
11. Decay schemes
12. Generalized decay scheme
13. Radionucleide productions
14. Cyclotrons
15. Nuclear reactors
16. Neutron activation
17. Radionuclide generators
18. Transient equilibrium
19. Secular equilibrium
20. Ideal radiopharmaceuticals
21. Mechanisms of localization

Contents

➢ Lecture 5: Alpha and Beta Decay

Time: 60 minutes + video-lecture

Keywords: ion, matter, atom, isotope, negatron

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. Democritus
6. History of the atom
7. Isotopes
8. Radioactive decay
9. Subatomic particles
10. Atomic structure

II. Alpha decay

1. Helium nucleus
2. Alpha particles properties
3. Specific ionizations
4. Linear energy transfer
5. Straight line paths
6. Alpha decay equation
7. Electrical interaction

III. Negative Beta decay

1. Beta decay
2. Negatron
3. Negative betas
4. Energy

5. Paths in matter
6. Penetrating ability
7. Best shielding
8. Bremsstrahlung
9. Negative beta equations
10. B-emitters
11. Radioactive decay schemes
12. Take quiz

Contents

➢ Lecture 6: Gamma Decay, Positron Decay and Electron Capture

Time: 60 minutes + two video-lectures

Keywords: isotopes, radioisotopes, gamma rays, photon, positrons

Objectives:

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

Content:

I. Matter and its history

1. Democritus
2. Aristotle
3. John Dalton
4. Rutherford
5. Bohr's model

II. Photons

1. Properties of a photon
2. Gamma photons
3. Electromagnetic radiation
4. The Electromagnetic Energy Spectrum
5. General gamma decay equation
6. Radionuclides
7. Gamma emitters
8. Types of radiation
9. Specific ionization

III. Positron Beta emission

1. Positrons
2. Positron properties
3. Energy requirements
4. Matter interaction
5. Annihilation radiation
6. Positron decay equation
7. Emmiters

IV. Electron capture

1. Proton-rich
2. Electron capture transformation
3. EC decay equation
4. Quiz

Contents

➢ Lecture 7: Photon and Particle Interaction in Matter

Time: 60 minutes

Keywords: Ionization, atom, excitation, photons, neutrino

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 particles
- Review the properties of 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. The atom

1. Basic model of 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

Contents

➢ Lecture 8: Gaseous Detectors Used in the PET Lab

Time: 90 minutes + video-lecture

Objectives:

- Discuss construction principles of gas filled detectors
- Review the various types of gas filled detectors
- Discuss the operating regions of gas filled detectors
- Discuss the relationship between applied voltage and ion pairs
- Review the general features of gas filled detectors
- Discuss the operations of a proportional counter
- Discuss the advantage and disadvantages of ionization detectors
- Discuss the various modes of operations of the ionization detectors
- Discuss how to read a G-M Scale

- Review how to perform a survey
- Discuss the operating principles of a Survey Meter
- Review the quality control program for a Survey Meter
- Review 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. Gaseous detectors

1. Construction
2. Three types of gas filled detectors
3. Instrumentation
4. Components
5. Indirect ionization process
6. Direct ionization process
7. Cyndrical proportional chamber
8. Radiation detection
9. Saturation current
10. Pulse height
11. Features
12. Proportional counters
13. Distinguishing Alpha & Beta

II. Geiger Mueller Detectors

1. Modes of operation
2. Advantages and disadvantages
3. Interaction rate
4. Dead time
5. Paralyzable or nonparalyzable
6. Current mode operation
7. Detection efficiency
8. Ionization chambers
9. GM counters

III. Survey meters

1. Types of survey meters
2. Collection of ions
3. Electric current
4. Check source
5. Reading GM scales
6. Proper surveying technique
7. Survey Meter Quality Control

IV. Quality control

1. Calibration
2. Constancy
3. Instructions
4. Wipe test procedure
5. Decay-in
6. Survey meter

V. Pocket dosimeters

1. Crosssection of the Pocket Dosimeter
2. Operational properties
3. General comments

VI. Ionization chambers

1. Exposure
2. Reading Ionization Chamber Scales
3. Cutie pie scales
4. Characteristics
5. General comments

VII. Dose calibrator

1. What is it?
2. Basic design
3. Quality control
4. Procedure for calibrating
5. Constancy test procedures

6. Linearity Test Procedures
7. Shield methods
8. Geometry Test Procedures
9. Accuracy Test Procedures

Contents

➢ Lecture 9: Scintillation Detectors Used in Nuclear Medicine and PET

Time: 90 minutes

Objectives:

- Review the basic principles of scintillation detection
- Discuss the components of a scintillation detector system
- Review the crystals used in Gamma Cameras and PET Scanners.
- Discuss the electronics of scintigraphy
- Discuss count rate limitations relative to dead time, efficiency, geometry and attenuation.
- Explore the basic design of the PET Scanner.
- Review the quality control procedures performed on a PET Scanner.

Content:

I. Introduction

II. Development

III. Anger scintillation camera

1. Design

IV. Crystals used in scintigraphic imaging

1. Good characteristics
2. Types of crystals
3. Properties

V. Photomultiplier Tubes

1. Key points
2. High voltage power supply
3. Preamplifier
4. Amplifier
5. Gain control

6. Pulse height
7. Spectrometers
8. Design
9. Analog camera
10. Hybrid camera
11. Digital camera
12. Collimators
13. Image formation
14. Measures of performance
15. Uniformity
16. Spatial resolution
17. Spatial linearity
18. Multienergy spatial resolution
19. System efficiency
20. Collimator efficiency
21. Energy resolution
22. Count rate performance

VI. Scintillation Detectors

VII. Dead time

1. Pulse mode
2. Current mode
3. Dead time graph

VIII. Efficiency

IX. Geometry/Attenuation

X. Pet scanners

1. PET
2. Pet radiation detectors
3. Dedicated PET
4. Scintillation Crystals
5. PET Scanner Design
6. Coincidence Detection
7. Data Acquisition

8. 2D and 3D Scanner Configuration

9. Scanner Calibration and Quality Control

10. PET Scanner Failures

11. PET/CT Scanners

Contents

➢ Lecture 10: Standards of PET Acquisition and Integration

Time: 30 minutes

Content: Standards for PET Image Acquisition and Quantitative Data Analysis.

I.SUV formula

II. Standards and recommendations for Pet

III. Overview of published recommendations and Guidelines

IV. Table 1

V. Table 2

VI. Overview of specific recommendations for quantitative PET studies

VII. Patient preparation procedures

VIII. Administration procedures

IX. Study acquisition, image quality and SNR

X. Image reconstruction and image resolution

XI. Data analysis procedures SUV normalization

XII. QC Measures and Qualification of Personnel

XIII. Discussion

1. Is There a Need for Different Levels of Standardization?

2. Issues in Maintaining and Updating Future Standards

XIV. Conclusion

Contents

➢ Lecture 11: PET instrumentation (Part I)

Time: 30 minutes

Content:

I. Positron physics

1. Positron decay
2. Positron Annihilation

II. Coincidence detection

1. Coincidence event
2. Table 1
3. Projections
4. Image reconstructions

III. Degrading Factors

1. Scatter
2. Attenuation
3. Attenuation correction
4. Random events
5. Dead time
6. Noise
7. Special resolution

IV. High performance PET systems

V. Hybrid systems

VI. Other systems

Contents

➢ Lecture 11: PET instrumental (Part II)

Time: 60 minutes

Objectives:

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

Content

IV. PET VS SPECT

1. Key points
2. PET diagram
3. Physics & Instrumentation in Positron Emission Tomography
4. Non-invasive Medical Imaging Techniques
5. Technical challenges in PET

6. Imaging overview

V. positron decay

1. Beta decay
2. Positron annihilation
3. Raw Data & Image Reconstruction
4. Important Detector Properties
5. New developments

VI. PET diagram

1. Block diagrams
2. Analog subsection
3. Condition
4. Digitize Energy, X Ratio, and Y Ratio
5. Process
6. Detector head interface
7. Coincidence Processor
8. Host computer

Contents

➢ Lecture 12: Acquisition Protocol Considerations for Combined PET/CT Imaging (Part I)

Time: 30 minutes

Content

I. Standard FDG PET/CT imaging protocol

1. Patient preparation
2. Table 1
3. PET Acquisition
4. Patient positioning

5. Data processing and reconstruction
6. Overview scan
7. CT acquisition
8. Image analysis and reporting

II. OPTIMIZATION OF STANDARD 18F-FDG PET/CT IMAGING PROTOCOLS

III. GENERAL ASPECTS OF 18F-FDG PET/CT IMAGING PROTOCOLS

1. Truncation artifacts
2. Respiration artifacts
3. Metal implants
4. CT contrast agents
5. Combined Scanning and Joint Report

IV. SPECIAL FDG PET/CT IMAGING PROTOCOLS

V.DISCUSSION

VI. CONCLUSION

Contents

- Lecture 12: Acquisition protocol considerations for combined PET/CT Imaging (Part II)

Time: 30 minutes

Content:

I. PET/CT Image Navigation and Communication

II. Dual-modality imaging techniques

1. Imaging protocols
2. Image Reconstruction and Data Management
3. Image Display and Data Visualization
4. Image Management Images Data Communication

VII. PET/CT workflow

VIII. Shortcoming and future developments

IX. Conclusion

Contents

➢ Lecture 13: PET quality control

Time: 30 minutes

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. PET images
2. Quality control
3. Problems

II. Characterization calibrations

1. Energy window calibration
2. Gain settings
3. Germanium chemical information
4. Coincidence timing calibration
5. Correction calibrations
6. Blank scans
7. Normalization calibrations
8. Absolute activity calibration
9. Fil phantoms
10. Heart filled phantoms

III. Uniformity and noise

IV. High contrast spatial resolution

V. Laser alignment

Contents

➢ Lecture 14: Physics of Positrons and Production of PET Tracers (Part I)

Time: 60 minutes

Keywords: positrons, proton-rich, annihilation radiation

Objectives:

- 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
- Review N-13
- Review O15
- Review F-18
- Discuss the synthesis process for manufacturing PET Radiopharmaceuticals

Content:

I. 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. Radionuclides decay
10. What is PET?

11. Value PET

II. PET radiopharmaceuticals

1. Preparation of 18F-FDG
2. Comparisons
3. Mechanism uptake
4. C Compounds
5. PET Reimbursement Issues
6. Clinical utility
7. Tumor imaging
8. Whole body PET scans
9. Cardiac PET scans
10. Cerebral PET
11. PET in neurology

III. Cyclotron manufacturing process

1. Hot cells
2. Synthesis molecules
3. PET radionuclides
4. PET radiopharmaceuticals
5. Preparation
6. Radiochemistry
7. Electrophilic substitution
8. Methylation
9. Synthesis of radiopharmaceuticals
10. Automated synthesis devices
11. Physicochemical test
12. Biological test
13. Specifications for routine

Contents

➢ Lecture 14: Physics of Positrons and Production of PET Tracers (Part II)

Time: 30 minutes

Content:

I. PET tracers

1. Principles of PET 1
2. Principles of PET 2
3. Principles of PET 3
4. Applications of PET tracers
5. Development of PET Radiotracers
6. Radioisotopes for PET
7. Chemistry
8. Important PET Radiotracer
9. Process of Cooperation

Contents

➢ Lecture 15: PET Radiopharmaceutical

Time: 30 minutes

Content:

I. PET Radiopharmaceuticals

1. Considerations for radiopharmaceuticals dose preparation
2. C-sodium acetate
3. C-choline
4. C-palmitate
5. F-FDG
6. F-fluorodopa
7. F-sodium Fluoride
8. F-fluorothymidine
9. F-fluoromisonidazole
10. N-Ammonia
11. Oxygen gas
12. O-water
13. Rb-chloride
14. Chapter review question

Contents

➢ Lecture 16: PET Radiopharmaceutical Quality Control (Part I)

Time: 30 minutes

Content:

I. Appearance

II. Radionuclidic identity

III. Radiochemical identity

IV. Radionuclidic purity

V. RCP

VI. Radiochemical Impurity

VII. Ph

VIII. Assay for radioactivity

IX. Chemical Purity

X. Specific activity

XI. Residual solvents

XII. Bacterial endotoxins

XIII. Sterility

XIV. Glucose

XV. Stabilizer

XVI. Osmolality

XVII. Membrane filter integrity

XVIII. Conclusion

Contents

➢ Lecture 16: PET Radiopharmaceutical Quality Control (Part II)

Time: 60 minutes

Objectives:

- Discuss the background of the USP
- Review personnel cleansing and gowning
- Discuss the responsibilities of compounding personnel
- Review the Risk Level Classifications
- Verifying the accuracy and sterilization technique

- Discuss personnel training and assessment
- Review quality control equipment
- Discuss the Storage and Beyond Use dating

Content:

I. United States Pharmacopeia

1. Legal and regulatory basis
2. Goal of chapter
3. Compounded sterile products
4. Scope of USP
5. Personnel cleansing and gowning
6. Responsibilities of compounding personnel
7. Low risk characteristics
8. Medium risk levels characteristics
9. High risk level characteristics
10. Media fill testing
11. Physical inspection
12. Compounding accuracy checks
13. Personnel training and assessment
14. Critical site
15. Equipment
16. Storage and beyond use dating

Contents

➢ Lecture 16: PET Radiopharmaceutical Quality Control (Part III)

Time: 30 minutes

Content:

I. Purpose

II. Background information and definitions

1. Radiopharmaceuticals
2. Physiologic and Pharmacologic Interventions

III. Procedures

1. Clinical use of radiopharmaceuticals
2. Elution of Generators and on-Site Preparation of Kits
3. Positron-Emitting Radiopharmaceuticals
4. Record Keeping
5. Adverse Reactions/Product Problems
6. Medical Events Involving Radiopharmaceuticals
7. Special Considerations for Labeled Blood Products
8. Drug Interactions and Altered Distribution Patterns

IV. Issues requiring further clarification

V. Concise bibliography

VI. Disclaimer

VII. Approval

Contents

➢ Lecture 17: Clinical Indications for Cardiac PET (Part I)

Time: 30 minutes

Content:

I. Patient information

II. Radiopharmaceuticals

III. Injected activities, dosimetry and radiation exposure

IV. Stress tests

V. Imaging protocols

VI. Image acquisition

VII. Quality control

VIII. Reconstruction methods

IX. Gated myocardial perfusion imaging

X. Attenuation and scatter compensation

XI. Data analysis

XII. Reports, image display

XIII. Positron emission tomography

Contents

➢ Lecture 17: Clinical Indications for Cardiac PET (Part II)

Time: 30 minutes

Content:

I. Materials and methods

1. Patient population
2. PET/CT system
3. Protocol
4. Data processing
5. PET/CT registration
6. Emission-Driven Correction

II. Results

1. Manual registration
2. Automatic Registration
3. Emission-Driven Algorithm

III. Discussion

IV. Conclusion

Contents

➢ Lecture 18: Cardiac Medication

Time: 30 minutes

Content:

I. Anticoagulants

II. Antiplatelet agents

III. Angiotensin-Converting Enzyme (ACE) Inhibitors

IV. Angiotensin II Receptor Blockers (or Inhibitors)

V. Beta blockers

VI. Calcium channel blockers

VII. Diuretics

VIII. Vasodilators

IX. Digital preparations

X. Statins

Contents

➢ Lecture 19: Cardiogen generators

Time: 120 minutes

Content:

I. Introduction

II. Rubidium-82

1. Physical data
2. History
3. Nuclear properties
4. Production
5. 82Sr/82Rb generator
6. Production of 82Sr
7. Control of product radiopurity
8. Target Issues -Rb Cl
9. Target Issues –Rb metal
10. Facilities
11. Sr-82 process flow chart
12. Sr-82 product specifications
13. Decay scheme of 82Sr to82Rb
14. Relevant nuclear properties

III. CardioGen-82

1. The generator
2. Radiopharmaceuticals
3. FDA Drug Safety Communication
4. The Root Cause
5. Return to Market Requirements
6. Uses for Cardiogen-82 Generator
7. Use in Positron Emission Tomography
8. Myocardial blood flow tracers with PET
9. History
10. Tools for risk stratification

11. PET perfusion imaging
12. Transitioning the perfusion market
13. Benefits
14. Thriving practice
15. Occupational Safety Data
16. Commonly used brand names
17. Chemical Characteristics
18. Physical characteristics
19. External radiation
20. Strontium Sr 82 decays to rubidium Rb 82
21. Physical decay
22. Infusion system
23. Injection dosage
24. Drug handling
25. Directions for eluting rubidium
26. Eluate testing protocol
27. Cardiogen-82 Expiration
28. Important safety information
29. Radiation Dosimetry
30. Dosage Forms and Strengths
31. Warnings and Precautions
32. Risks Associated with Pharmacologic Stress
33. Volume Overload
34. Cumulative Radiation Exposure
35. Adverse Reactions
36. Drug interactions
37. Use in specific populations
38. Clinical pharmacology
39. Nonclinical toxicology
40. Dose calibrator
41. CardioGen-82 QC Procedures
42. CardioGen-82 Infusion System QC

43. 1st Elution

44. 2nd Elution.

45. 3rd Elution.

IV. Patient Preparation and Imaging Protocols

1. Medications

2. Clothing

3. Examination

4. Methods of Stress Testing

5. Examples of Radiotracers and their Applications

6. The Radioactive Tracer

7. Patient Radiation Dosimetry

8. Rubidium-82 Dosage

9. Warnings

10. Precautions

11. Study Time Frame

12. Imaging Protocols

13. 82Rb PET perfusion image acquisition and processing

14. Image processing and common artifacts

15. Patient History

16. SPECT Procedure

17. SPECT Study CT Fusion

18. SPECT Impression

19. PET Rb-82 MPI Procedure

20. PET Impression

21. PET Rb-82 MPI Imaging

22. How supplied

23. Disposal

24. Storage

25. Expiration date

26. Cardiogen-82 Generator Side Effects

27. Safety data sheet

28. Hazard(s) identification

29. First-aid measures
30. Transport information
31. Advantages
32. Limitations

Contents

➢ Lecture 20: Clinical Indications for Brain PET (Part I)

Time: 30 minutes

Content:

I. Anatomical Imaging of Brain Tumors

1. CT and MRI
2. Nuclear medicine procedures
3. Brain scan
4. Functional imaging
5. Spect
6. Thallium-201
7. Dynamic process of 201Tl accumulation
8. TI retention index
9. Patient prognosis
10. Clinical indications
11. Assessment of [18 Assessment of [F]FDG uptake
12. Uptake and histology
13. Uptake and prognosis

Contents

➢ Lecture 20: Clinical Indications for Brain PET (Part II)

Time: 30 minutes

Keywords: Glucose, Metabolism, PET, Dementia, Oncology, Epilepsy, Movement disorders

Content:

I. Abstract

II. Background and definitions

III. Indications

IV. Procedure

Contents

➢ Lecture 21: PET Oncology (Part I)

Time: 30 minutes

Keywords: PET/CT scanner, PET/CT registration, PET/CT fusion, PET/CT acquisitions

Objectives:

- Explain what the purpose of F-FDG is
- Follow the Patient preparation procedures
- Define what PET is
- List the methods of attenuation correction
- Understand what kind of technique CT uses

Content:

I. Procedure

1. Patient Preparation
    a. Pregnancy and breast-feeding
    b. Before arrival
    c. Before injection
2. Information Pertinent to Performing Procedure
    a. Focused history, including the type and site of malignancy, dates of diagnosis and treatment (biopsy results, surgery, radiation, chemotherapy, and administration of bone marrow stimulants and steroids), and current medications.
    b. History of diabetes, fasting state, and recent infection
    c. Patient's ability to lie still for the duration of the acquisition (15–45 min)
    d. History of claustrophobia
    e. Patient's ability to put his or her arms overhead
3. Precautions
4. Radiopharmaceutical
5. Image Acquisition
    a. Field of view, positioning, and preacquisition preparation

b. Protocol for CT imaging
c. Protocol for PET emission imaging

6. Interventions
   a. Urinary tracer activity in the bladder.
   b. How to minimize brown fat uptake
7. Processing
   a. PET reconstruction
   b. CT reconstruction
   c. Display
8. Interpretation Criteria
   a. Normal physiologic uptake of 18F-FDG
   b. Detection of cerebral metastases
   c. Increased uptake of 18F-FDG
   d. 18F-FDG uptake and specific CT findings
   e. Description of findings
   f. Impression (conclusion or diagnosis)
9. Reporting
   a. Study identification
   b. Clinical information
   c. Procedure description and imaging protocol
10. Quality Control
    a. Radiopharmaceuticals
    b. Instrumentation specifications
    c. Emergency procedures
11. Sources of Error
    a. False-positive findings
    b. False-negative findings

II. Qualification of Personnel
1. Physicians
2. Technologists
3. Qualified Medical Physicists

III. Issues Requiring Further Clarification

IV. Concise bibliography

V. Disclaimer

VI. Approver

Contents

➢ Lecture 21: PET Oncology (Part II)

Time: 30 minutes

Content:

I. Indication

1. Evaluating an abnormality detected by another imaging method to determine the level of metabolism and the likelihood of malignancy.

2. Searching for an unknown primary tumor when metastatic disease is discovered as the first manifestation of cancer.

3. Staging patients with known malignancy.

II. Qualifications and Responsibilities of Personnel

1. Physician

   a. PET/CT examinations

   b. Documented training in the physics of nuclear medicine, diagnostic radiology and in the principles of radiation protection.

   c. Morphologic, pathologic, and physiologic radiopharmaceutical distributions with artifacts demonstrated on PET/CT.

   d. Familiarity with patient

   e. Indications for the examination

2. Qualified Medical Physicist

3. Radiologic and Nuclear Medicine Technologist

III. Specification of the Examination

1. Written or electronic request for an FDG-PET/CT

2. Patient Preparation

3. Radiopharmaceutical

4. Protocol for CT Imaging

5. Protocol for PET Emission Imaging

6. Interpretation

a. False-positive findings

IV. Equipment Specifications

1. Performance Guidelines

b. For the CT scanner

c. For the PET scanner

d. For the combined PET/CT scanner

2. Appropriate emergency equipment and medications

3. A fusion workstation

4. PET/CT scanning

V. Documentation

VI. Equipment Quality Control

VII. Radiation Safety in Imaging

VIII. Quality Control and Improvement, Safety, Infection Control, and Patient Education

Contents

➢ Lecture 21: PET Oncology (Part III)

Time: 30 minutes

Content:

I. Table 1 - Patient Preparation

1. Fasting—nothing by mouth for 4–6 h

2. No strenuous exercise 24 h before PET

3. Check blood glucose level (ideally between 120 and 150 mg/dL)

4. Start intravenous line for 18F-FDG administration

5. During circulation time, the patient should rest on a cart or recliner

6. Patient should void before scanning

7. Remove any metallic objects

8. Make the patient comfortable under the scanner—that is, use head and arm support

II. Table 2 - Relevant Patient History and Data

1. Surgical history: type, site, date of previous surgery or biopsy, site and types of stomas if present

2. Clinical history: complaints, type and site of tumor, date of diagnosis

3. Current therapy: chemo/radiotherapy, bone marrow–stimulating factors—for example, granulocyte colony-stimulating factor

4. Previous therapy received

5. History of trauma or recent falls

6. Results of previous radiologic investigations; review the patient's film (CT, MRI, and so forth)

III. Head and Neck

IV. Myocardium

V. Gastrointestinal Tract

VI. Genitourinary

VII. Muscular Activity

VIII. Thymus Uptake

IX. Bone Marrow

X. Splenic Uptake

XI. Benign Pathologic Causes of 18F-FDG Uptake

Contents

➢ Lecture 21: PET Oncology (Part IV)

Time: 60 minutes

Content:

I. Positrons Emitters

1. Produced in a cyclotron
    a. Fluorine-18
    b. Nitrogen-13
    c. Carbon-11
    d. Oxygen-15
    e. Copper-64
    f. Iodine-124
2. Produced by generator
    a. Rubidium-82
    b. Gallium-68
    c. Copper-62

II. Assessment of Tumor Biology with PET

1. PET assesses physiology and biochemistry rather than anatomy
2. Therefore PET provides the potential for earlier, more sensitive detection of disease

III. PET Tracers of Perfusion

1. Tracers of Perfusion
    a. 15O-water
    b. 13N-ammonia
    c. 82Rubidium

IV. Assessment of Tumor Biology with PET

1. Perfusion
2. Metabolism
    a. Glucose metabolism
    b. Bone metabolism
    c. Membrane lipid synthesis
    d. Amino acid transport and metabolism
3. Cellular proliferation: 18F-fluorothymidine (FLT)
4. Receptor expression
    a. Estrogen receptors
    b. Dopamine receptors
    c. Benzodiazepine receptors
    d. Somatostatin receptors

V. More Promising PET Tracers

1. Cellular oxygenation-hypoxia: 18 F -MISO, 64Cu - ATSM
    a. Hypoxia increases resistance to XRT
    b. Hypoxia leads to phenotypic heterogeneity
2. Drug binding-sensitivity
3. Gene expression/Gene therapy
4. Cell death/apoptosis
5. Angiogenesis
    a. Targeting avB3 integrin expression, a critical angiogenic modulator

VI. Clinical Applications for FDG PET and PET/CT

1. PET with FDG = imaging modality allowing direct evaluation of the cellular glucose metabolism

2. Neurology
    a. Brain Tumor
    b. HIV positive patients with neurological symptoms
    c. Epilepsy
    d. Neuropsychiatric disorders (dementias)
    e. Cerebrovascular disease
3. Cardiology
    a. Myocardial perfusion
    b. Myocardial viability
4. Oncology

VII. Normal Distribution of FDG

1. Brain: high uptake in the gray matter
2. Myocardium: variable uptake
3. Lungs: low uptake
4. Mediastinum: low uptake
5. Liver: low uptake
6. GI tract: variable activity (esophagus, stomach, colon)
7. Urinary tract: excretes FDG
8. Muscular system: low uptake at rest

VIII. Clinical Applications for PET in Oncology

1. Most malignant tumors
    a. Increased number of glucose transporter proteins
    b. Increased glycolytic enzyme levels
2. FDG PET became an established imaging modality for:
    a. Diagnosing malignancies
    b. Staging and restaging malignancies
    c. Monitor therapy
    d. Assess recurrence
    e. Surveillance
    f. Screening

IX. Positron Decay

X. Instrumentation for PET Imaging

XI. Anatomical & Molecular Imaging is Complementary

1. Limitations of CT
    a. Size criteria for lymph nodes involvement
    b. Differentiation of unopacified bowel versus lesion
    c. Evaluation of tumors after therapy
    d. Equivocal lesions
2. Limitations of FDG PET
    a. Limited resolution
    b. Accurate localization of the abnormalities
    c. Physiological variation of FDG distribution
3. Optimal interpretation: In conjunction with each other

XII. Integrated PET/CT Imaging Systems

1. Diagnostic CT Scanner

XIII. Properties of common scintillation crystals

1. Density
2. Atomic #
3. Light output
4. Decay time
5. Hygroscopic
    a. Crystal
    b. Effect
    c. NaI (T1)
    d. BGO
    e. GSO
    f. LSO

XIV. Integrated PET/CT Imaging System

1. Attenuation correction with CT
2. Anatomical localization

XV. Integrated PET-CT Scanners

1. Spectrum of equipment available:
    a. The quality of the PET images depends on the system and the PET protocol
2. Issues

a. Optimal CT protocols
b. Patient positioning
c. Operation of PET-CT systems
d. Interpretation and reports
e. Cost and billing

XVI. Correction for Attenuation Artifacts

1. Attenuation effects are more significant in coincidence imaging significant in coincidence imaging than SPECT because both annihilation photons must pass through the region without interaction

2. Methods

a. Calculated attenuation correction
b. Measured attenuation correction using attenuation maps obtained with various transmission sources

XVII. Advantages of Correction for Attenuation

1. Improvement of the anatomic delineation

a. Lesions can be localized more accurately

2. Necessary for semiquantitative evaluation with SUV

a. May be helpful for specific clinical situation

3. The quality of the images with attenuation depends on the accuracy of registration of the emission and transmission scan.

a. Inaccurate repositioning of the patient between scans can be avoided by performing simultaneous or sequential transmission/emission scans without moving the patient from the imaging table
b. Motion of the patient is a problem

4. Optimal correction for attenuation can be obtained using integrated PET/CT systems

XVIII. CT for Attenuation Maps

1. High quality maps because of high photon flux

a. Low (10 mA) current provides satisfactory attenuation maps

2. Short duration

a. <1 minute from base of the skull to mid-thigh with multi-detector CT
b. 3. Also provide anatomical maps for lesion localization
c. Current of ~80 mA is a compromise for limited radiation dose

d. Whole body dose equivalent ~700 mrem (7.0 mSv)
e. Whole body dose equivalent for FDG (10 mCi) ~700 mrem
f. Whole body dose equivalent for whole body PET-CT

3. Technical Protocol for whole body PET/CT (GE Discovery STE at VUMC)
4. Transmission CT
    a. 80 mA
    b. 130-140 kVp
    c. 40-90 msec
    d. 5 mm slices
    e. Pitch 3/1
    f. No IV contrast
    g. Breath-hold at Tidal volume or normal breathing
5. Emission PET
    a. 2D
    b. 3D
6. Regional diagnostic CT with IV and oral contrast if indicated

XIX. Artifacts on CT-attenuated PET images

1. Inaccurate co-registration due to:
    a. Random motion
    b. Respiratory motion
2. Hot spots due to over-correction correction related to:
    a. IV contrast
    b. Focal accumulation of oral contrast
    c. Metallic implants
3. Overestimation of SUV values by up to 10% compared to Ge-68 based attenuation correction

XX. SNM Procedure Guideline

XXI. SNM Procedure Guidelines for FDG PET/CT

1. Purpose
2. Background Information and Definitions
3. Procedure
    a. Patient preparation
    b. Information Pertinent to Performing the Procedure (focused history)

c. Radiopharmaceutical
d. Image Acquisition

4. Intervention
5. Processing
6. Interpretation Criteria
7. Reporting
8. Quality Control
9. Sources of Error
10. Qualification of Personnel

XXII. Sources of False +/- Interpretations

1. F+: Physiologic FDG uptake
    a. Lymphoid tissue
    b. Brown adipose tissue
    c. Glandular tissue
    d. Muscular system
    e. GI tract
    f. GU tract
2. F+: Inflammation
    a. Therapy-related
    b. Trauma
    c. Infection
    d. Granulomatous disease
3. False negative include:
    a. Small lesions
    b. Low cellular density
    c. Some low grade tumors
    d. Low sensitivity: 50~80%
    e. Hyperglycemia and/or insulin less than 3 H prior to FDG

XXIII. NOPR: National Oncologic PET Registry A Nationwide (US) Collaborative Program 2006-2008

1. Nationwide prospective registry
2. Goal: evaluate the impact of PET on physicians plans of patient management

3. Providers are required to submit data from pre-PET and post-PET physician questionnaires to NOPR as a condition for reimbursement

XXIV. NOPR: Cohort Profile

XXV. NORP: National Oncologic PET Registry PET Changed Intended Management in 36% of Cases

XXVI. NOPR: National Oncologic PET Registry PET Impact on Management by Cancer type Overall 38% of Cases

XXVII. NOPR: National Oncologic PET Registry PET Changed Intended Management during Cancer Treatment

1. 8,240 patient who had 10,497 treatment monitoring PET scans at 946 centers
2. If PET was not available, intended management
3. Post-PET intended management
4. PET enabled 91% of patients to avoid future tests

XXVIII. Summary Table of Medicare Coverage Policy (US) for FDG PET/CT as of April 2009

XXIX. NCCN: Task Force meeting Nov 2006

XXX. NCCN: Task Force meeting Nov 2008

1. NOPR update
2. Genitourinary cancers
3. Gynecological cancers
4. Pancreatic cancer
5. Hepatobiliary cancer
6. Sarcoma
7. Thyroid cancer
8. Brain cancer
9. Small cell lung cancer
10. Myeloma
11. Gastric and esophageal cancers

Contents

➢ Lecture 21: PET Oncology (Part V)

Time: 30 minutes

Content:

I. Head and Neck Cancer

1. The application of 18F-FDG PET and PET/CT in head and neck cancer
    a. Detection of occult primary tumors in patients presenting with metastatic disease.
    b. Initial staging – including detection of cervical lymph node metastases in the clinically node negative neck, and detection of distant metastases in patients with locally advanced disease
    c. Detection of residual or recurrent disease
2. SNM, 2008
    a. Identification of unknown primary tumors if conventional imaging tests are negative.
    b. Local (lymph node) staging in addition to CT or MRI.
    c. Detection of distant metastases in patients with advanced stage disease (might be beneficial)
    d. Detection of potential recurrence in addition to conventional imaging
3. National Comprehensive Cancer Network, 2010
    a. Localization of occult primary lesions before biopsy if nasopharyngolaryngoscopy, chest imaging, and either contrast-enhanced CT scan or MRI do not identify a primary lesion
    b. Initial staging of most cancer subtypes (cancer of the oral cavity, oropharynx, hypopharynx, glottic larynx, and supraglottic larynx), particularly in suspected Stage III or IV disease
    c. Initial staging of nasopharyngeal carcinoma for detection of distant metastases (chest. liver, bone) for WHO class 2-3/N2-3 (may include PET scan and/or CT)
    d. Initial staging of mucosal melanoma: Chest imaging or consider PET scan to rule out metastatic disease
    e. Post-chemotherapy or post-radiation neck evaluation for residual or recurrent tumor (suggested to be performed at minimum of 12 weeks post-treatment
4. American Head and Neck Society, 1995
    a. Identification of occult primary tumors in patients presenting with cervical nodal metastases, especially in difficult cases where no obvious mass was seen clinically or on either CT or MR
    b. Post-treatment neck evaluation for residual or recurrent tumor

II. Thyroid Cancer

1. The application of 18F-FDG PET and PET/CT in thyroid cancer

a. Detection of residual or recurrent thyroid cancer when serum thyroglobulin is elevated and radioiodine scan is negative.
b. Staging of patients with poorly differentiated thyroid cancers and invasive Hurthle cell carcinomas.
c. Evaluation of treatment response following systemic or local therapy of metastatic or locally invasive disease.

2. SNM, 2008
   a. 18F-FDG PET should routinely be performed on patients previously treated for well-differentiated (follicular or papillary) thyroid cancer when the findings of 131I whole-body scintigraphy are negative and the thyroglobulin serum marker is more than 10 ng/mL

3. National Comprehensive Cancer Network, 2011
   a. For surveillance and maintenance of patients with papillary carcinoma, follicular carcinoma, and Hurthle cell carcinoma: consider additional non-radioiodine imaging if 131I scans negative and stimulated Tg > 2-5 ng/ml
   b. For patients with medullary thyroid carcinoma post thyroidectomy consider FDG PET ± CT scan in patients with very elevated calcitonin levels
   c. For patients with anaplastic thyroid carcinoma: consider FDG PET ± CT scan to evaluate extent of disease

4. American Thyroid Association, 2009
   a. In patients with differentiated thyroid carcinoma, routine preoperative PET scanning is not recommended.
   b. In patients with elevated Tg but negative post-treatment scan following an empiric RAI dose (100-200 mCi of I-131), FDG PET ± CT scanning should be considered
   c. FDG PET or PET/CT scanning may be employed as part of initial staging in poorly differentiated thyroid cancers and invasive Hurthle cell carcinomas
   d. The sensitivity of FDG PET scanning may be marginally improved with TSH stimulation

5. Association of American CLinical Endocrinologists, 2001

III. Breast Cancer

1. The applications of 18F-FDG PET and PET/CT in breast cancer
   a. Initial staging of patients with locally advanced or metastatic breast cancer when conventional staging studies

b. Follow-up or surveillance patients with breast cancer when conventional studies

2. SNM, 2008

3. National Comprehensive Cancer Network, 2011

a. The use of PET or PET/CT scanning is not indicated in the staging of clinical stage I, II, or operable III breast cancer

b. In initial staging of patients with locally advanced invasive breast cancer or inflammatory breast cancer, FDG PET/CT (category 2B) is most helpful in situations where standard staging studies are equivocal or suspicious

c. In follow-up or surveillance of patients with invasive breast cancer, the use of PET or PET/CT scanning should generally be discouraged for the evaluation of metastatic disease

4. American Society of Breast Surgeons

IV. Non-Small Cell Lung Cancer

1. The applications of 18F-FDG PET and PET/CT in lung cancer

a. Characterization of indeterminate pulmonary nodules which are at least 8-10 mm in diameter.

b. Initial staging in patients with non-small cell lung cancer.

c. Delineation of gross-tumor volume in patients receiving radiation therapy.

2. SNM, 2008

a. 18F-FDG PET should routinely be obtained in the diagnostic work-up of patients with a solitary pulmonary nodule.

b. PET should routinely be added to the conventional work-up of patients with non-small cell lung cancer.

3. National Comprehensive Cancer Network, 2011

a. Non-small cell lung carcinoma (NSCLC)

b. Small cell lung carcinoma (SCLC)

c. Malignant pleural mesothelioma (MPM)

4. American College of Chest Physicians, 2007

a. Pulmonary Nodules

b. Non-small cell lung cancer

c. Special treatment issues

d. Bronchoalveolar cancer

e. Small cell lung cancer
f. Surveillance

V. Esophageal Cancer

1. The applications of 18F-FDG PET and PET/CT in esophageal cancer
    a. Initial staging
    b. Restaging after neoadjuvant chemoradiation therapy.
    c. Delineation of gross tumor volume in patients receiving radiation therapy.
2. SNM, 2008
3. National Comprehensive Cancer Network, 2010
    a. For initial staging, imaging modalities should include endoscopic ultrasound, chest/abdominal CT, and PET/CT
    b. Following neoadjuvant chemoradiation in patients medically fit, resectable Tis, T1-T4, N0-1, NX, or stage IVA, PET/CT (preferred) or PET scan
    c. General radiation information

VI. Colorectal Cancer

1. The applications of 18F-FDG PET and PET/CT in colorectal cancer include
    a. Preoperative evaluation of patients with potentially resectable hepatic or other metastases.
    b. Determining location of tumors when rising CEA level suggests recurrence.
2. SNM, 2008
    a. 18F-FDG PET should be used routinely in addition to conventional imaging in the preoperative diagnostic work-up of patients with potentially resectable hepatic metastases from colorectal cancer
3. National Comprehensive Cancer Network, 2011
    a. In the initial workup / staging of colorectal cancer that is felt nonmetastatic and appropriate for resection
    b. In patients with suspected or proven metastatic synchronous adenocarcinoma from the large bowel
    c. PET/CT should not be used to monitor response to chemotherapy
    d. Routine use of PET/CT for surveillance to monitor for disease recurrence is not recommended
    e. Upon documentation on dedicated contrast-enhanced CT or MRI

f. In the setting of serial CEA level elevation, contrast-enhanced CT is typically be imaging modality of choice

VII. Cervical Cancer

1. The applications of 18F-FDG PET and PET/CT in cervical cancer
    a. Initial treatment planning assistance, including determination of nodal status and systemic spread
    b. Detection of residual or recurrent disease following initial treatment
2. National Comprehensive Cancer Network, 2011
    a. For initial staging, imaging staging is optional for patients with stage IB1 or smaller tumors, including Chest X-ray, chest CT, PET/CT, MRI.
    b. For initial staging of patients with stage IA1 with lymphovascular space invasion or > or = stage IA2
    c. If para-aortic lymph nodes are found positive during surgical staging
    d. For surveillance, PET/CT scan as clinically indicated

VIII. Melanoma

1. The applications of 18F-FDG PET and PET/CT in melanoma include the following
    a. Detection and localization of potential extranodal metastatic lesions in initial evaluation of patients with advanced stage disease
    b. Evaluate the extent of metastatic disease burden in patients with recurrent disease following treatment
2. National Comprehensive Cancer Network, 2011
    a. Initial staging
    b. Restaging
3. American Society of Plastic Surgeons, 2007

IX. Lymphoma

1. The applications of 18F-FDG PET and PET/CT in lymphoma include
    a. Routine pre-treatment staging of patients with HD and most NHL subtypes
    b. Routine restaging after chemotherapy and/or radiation therapy
2. SNM, 2008
    a. 18F-FDG PET should routinely be obtained in addition to the conventional work-up in the pretreatment staging of lymphoma

b. 18F-FDG PET may be added to bone marrow biopsy for staging bone marrow infiltration in the staging of lymphoma
c. 18F-FDG PET should routinely be added to the conventional work-up for restaging or detecting recurrence
d. The panel concluded against the use of 18F-FDG PET in the routine follow of asymptomatic patients with HD or NHL

3. National Comprehensive Cancer Network, 2011
4. NHL
    a. CLL/SLL
    b. Follicular lymphoma, grade 1-2
    c. Non-gastric MALT lymphoma, marginal zone lymphoma
    d. Diffuse large B-cell lymphoma
    e. Burkitt lymphoma
    f. Peripheral T-cell lymphoma
    g. Mycosis Fungocides / Sezary Syndrome
    h. Extranodal NK/T-cell lymphoma nasal type
    i. NCCN endorses International Harmonization revised response criteria
5. HD
    a. For initial staging, PET/CT scan essential
    b. For restaging
    c. For surveillance, PET scans are not recommended for routine surveillance
    d. NCCN endorses International Harmonization revised response criteria
6. International Harmonization Project in Lymphoma, 2008
    a. Baseline PET
    b. Timing of PET after therapy
    c. Criteria for interpretation
    d. PET or PET/CT scanning during treatment of patients with HL

Contents

Module II: Introduction to MRI

➢ Lecture 22: MR Terminology

Time: 60 minutes

Keywords: Acoustic noise, Bloch equations, Coil, Dynamic range, ETL, Fringe field, Gradient pulse

Objectives:

- Describe the functions of a coil
- Explain technique can be used to study reaction kinetics of suitable molecules
- Compare the difference between neutron and proton
- Discuss basic anatomical directions
- Understand the mathematical procedure to separate out the frequency components of a signal from its amplitudes as a function of time

Content:

A

Absorption mode

Acceleration factor

Acoustic noise

Acquisition matrix

Acquisition Time

Acquisition window

Active shielding

Active shimming

ADC

Adiabatic fast passage (AFP)

Adiabatic rapid passage

AFP

Aliasing

Analog to digital converter (ADC)

Angiography

Angular frequency (ω)

Angular momentum

Annotation

Antenna

Apodization

Array coil

Array processor

Artifacts

Asymmetric sampling

Attenuation

Attenuator

Axial plane

Autotuning

B

Bo

B1

Balanced gradient

Balanced steady-state free precession

Bandwidth

Baseline

Baseline correction

Bilateral imaging

Birdcage coil

Bloch equations

Blood oxygen level dependent effect (BOLD)

Bolus tracking

Boil off rate

Boltzmann distribution

C

CBF

CBV

Cardiac gating

Cardiac phase

Carr-Purcell (CP) sequence

Carr-Purcell-Meiboom-Gill (CPMG) sequence

Cerebral blood flow (CBF)

Cerebral blood volume (CBV)

Chemical shift (δ)

Chemical shift artifact

Chemical shift imaging

Chemical shift reference

Chemical shift spatial offset

Cine acquisition

C/N

Circularly polarized coil

CNR

Coherence

Coherent

Coil

Coil loading

Complex conjugate

Composite excitation

Continuous wave NMR (CW)

Contrast

Contrast agent

Contrast-to-noise ratio

Convolution differencing

Coronal plane

Correlation time

Coupled array coils

Coupling

Coupling constant

CP

CPMG

Crossed-coil

Cryogen

Cryomagnet

Cryoshielding

Cryostat

CSI

CW

DAC

Data system

D

dB

dB/dt

DC artifact

Decibel (dB)

Decoupling

Δx, Δy, Δz

Demodulator

Dephasing

Dephasing gradient

Depth pulses

Detector

Diamagnetic

Diffusion

Diffusion-weighted imaging (DWI)

Digital to analog converter (DAC).

Digitization.

Digitization noise

Digitizer

Dipole

Dipole-dipole interaction

Dipole field

DWI

Dynamic range

E

Echo

Echo offset

Echo planar imaging (EPI)

Echo spacing

Echo time

Echo train length (ETL)

Eddy current compensation

Eddy currents

Electron paramagnetic resonance (EPR)

Electron spin resonance (ESR)

Energy level

EPI

Epoch

EPR

ESR

Ernst angle

ETL

Even echo rephasing

Excitation

Exponential weighting

F

Faraday shield

Fast Fourier transform (FFT)

Fat Suppression

Ferromagnetic

FFT

FID

Field echo

Field gradient

Field lock

Field of view (FOV)

Filling factor

Filter

Filtered back projection

Flip angle

Flow compensation

Flow effects

Flow-related enhancement

Flow void

fMRI

Fourier transform

Fourier transform imaging

FOV

Free induction decay (FID)

Frequency (f)

Frequency encoding

Frequency offset

Frequency selective RF pulse

Fringe field

FT

Full-width at half-maximum (FWHM)

Functional magnetic resonance imaging (fMRI)

FWHM

G

Gx, Gy, Gz

Gadolinium

Gating

Gauss (G)

Gaussian line shape

Gaussian noise

Gibbs phenomenon

Gigahertz (GHz)

Golay coil

Gradient

Gradient and spin-echo imaging (GRASE)

Gradient coils

Gradient-echo

Gradient-echo pulse sequence

Gradient magnetic field

Gradient moment nulling

Gradient pulse

Gradient recalled echo

Gyromagnetic ratio (γ)

H

Ho

H1

Hahn echo

Half Fourier

Hardware

Helmholtz coil

Hertz (Hz)

Homogeneity

Homospoil

Hybrid magnet

Hz

I

Isotropic Imaging

Imaginary signal

Impedance matching

Incoherent spins

Inductance

Induction (B)

Inhomogeneity

In-phase image

Interleaved image acquisition

Interleaved k-space coverage

Interpulse times (t)

Inverse Fourier transform

Inversion

Inversion-recovery (IR)

Inversion-recovery-spin-echo (IRSE)

Inversion time

Inversion transfer

IR

IRSE

Isocenter, magnetic

Isochromat

Isotopes

Isotopic motion

Isotropic voxel

J

J-coupling

J-modulation

K

Keyhole imaging

kHz

Kilohertz (kHz)

K-space

K-space filling

K-space trajectory

L

Larmor equation

Larmor frequency

Lattice

Line imaging

Line scanning

Line, spectral

Line spread function (LSF)

Line width

Linearity

Linearly polarized coil (LP coil)

Liquifier

LMR

Loading

Localization techniques

Localized magnetic resonance (LMR)

Lock

Longitudinal magnetization (Mz)

Longitudinal relaxation

Longitudinal relaxation time

Lorentzian line

LSF

M

Mxy

Mz

Mo

Macroscopic magnetic moment

Macroscopic magnetization vector

Magnet stability

Magnetic dipole

Magnetic field (H)

Magnetic field gradient

Magnetic forces

Magnetic fringe field

Magnetic induction (B)

Magnetic moment

Magnetic resonance (MR)

Magnetic resonance angiography (MRA)

Magnetic resonance imaging (MRI)

Magnetic resonance spectroscopy (MRS)

Magnetic shielding

Magnetic susceptibility (χ)

Magnetization

Magnetization transfer

Magnetization transfer contrast (MTC)

Magnetogyric ratio

Magnitude calculation

Matching

Matching network

Matrix size

Maximum intensity projection (MIP)

Maxwell coil

Megahertz (MHz)

Meiboom-Gill sequence

MHz

Moment

MPR (multiplanar reconstruction)

MR

MR Signal

MRA

MRI

MRS

MTC

Multiple coil array

Multiple echo imaging

Multiple line-scan imaging (MLSI)

Multiple quantum coherence

Multiple sensitive point

Multiple slice imaging

Multiple spin echo

Multiplet

Multiply tuned coil

N

N(H)

NEX

NMR

NMR imaging

NMR signal

NOE

Noise

Noise figure

NSA

Nuclear magnetic resonance (NMR)

Nuclear Overhauser effect (NOE)

Nuclear spin

Nuclear spin quantum number (I)

Nucleon

Nutation

Nx, Ny, Nz

Nyquist limit

O

Off resonance

On resonance

Opposed-phase image

Orientation

P

Pacemaker effect

Paradoxical enhancement

Parallel imaging

Paramagnetic

Partial Fourier imaging

Partial saturation (PS)

Partial saturation spin echo (PSSE)

Partial volume effect

Passive shielding

Passive shimming

PD

Peak

Permanent magnet

Permeability (μ)

Phantom

Phase

Phase correction

Phase cycling

Phase encoding

Phase encoding order

Phase sensitive detector

PIN diode

Pixel

Planar imaging

Point spread function (PSF)

Pole piece (or pole tip)

Population

Preamplifier

Precession

Precessional frequency

Preemphasis

Presaturation

Probe

Progressive saturation

Projection profile

Projection-reconstruction imaging

Prospective synchronization

PS

PSF

PSSE

Pulse, 90° (π/2 pulse)

Pulse, 180° (π pulse)

Pulse, gradient

Pulse, RF

Pulse length (width)

Pulse NMR

Pulse programmer

Pulse sequences

Pulsed gradients

Q

Quadrature coil

Quadrature detector

Quadrupole moment

Quality factor (Q)

Quantization noise

Quenching

R

R1

R2

ROI

Radian

Radiofrequency (RF)

Ramp time

Ramping

Random noise

Rapid-excitation MR imaging

Raw data

Rayleigh noise

Readout delay

Real signal

Receiver

Receiver coil

Receiver dead time

Reconstruction from projections imaging

Sampling window

SAR

Saturation

Saturation pulses

Saturation recovery (SR)

Saturation transfer (or Inversion transfer)

Scalar

SE

Segmented k-space data acquisition

Selective excitation

Selective irradiation

Self-shielding

Sensitive plane

Sensitive point

Sensitive volume

Sequence time

Sequential line imaging (Line scanning, Line imaging)

Sequential plane imaging (Planar imaging)

Sequential point imaging (Point scanning)

SFP

Shaped pulse

Shielded gradient coils

Shielding

Shift reagents

Shim coils

Shimming

SI (International System of Units)

Signal averaging

Signal-to-noise ratio (SNR or S/N)

Signal suppression

Sinc interpolation

Single-shot imaging

Skin depth

Slice

Slice profile

Slice selection

Slice thickness

S/N

SNR

Solenoid coil

Solvent suppression

Spatial frequency

Spatial resolution

Spatially localized spectroscopy

Spatial-spectral (or spectral-spatial) excitation

Specific absorption rate (SAR) (W/kg)

Spectral editing

Spectral line

Spectral width

Spectrometer

Spectroscopy

Spectroscopic imaging

Spectrum

Spin

Spin density (N)

Spin echo (SE)

Spin echo imaging

Spin-lattice relaxation time

Spin number, nuclear

Spin quantum number (I)

Spin-spin coupling

Spin-spin relaxation time

Spin tagging

Spin warp imaging

Spiral k-space coverage

Spoiler gradient pulse

SR

SSFP

Steady-state coherent

Steady state free precession (SFP or SSFP)

Stimulated echo

Superconducting magnet

Superconductor

Suppression

Surface coil

Surface coil MR

Susceptibility

Susceptibility artifact

Switchable coil

Synchronization, cardiac

Synchronization, prospective

Synchronization, respiratory

Synchronization, retrospective

T

T1 or T1 (“T-one”)

T1-weighted (T1W)

T2 or T2 (“T-two”)

T2* (“T-two-star”)

T2-weighted (T2W)

TAD

Tagging

Tailored excitation

Tailored pulse

TD

TE

Temporal resolution

TED

Tesla (T)

Thermal equilibrium

Three-dimensional Fourier transform imaging (3DFT)

TI

Time-of-flight

Tip angle

Torque

TR

Transaxial plane

Transmit/receive (T/R) coil

Transmitter

Transmitter coil

Transverse magnetization (Mxy)

Transverse place

Transverse relaxation

Transverse relaxation time

Traveling saturation pulse

Trigger delay time

Triggering

Truncation artifact

Two dimensional Fourier transform imaging (2DFT)

Tuning

Twister gradient

Two-dimensional MR

V

Variable flip angle

Variable TE

Variable TR

Vector

Velocity compensation

Vessel tracking

View

VOL

Volume coil

Volume of interest (VOI)

Volume imaging

Volume-selective excitation

Voxel

W

Wash-in effects.

Wash-out effects

Water-suppression

X

x

x’

Y

y

y’

Yoke

Z

Zero filling

Zeugmatography

γ

δ

μ

τ

χ

ω

ωo

Contents

➢ Lecture 23: MR Fundamentals

Time: 30 minutes + video-lecture

Keywords: Resistive Magnet, MR Examination, Magnetic Fields, Vectors, Definition of T1

Objectives:

- Understand the evolution of magnetic resonance (MR)
- Differentiate MR from CT
- Name the Magnetic types
- Explain the Magnetic Field Strength
- Discuss the MR History and application
- Describe the MR examination and procedure

Content:

I. Advantages of MR

II. MR vs. CT

1. Superior soft-tissue contrast resolution.

2. Ability to scan in all three planes.

3. No artifacts from bone or air.

4. Technologist flexibility to manipulate the degree of brightness for various soft-tissue types by adjusting MR imaging parameters

III. MR Scanners

1. Long-bore scanners are the traditional, closed-bore MR scanners.

2. Short-bore scanners are closed at one end and are 50 percent shorter and 5 percent wider than conventional long-bore scanners. They are designed to make patients feel less confined.

3. Open-bore scanners originally were designed to accommodate larger patients and patients with claustrophobia.

4. Ultra-low field scanners contain magnets with field strengths of 0.2 to 0.01 tesla (T). They typically are used for orthopedic applications in which the bore encloses only the body part of interest.

5. Low-field open scanners operate at field strengths from 0.2 to 0.4 T but are being redesigned to operate at higher strengths to improve image quality.

6. High-field scanners include 1.5-T and 3.0-T strengths and higher. Magnets operating at 3.0 T or higher are considered ultra-high field MR scanners. Ultra-high field scanners once were used solely for research, but many hospitals now have MR equipment with 3.0-T technology. Clinical

scanners with superconducting magnets are commercially available with field strengths up to 3.0 T, and whole-body systems at research facilities have fields as high as 9.4 T.

7. Upright scanners are low-field strength magnets that chiropractors use to display spinal alignment through flexion and extension.

IV. Magnet Types

V. Permanent Magnet

VI. Resistive Magnet

VII. Superconducting Magnet

VIII. Magnetic Field Strength

IX. Magnetic Field Strength

X. MR Safety

XI. Planes

XII. MR Defined — Evolution

XIII. History of MR Imaging

1. Nuclear — only the nuclei of certain atoms reacted in this way.
2. Magnetic —a magnetic field is required.
3. Resonance — the direct frequency dependence of the magnetic and RF fields

XIV. MR History — Clinical Application

XV. MR Innovation

XVI. MR Examination

XVII. MR Requirements

XVIII. MR Physics

1. Are positively charged.
2. Are located in nuclei.
3. Spin on their axes.

XIX. The Faraday Law

XX. Electromagnetism and MR

XXI. Magnetic Induction

XXII. Vectors

XXIII. Hydrogen Atoms

XXIV. No External Field Applied

XXV. External Field Applied

XXVI. Increasing Field Strength

XXVII. External Field Applied

XXVIII. Net Magnetization Vector

1. The nuclei align in one of two positions depending on their energy state.

2. Low-energy nuclei align with the field in parallel position.

3. High-energy nuclei align against the field in antiparallel position

XXIX. Magnetic Fields

1. Static magnetic field — the main field created by the MR magnet, or B0.

2. Radiofrequency (RF) magnetic field — created by the RF transmitters B1.

3. Gradient magnetic field — created by the gradient coils Bg.

XXX. Precession

1. Each proton spins and the direction of the proton's spin is randomly distributed in nature. If the human body is placed inside a large magnet with a magnetic field strength much greater than the earth's natural magnetic field, the tiny spins of lower-energy particles align with the strong magnetic field.

2. The influence of B0 produces an additional spin, or "wobble," which is called precession. Precession is the motion of net magnetization as it wobbles around the main magnetic field of the MR scanner. MR measures the signal from the wobbling protons, and this phenomenon happens thousands of times during an MR examination.

XXXI. Precessional Frequency

XXXII. In-phase Precession

XXXIII. Out-of-phase Precession

XXXIV. Larmor Equation

1. The f in the Larmor equation stands for the frequency of the wobbling of the net magnetization; it is measured in hertz (Hz), or cycles per second.

2. The k is the frequency of hydrogen.

3. The B stands for the magnetic field strength, which is measured in tesla.

XXXV. Larmor Frequency and Magnetic Field Strength

XXXVI. Radiofrequency

XXXVII. Resonance

1. The nuclei enter a high-energy state and align themselves antiparallel to the external magnetic field as they precess in-phase.

2. The changes in the nuclei are represented by the net magnetization vector. They either rotate, or precess, away from the longitudinal axis or rotate in a new position.

XXXVIII. Generating MR Signal

XXXIX. Longitudinal Direction

XL. Transverse Magnetization

XLI. RF Excitation Pulse

XLII. Resonance

XLIII. RF Energy Absorption

XLIV. Superconducting Magnet

XLV. Coordinate System

XLVI. Relaxation

XLVII. Types of Relaxation

XLVIII. Definition of T1

XLIX. Longitudinal Relaxation

L. Transverse Relaxation

LI. T2 Relaxation

LII. Relaxation Process

LIII. Free Induction Decay (FID)

LIV. T1-weighted Contrast

LV. T2-weighted Contrast

LVI. Excitation

LVII. T1 and T2 Relaxation

LVIII. Computers in MR Imaging

LIX. Advances in MR

LX. Integrated Modalities

LXI. MR-safe Pacemakers

Contents

➢ Lecture 24: MR Equipment and Instrumentation

Time: 30 minutes + video-lecture

Keywords: Resistive Electromagnet, Magnetic Field, Dielectric Effect, Chemical Shift

Objectives:

- Identify the key component of Magnetism
- Understand the Dielectric Effect
- Define Magnetic Field Strength
- Describe the Cryogens
- Discuss the difference of High-Field vs. Low-Field
- Explain the functions of Diamagnetic, Paramagnetic, Superparamagnetic and Ferromagnetic Substances

Content:

I. Equipment

II. Gantry

III. Coordinates

IV. MR Unit Length

V. Laser Positioning Lights

VI. Patient Table

VII. Operator's Console

VIII. MR Computer

IX. Magnetism

X. Diamagnetic Substances

XI. Paramagnetic Substances

XII. Superparamagnetic Substances

XIII. Ferromagnetic Substances

XIV. Magnetic Field Strength

XV. Ultra-high Field Magnets

XVI. Specific Absorption Rate (SAR)

XVII. Chemical Shift

XVIII. Dielectric Effect

XIX. Ultra-high Field Imaging

XX. High-Field Imaging

XXI. Midfield Magnets

XXII. Low-Field Magnets

XXIII. Ultra-low Field Magnets

XXIV. High-Field vs. Low-Field

XXV. Magnet Configuration

XXVI. Permanent Magnet

XXVII. Resistive Electromagnet

XXVIII. Magnetic Field

XXIX. Resistive Magnet

XXX. Superconducting Electromagnet

XXXI. Cryogens

XXXII. Superconducting Magnet

XXXIII. High-Field Open MR

XXXIV. Fringe Fields

XXXV. Shielding

XXXVI. Passive Shielding

XXXVII. Active Shielding

XXXVIII. Magnetic Moment

XXXIX. Larmor Frequency

XL. Shimming

XLI. Passive Shimming

XLII. Active Shimming

Contents

➢ Lecture 25: MR Radiofrequency and Gradients

Time: 30 minutes + video -lecture

Keywords: RF Safety, Incoherent Gradient Sequence, Magnetism, Multiple Coils

Objectives:

- Explain the Magnetic Isocenter
- Differentiate T1 Recovery from T2 Decay
- Define the Proton Density
- List types of Specific Absorption Rate (SAR)
- Understand different types of Coils

Content:

I. Gradient Composition

II. Magnetic Isocenter

III. Gradient Coils and Amplifiers

IV. Applying Gradients

V. Gradient Composition

1. Steep slice-select gradients are required for thin slices.
2. Steep phase-encoding gradients are required for fine-phase matrices.
3. Steep frequency-encoding gradients are required for small fields of view.
4. The rise time of a gradient is the time required to achieve the maximum amplitude.
5. Slew rate is a function of the rise time and amplitude; it determines the shortest scan times achievable.
6. The duty cycle is the percentage of time the gradient is at maximum amplitude.

VI. Hardware - Gradient Coils

VII. Gradient Axes

VIII. Partial Gradients

IX. Oblique Angle

X. Gradients

XI. Pulse Sequence

XII. Slice-select Gradient

XIII. Phase Encoding

XIV. Phase Shift

XV. Frequency Encoding

XVI. Frequency-encoding Gradient

XVII. Balanced Gradient System

XVIII. Gradient Strength

XIX. Gradient Rise Time and Slew Rate

XX. Duty Cycle

XXI. Eddy Current

XXII. Eddy Current Compensation

XXIII. Safety

XXIV. 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

XXXVII. Volume Coil

XXXVIII. Quadrature Coils

XXXIX. Circular-polarized design

XL. Linear Polarized Design

XLI. Surface Coils

XLII. Phased-array Coils

XLIII. Multiple Coils

XLIV. RF Shielding

XLV. Magnetic Field Strength

XLVI. Angular Momentum

XLVII. Precession

XLVIII. Active Nuclei

XLIX. Resonance

L. Magnetism

LI. Net Magnetization Vector (NMV)

LII. The MR Signal

LIII. Gradient-echo Pulse Sequences

LIV. Coherent Gradient-Echo Pulse Sequences

LV. Rewinder Gradient

LVI. Incoherent Gradient Sequence

LVII. Gradient Spoiling

LVIII. Using Gradients

LIX. T1 Recovery

LX. T2 Decay

LXI. Proton Density

LXII. RF Safety

LXIII. Tissue Heating

LXIV. Specific Absorption Rate (SAR)

1. Whole body – 4 W/kg (averaged over 15 min).
2. Head – 3 W/kg (averaged over 10 min).
3. Torso – 8 W/kg (per gram of tissue).
4. Extremities – 12 W/kg (per gram of tissue).

LXV. Burns

Chart: MR Parameters - Actions and Associated Trade-offs

1. TR
2. TE
3. NSA/NEX
4. Slice Thickness
5. FOV
6. Matrix
7. Receive bandwidth
8. Large Coil
9. Small Coil
    a. Parameter
    b. Action
    c. Benefit
    d. Limitation

Chart: Optimizing Image Quality

1. Maximize SNR
2. Minimize scan time
3. Maximize spatial resolution
    a. Adjusted Parameter
    b. Consequences

Contents

➢ Lecture 26: MR Image Production Parameters

Time: 30 minutes + video -lecture

Keywords: T1 Contrast, Saturation, Inversion Time, Spin-Echo, Parameter of Tau, Magnetic Field Gradients

Objectives:

- Explain the difference between intrinsic parameters vs. extrinsic parameters
- Explain the Combined Effects of T1 and T2 Relaxation
- Define the Longitudinal Magnetization
- Describe image contrast appearance according to image weighting.

Content:

I. MR Advantages and Parameters

II. Intrinsic Parameters

III. Extrinsic Parameters

IV. Signal and Flip Angle

V. Manipulating Extrinsic Parameters

VI. T1 Weighting in MR Imaging

VII. T1 Relaxation Time

VIII. T1 Brain Images

IX. T1 Contrast

X. Contrast vs T1 and TR

XI. T2 Weighting in MR Imaging

XII. T2 Relaxation Time

XIII. T2 Contrast Curve

XIV. T2-weighted Images

XV. TE Values and T2 Weighting

XVI. Contrast vs. T2 and TE

XVII. Summary of T1 and T2 Relaxation

XVIII. Combined Effects of T1 and T2 Relaxation

XIX. T2* Weighting

XX. Longitudinal Magnetization

XXI. Spin-Echo vs. Gradient Echo

XXII. Shimming

XXIII. Comparing T2 and T2* Images

XXIV. Proton-Density Weighting in MR Imaging

XXV. Proton-Density Weighting

XXVI. Hydrogen Content in Tissues

XXVII. Uses of Proton-Density Scans

XXVIII. Image Weighting Parameters

XXIX. Image Contrast Comparisons

XXX. Introduction to Pulse Sequences

XXXI. Saturation

XXXII. T1-weighted Images and Saturation

XXXIII. Partial Saturation Sequence

XXXIV. Conventional Spin-Echo Pulse Sequences

XXXV. Spin-Echo Pulse Sequences

XXXVI. Relaxation

XXXVII. Review of Spin-Echo Sequence Steps

XXXVIII. Remove RF Pulse

XXXIX. Free Induction Decay

XL. Rephrase With 180-degree Pulse

XLI. Spins Return to In-Phase

XLII. Spin-Echo

XLIII. Parameter of Tau

XLIV. Advantages of Spin-Echo

XLV. Disadvantages of Spin-Echo

XLVI. Fast Spin-Echo Sequences

XLVII. Gradient-Echo Pulse Sequences

XLVIII. Magnetic Field Gradients

XLIX. Gradient-Echo Pulse Sequence

L. Advantages of Gradient Echo

LI. Shorter TE and TR Times

LII. Disadvantages of Gradient-Echo

LIII. Steady-State Gradient-Echo

LIV. T2 Coherent Gradient-Echo

LV. Inversion recovery Sequences

LVI. Fast Spin-Echo Inversion Recovery

LVII. Inversion Time

LVIII. Short Tau Inversion Recovery

LIX. Fluid-Attenuated Inversion Recovery

LX. Image Quality Comparison

LXI. Balancing Parameters

LXII. Conclusion

Chart: MR Parameters - Actions and Associated Trade-offs

1. TR
2. TE
3. NSA/NEX
4. Slice Thickness
5. FOV
6. Matrix
7. Receive bandwidth
8. Large Coil
9. Small Coil
    a. Parameter
    b. Action
    c. Benefit
    d. Limitation

Chart: Optimizing Image Quality

1. Maximize SNR
2. Minimize scan time
3. Maximize spatial resolution
    a. Adjusted Parameter
    b. Consequences

Contents

➢ Lecture 27: MR Contrast Medias

Time: 30 minutes + video-lecture

Keywords: Contraindication, Blood Vessels, Cardiac Gating Images, MRA Scans, MR Arthrograms

Objectives:

- Discuss the difference between the Local Injection-related Complications and the other Injection-related Complications
- Describe the Universal Precautions
- Define the Gadolinium Pharmacology
- Explain the Types of MR Contrast

Content:

I. Contrast-enhanced MR Imaging

II. Magnetism

III. Diamagnetic Substances

IV. Paramagnetic Substances

V. Superparamagnetic Substances

VI. Ferromagnetic Substances

VII. MR Contrast Agents

VIII. Types of MR Contrast

IX. Gadolinium-based Contrast

X. Gadolinium Mechanism of Action

XI. Gadolinium Pharmacology

XII. Gadolinium-based Pharmacokinetics

XIII. Blood Pool Agents

XIV. Iron-oxide Contrast Agents

XV. Iron-oxide Mechanism of Action

XVI. Manganese-based Agents

XVII. Tissue-specific Contrast Agents

XVIII. Patient History

XIX. Patient Prescreening

1. Inquire whether the patient has had a previous MR examination. If so, ask when and where.

2. Ask whether the patient has ever had a reaction to a contrast agent or to iodinated contrast media.

3. Ask about prior medical imaging.

4. Inquire whether the patient has a history of allergies or asthma.

5. Inquire whether the patient has a history of significant cardiac disease.

6. Ask the patient about any history of renal disease, including renal disease in first-degree relatives.

XX. Prescreening for Gadolinium-based Contrast

XXI. Glomerular Filtration Rate (GFR)

XXII. Prescreening for Gadolinium-based Contrasts

XXIII. Contraindication

XXIV. ACR Recommendations

XXV. Patient Preparation

XXVI. Contrast Preparation

XXVII. Contrast Administration

1. Exercise precaution with at-risk patients, such as those with diabetes, sickle cell disease, asthma and renal insufficiency with or without hepatic impairment.

2. Follow facility policies and procedures regarding patients who are pregnant or breastfeeding.

3. Be aware that contrast media reactions can be serious, life-threatening or fatal and appear as anaphylactic or cardiovascular responses.

4. Obtain the patient's GFR, calculated contrast dose and rate of administration.

XXVIII. Universal Precautions

XXIX. Blood Vessels

XXX. IV Administration Sites

XXXI. Contrast Administration

XXXII. Power Injector Administration

XXXIII. Standard IV Procedural Steps

XXXIV. Adverse Reactions

XXXV. Local Injection-related Complications

XXXVI. Other Injection-related Complications

XXXVII. Reactions to Gadolinium

XXXVIII. Mild Reactions to Gadolinium

XXXIX. Moderate-to-Severe Reactions

XL. Nephrogenic Systemic Fibrosis

XLI. Reactions to Blood-pool Agents

XLII. Reactions to Iron-oxide Agents

XLIII. Reactions to Manganese Agents

XLIV. Reactions to Secretin

XLV. MR Contrast Application

XLVI. Extracellular Contrast Agents

XLVII. Magnetic Resonance Angiography (MRA) MRA Scans

XLVIII. MRA Renal Scan

XLIX. Other Cardiovascular Applications

L. Breath-hold and Cardiac Gating

LI. Breath-hold Image

LII. Cardiac Gating Images

LIII. Hepatic Applications

LIV. Hepatic Imaging

LV. Superparamagnetic Contrast Media

LVI. Iron-oxide Agents

LVII. MRCP Sequences

LVIII. MRCP Scans

LIX. Oral Contrast for Abdomen

LX. Imaging Lymph Nodes

LXI. Abdominal Images

LXII. Intracranial Images

LXIII. MRA Imaging with Contrast

LXIV. MR Arthrograms

LXV. New Contrast Agents

LXVI. Reporting Serious Adverse Events

Contents

➢ Lecture 28: MR Pulse Sequences

Time: 30 minutes + video-lecture

Keywords: Hydrogen Atoms, Pulse Sequences, Gradient Slew Rate, Geometric Distortion

Objectives:

- List Fast Spin-Echo Sequences
- Define Phase and Frequency Encoding
- Understand the The Larmor Equation
- Explain the Pulse Sequences
- Describe K-space

Content:

I. Image Balancing Act

II. Hydrogen Atoms

III. Magnetic Field Effect

IV. Net Magnetization Vector

V. Procession in the Magnetic Field

VI. The Larmor Equation

VII. The Gyromagnetic Ratio

VIII. Calculating Processional Frequency

IX. Longitudinal and Transverse Magnetization

X. Faraday Law of Induction

XI. T1 and T2 Relaxation Times

XII. Image Contrast

XIII. Pulse Sequences

XIV. Repetition Time (TR)

XV. Echo TIme (TE)

XVI. Scan Timing Parameter Chart

XVII. Pulse Sequence Diagram

XVIII. Slice Selection

XIX. Gradients

XX. Phase and Frequency Encoding

XXI. Phase-encoding Gradient

XXII. Matrix Size

XXIII. K-space

XXIV. Spiral Filling

XXV. Zero FIlling

XXVI. Number of Signals Averaged

XXVII. Gradient Slew Rate

XXVIII. Field of View

XXIX. Echo Spacing

1. Gradient slew rate.
2. Receive bandwidth.
3. Number of shots.
4. Frequency-encoding steps.
5. Frequency field of view

XXX. Receive Bandwidth

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

XXXII. Calculating Spin-Echo Scan Time

XXXIII. Fast Spin-Echo

XXXIV. Fast Spin-Echo and K-space

XXXV. Calculating Fast Spin-Echo and K-space TIme

XXXVI. Fast Spin-Echo Pulse Sequences

XXXVII. Fast Spin-Echo Tradeoffs

XXXVIII. Fast Spin-Echo Sequences

1. Decrease echo train length.
2. Increase bandwidth.
3. Increase frequency field of view; decrease phase field of view.
4. Reduce slice thickness.
5. Increase phase-encoding matrix
6. Reduce frequency-encoding matrix

XXXIX. Gradient-Echo Pulse Sequences

XL. Gradient-Echo and Spin-Echo Pulse Diagrams

XLI. Inversion Recovery

XLII. Calculating Gradient-Echo Scan Time

XLIII. Gradient-Echo Sequences

XLIV. Gradient-Echo Pulse Sequences

XLV. Gradient-Echo T2-Weighting

XLVI. Echo Planar Imaging

XLVII. Calculating EPI Scan Time

XLVIII. EPI vs. Fast Spin-Echo Imaging

XLIX. Increased Resolution

L. White Matter Sensitivity

LI. Faster Imaging Applications

LII. Ultrafast EPI

LIII. EPI Sequences for Stroke

LIV. Diffusion-weighted Imaging

LV. Dynamic Studies

LVI. Pulse Sequence Comparison

LVII. Magnetic Susceptibility Artifacts

LVIII. Geometric Distortion

1. Using multishot rather than single-shot EPI.
2. Performing a localized shim over the region of interest.
3. Using thinner slices.
4. Using shorter TEs.

Contents

➢ Lecture 29: MR Safety Essentials

Time: 30 minutes + video-lecture

Keywords: Pre-examination Screening, Static Magnetic Field, Controlled Quench, Verbal Monitoring

Objectives:

- Discuss the difference between Translation Force and Rotation Force
- Understand Equipment or Environmental Emergencies
- Explain Diamagnetic Substances and Diamagnetic Objects
- Describe the Patient Preparation

Content:

I. Importance of Safety

II. MR Safety Incidents

III. MR Safety Considerations

IV. Magnetic Classification of Objects

V. Diamagnetic Substances

VI. Diamagnetic Objects

VII. Paramagnetic substances

VIII. Paramagnetic Materials

IX. Superparamagnetic Substances

X. Ferromagnetic Substances

XI. Ferromagnetic Objects

XII. Field Strength Measurement

XIII. Field Strengths and Safety

XIV. 5-Gauss Warning

XV. Static Magnetic Field

XVI. Fringe Field

XVII. Shielding

XVIII. Translation Force

XIX. Rotation Force

XX. Screening and Testing Objects

XXI. Summary for Static Magnetic Field

1. MR personnel must be familiar with all safety concerns related to the static magnetic field.
2. MR technologists must thoroughly screen patients, visitors and anyone who enters the MR environment for materials that could be unsafe.
3. All equipment or devices must be checked before being brought into the MR environment to ensure they are safe for use in a magnetic field and do not possess any ferromagnetic components that can be pulled into the MR scanner.
4. MR personnel should lock the MR scanner room door when the area is unattended to prevent untrained personnel from accidentally entering the room.
5. The appropriate MR safety warning signs should be posted at all entrances of the MR facility.

XXII. Electromagnetic Spectrum

XXIII. RF Radiation Exposure

XXIV. Specific Absorption Rate

XXV. How a Scanner Estimates SAR

XXVI. Heating

XXVII. Thermal Increases

XXVIII. Preventing Thermal Burns

XXIX. Implanted Medical Devices

XXX. Medical Devices and Overheating

1. Cardiac pacemakers and implantable cardiac defibrillators (ICDs).
2. Neurostimulation systems.
3. Halo vests and cervical fixation devices.
4. Transdermal medication patches.
5. Damaged ECG leads.
6. Pulse oximeters

XXXI. Jewelry, Body Piercings and Tattoos

XXXII. Gradient Magnetic Fields

XXXIII. Nerve Stimulation

XXXIV. Acoustic Noise

XXXV. Peripheral Nerve or Muscle Stimulation

XXXVI. Magnetohemodynamic Effect

XXXVII. Safety Zones

XXXVIII. Zone I

XXXIX. Zone II

XL. Zone III

XLI. Zone IV

XLII. Safety Screening

1. Non-MR personnel include patients, visitors or staffs who have not been trained. Specifically, people who have not undergone formal training within the previous 12 months.

2. Level 1 MR personnel are facility staff members who have participated in minimal safety educational programs to ensure their own safety as they work in Zone III. Examples include MR department office staff and patient aides.

3. Level 2 MR personnel are staff members who have been more extensively trained in the broader aspects of MR safety issues, including the potential for thermal burns and peripheral nerve stimulation. Examples include MR technologists, radiologists and radiology department nursing staff.

XLIII. Patient and Personnel Safety Screening

XLIV. Patient Screening - Referring Physician

XLV. Pre-examination Screening

1. The following checklist reviews steps MR personnel can take to reduce safety incidents.

2. Ensure the patient has the correct order from the referring physician.

3. Prescreen patients for contraindications, such as noncompatible pacemakers or ferromagnetic aneurysm clips.

4. Prescreen patients for surgically implanted devices and details such as device name and model number to verify that the apparatus is safe for the facility's magnet field strength.

5. Ensure that prescreening radiographs are completed, reviewed and approved by a radiologist. If contrast is indicated, ensure the appropriate lab work is completed, reviewed and approved.

6. Ask whether a female patient of childbearing age is pregnant or breast-feeding.

7. Verify that the patient's weight does not exceed the MR scanner's table weight limits.

8. Remind patients with claustrophobia to discuss pre-examination medication with their referring physician, and that they might need a ride home.

9. Inquire whether patients who will receive a contrast injection have any known difficulties with venipuncture. If so, instruct the patient to arrive early to allow a qualified health care provider additional time to start an IV.

XLVI. Patient and Examination Identification

XLVII. Final Patient Screening

XLVIII. Safety Questionnaire

XLIX. Contraindications and Precautions

L. Intracranial Vascular Clips

LI. Pacemakers and Other Implanted Devices

LII. Implanted Devices and Field Strength

LIII. Intraocular Ferrous Foreign Bodies

1. Have you ever had metal fragments or shavings in your eye? If so, did you have them removed?

2. Have you ever had eye surgery?

3. Have you ever worked with metal?

4. Have you ever been hit in the eye with anything metal?

5. Is there any chance you might have gotten metal in your eyes?

LIV. Patient Preparation

LV. Objects With Metal

LVI. Contrast Media and Pregnancy

LVII. Patient Monitoring

LVIII. Verbal Monitoring

LIX. Monitoring Unconscious or Sedated Patients

LX. Patient Emergencies

1. Remove the patient from the MR scanning room to a safe area as soon as possible before attempting any lifesaving procedures. An MR-conditional stretcher should be used to move the patient.

2. Close and lock the MR scanner room once the patient is moved to prevent any untrained MR personnel from accidentally entering the room.

4. Activate the facility's emergency response team LXI. Equipment or Environmental Emergencies

5. Move the patient from the MR scanner room to a safe area as soon as possible.

6. After the patient is removed, close and lock the scanner room door to prevent any untrained personnel from accidentally entering the room.

7. Activate the facility's emergency response code.

8. Participate in the decision regarding whether to quench the magnet if fire department personnel need to enter the scanner room with their emergency equipment.

LXII. Ancillary Equipment

LXIII. Cryogen Gas Monitoring

LXIV. Quenching the Magnet

LXV. Controlled Quench

LXVI. Uncontrolled Quench

LXVII. During a Quench

LXVIII. Cryogen Gas Release

LXIX. Quench Response

Contents

➢ Lecture 30: MR Image Quality

Time: 30 minutes + video-lecture

Keywords: Technical Error Artifacts, Scan Parameters, Echo Time, Respiratory Compensation

Objectives:

- List the Voxel Characteristics
- Describe how Slice of Thickness is selected
- Define Temporal Resolution
- Understand the difference between 2-D vs. 3-D digital images

Content:

I. Introduction to MR Image Quality

II. Intrinsic and Extrinsic Parameters

III. MR Parameters and Options

IV. MR Artifacts

V. Physics Artifacts

VI. Sampling Artifacts

VII. Instrumentation Artifacts

VIII. Technical Error Artifacts

IX. Beneficial Artifacts

X. Nonbeneficial Artifacts

XI. Scan Parameters

XII. Hardware - Field Strength

XIII. Hardware - Field Strength and Noise

XIV. Susceptibility Artifacts

XV. Hardware RF

XVI. RF Coils

XVII. Hardware Positioning

XVIII. Positioning

XIX. Voxel Size

XX. Pixel Size

XXI. Isotropic Voxel

XXII. Partial Volume Averaging

XXIII. Non-Isotropic Voxels

XXIV. Voxel - Slice Thickness

XXV. Voxel - Field of View

XXVI. Field of View and Aliasing

XXVII. Voxel - Matrix

XXVIII. Sampling - Number of Signals Averaged

XXIX. Sampling - Bandwidth

XXX. 2-D vs. 3-D

XXXI. Pulse Sequences - Time and Quality

XXXII. Pulse Sequences and Quality

XXXIII. Temporal Resolution

XXXIV. Quality and Repetition Time

XXXV. Repetition TIme

XXXVI. Quality and Echo Time

XXXVII. Echo Time

XXXVIII. Quality and T1

XXXIX. Flip Angle Effects

XL. Flip Angle and Noise

XLI. Contrast Enhancement

XLII. Flow Motion Compensation

XLIII. Respiratory Compensation

Contents

➢ Lecture 31: MR Neuroimaging

Time: 30 minutes + video-lecture

Keywords: Brain Anatomy, Clinical Indications, Stroke, Syrinx, Ghosting

Objectives:

- Identify Developmental Brain Anomalies
- Compare Magnetic Resonance Angiography with Magnetic Resonance Venogram
- List the steps for STIR Imaging
- Define Spinal Cord Compression
- Explain the difference between Myelopathy vs. Radiculopathy
- Describe Stroke Symptoms

Content:

XXXII. Spinal Subluxation

XXXIII. Patient Care

XXXIV. Patient Identification

XXXV. Evaluation of MR Orders

XXXVI. Patient Rapport

XXXVII. Patient Education

XXXVIII. Patient Screening

XXXIX. Screening for Outside Metal

XL. Noncompatible Metal Items

1. Body piercing and other jewelry. Jewelry may contain ferromagnetic or magnetic materials. Hair accessories that containing metal.

2. Hair pins can potentially become dangerous projectiles, flying into the magnet at 60 to 90 mph.

3. Bras with metal hooks or underwire. Some women may experience a deflection, or twisting of the metal in the magnetic field, or a mild heating sensation or burn if the garment is left on.

4. Mascara containing iron particles. The iron particles could increase the likelihood of a heating sensation and may create a magnetic susceptibility artifact on the images.

XLI. Screening for Metal Inside the Patient

1. Noncompatible cardiac pacemakers or other electronic implants.

2. Cochlear or other ear implants.

3. Thalamic/neural stimulators.

4. Epicardial and intracardiac pacing wires. Ferrous intracranial aneurysm clips. Certain aneurysm clips may be safely scanned, but there are a large number that should not be near the MR magnet.

5. Metallic foreign bodies. Examples of these objects include bullets, pellets and shrapnel. Some bullets and fragments may be safely scanned, but should be evaluated on an individual basis. Knowing the metallic composition of the bullet or fragment, the location and how long the object has been in the body help the radiologist determine whether the metallic object should be scanned.

6. Metallic orbital foreign bodies. MR technologists should question patients about being struck previously in the eyes with pieces of metal. If there is a chance that metal is still in the eye, orbital radiographs should be taken before proceeding with the MR examination.

XLII. Ancillary Staff in the MR Environment

XLIII. Screening for Contrast Contraindications

XLIV. Position for Routine MR Exams

XLV. Special Needs Patients

XLVI. Special Positioning

XLVII. Patient Monitoring

XLVIII. Traumatic Brain Injury

XLIX. Anesthesia

L. Image Acquisition

LI. Coil Selection

LII. Coil Types

LIII. Phased-Array Coil

LIV. Localization

1. The glabella for the head/brain.
2. The menton for the cervical spine.
3. The manubrial notch and sternal angle for the thoracic spine.
4. The level of the iliac crest for the lumbar spine

LV. Imaging Planes

LVI. Slice Thickness

LVII. Slice Direction

LVIII. Pulse Sequences

LIX. Standard Screening Pattern Tissue Characteristics of T1

LX. Hemosiderin

LXI. Spin-Echo Sequences

LXII. Tissue Characteristics of T2

LXIII. Fast Spin-Echo

LXIV. Inversion Recovery Sequence

LXV. STIR Imaging

LXVI. Gradient-Echo Sequences

LXVII. Echo-Planar Imaging

LXVIII. EPI Sequences for Stroke

LXIX. Magnetic Resonance Angiography

LXX. Magnetic Resonance Venogram

LXXI. Pulse Sequences for MRA

LXXII. MR Spectroscopy

LXXIII. Contrast Administration

LXXIV. Contrast Agents

LXXV. Image Artifacts

LXXVI. Motion Artifacts

LXXVII. Susceptibility Artifacts

LXXVIII. Zipper Artifact

LXXIX. Ghosting

Contents

➢ Lecture 32: MR Body and Joint Imaging

Time: 30 minutes + video-lecture

Keywords: Coil types, Time and Motion, Mismapping or Ghosting, Neoplasia

Objectives:

- List the steps in Parameters
- Describe how to apply Contrast Agents
- Differentiate between T1 Enhancement Agents and T2 Enhancement Agents
- Understand Moiré Pattern
- Define Contrast Contraindication

Content:

I. Imaging considerations

1. Coil types
2. Pulse sequences
3. Parameters such as phase/frequency direction
4. Flow and motion effects
5. Motion and reduction techniques
6. Contrast agents
7. Artifacts
8. Windowing

II. Coil Types

1. Permanent magnets
2. Resistive magnets
3. Superconducting magnets

III. Coil Types Used With Superconducting Magnets

1. Body coil
2. Surface or local coils
3. Volume coils
4. Phased-array coils
5. Parallel imaging or multicoils

IV. Body Coil

VI. Surface or Local Coil

VII. Volume Coil

VIII. Phased-array Coil

IX. Parallel Imaging or Multicoils

X. Pulse Sequences

1. Spin-echo
2. Fast spin-echo or turbo spin-echo
3. Single-shot fast spin-echo
4. Driven equilibrium.
5. Inversion recovery.
6. Steady-state free precession.
7. Coherent gradient-echo.
8. Incoherent gradient-echo

XI. Spin-Echo

XII. Fast Spin-Echo or Turbo Spin-Echo

XIII. Fast Spin-Echo Pulse Sequence

XIV. Single-shot Fast Spin-Echo

XX. Driven Equilibrium

XXI. Inversion Recovery

XXII. STIR Sequences

XXIII. FLAIR Sequences

XXXIV. Steady-state Free Precession

XXXV. Coherent Gradient-Echo

XXXVI. Incoherent Gradient-Echo

XXXVII. RF Spoiling

XXXVIII. Gradient Spoiling

XXXIX. Echo-Planar Imaging

XXXX. Magnetic Resonance Angiography

1. Digital subtraction MR angiography (DS-MRA)
2. Time-of-flight MRA (TOF-MRA)
3. Phase-contrast MRA (PC-MRA)
4. Contrast-enhanced MRA (CE-MRA)

XXXXI. Digital subtraction MR angiography

XXXXII. TIme-of-Flight MRA

XXXXIII. Phase-Contrast MRA

XXXXIV. Contrast-Enhanced MRA

XXXXV. Rental Contrast-Enhanced MRA Images

XXXXVI. Parameters

1. Repetition time (TR)
2. Echo Time (TE)
3. Flip angle
4. Phase oversampling
5. Matrix (phase and frequency)
6. Slices and slice thickness

XXXXVII. Repetition Time

XXXXVIIII. Echo TIme

XXXXIX. Flip Angle

L. Phase Oversampling

LI. Phase and Frequency Matrix

LII. Slices and Slice Thickness

LIII. Time and Motion

LIV. Flow and Motion Effects

LV. Motion Reduction Techniques

LVI. Contrast Agents

LVII. T1 Enhancement Agents

LVIII. T2 Enhancement Agents

LIX. Other Contrast Agents

LX. Risks of Contrast Agents

LXI. Artifacts

1. Mismapping or ghosting.
2. Aliasing or wraparound.
3. Chemical shift.
4. Chemical misregistration.
5. Truncation, also called a Gibbs artifact.
6. Magnetic susceptibility.
7. Cross-excitation, or cross-talk.
8. Zipper artifact.
9. Shading artifact.
10. Moiré pattern.
11. Magic angle.

LXII. Mismapping or Ghosting

LXIII. Aliasing or Wraparound

LXIV. Chemical Shift

LXV. Chemical Misregistration

LXVI. Truncation or Gibbs Artifact

LXVII. Magnetic Susceptibility

LXVII. Cross-excitation or Cross-talk

LXVIII. Zipper Artifact

LXIX. Shading Artifact

LXX. Moiré Pattern

LXXI. Magic Angle

LXXII. Windowing

LXXIII. Windowing

LXXIV. Imaging Planes

LXXV. Slice Thickness

LXXVI. Signal Characteristics

LXXVII. Signal Characteristics of Normal Anatomy

LXXVIII. Signal Characteristics of Pathology

LXXIX. General Considerations

LXXX. Evaluation of MR Orders

1. Verify that you have the right patient for the right procedure.
2. Explain the procedure to the patient.
3. Establish a good rapport with the patient.
4. Let's talk about each of these steps in more depth

LXXXI. Verify Patient

LXXXII. Verify the Procedure

LXXXIII. The MR Checklist

LXXXIV. Establish Good Rapport

LXXXV. Describe the Procedure

LXXXVI. Contrast Contraindication

LXXXVII. Patient Preparation

LXXXVIII. During the Examination

LXXXIX. After the Examination

XC. Considerations for Routine MR Procedures

LXXXXI. Localizer Images

LXXXXII. Special Needs Patients

LXXXXIII. MR of the Musculoskeletal System

LXXXXIV. MR Images of the Knee

LXXXXV. Common Musculoskeletal System Conditions

1. Cellulitis
2. Osteomyelitis
3. Plantar fasciitis
4. Myositis
5. Soft-tissue abscesses

LXXXXVI. Musculoskeletal System Conditions

LXXXXVII. MR Image of Plantar Fasciitis

LXXXXVII. Vascular Diseases

LXXXXVIII. MR and Trauma

LXXXXIX. Neoplasia

1. Multiple myelomas — cancerous lesions in the bone marrow.

2. Osteosarcomas — cancerous tumors in the bone.

3. Unicameral bone cysts — benign, fluid-containing lesions that usually occur in the metaphyses of long bones.

4. Lipomas — benign fatty tumors. Liposarcomas — malignant fatty tumors.

5. Leiomyomas — benign tumors in the muscle.

6. Leiomyosarcomas — malignant tumors in the muscle.

7. Neurofibromas, schwannomas and neuromas — benign tumors of the nerves. Neurofibrosarcomas — malignant tumors of the nerves.

8. Malignant schwannomas — sarcomas that arise from the sheath of Schwann surrounding peripheral nerve fibers.

9. Hemangiomas — benign tumors of the blood vessels.

10. Angiosarcomas — malignant tumors of the blood or lymph vessels.

11. Fibromas — benign tumors in fibrous tissue.

12. Fibrosarcomas — malignant tumors of the fibrous tissues. Nodular tenosynovitis — benign inflammation in a joint.

13. Synovial sarcomas — malignant tumors in joints.

C. Osteosarcoma in Humerus

CI. Enchondroma in Shoulder

CII. Imaging Protocols for the Musculoskeletal System

CIII. MR of the Abdomen and Pelvis

CIV. Pathology of the Abdomen and Pelvis

1. Colitis — inflammation of the colon.

2. Diverticulitis — inflammation of one or more diverticula in the colon.

3. Appendicitis — inflammation of the appendix.

4. Crohn disease — inflammatory disease of the intestines that can be symptomatic from the mouth to the anus.

5. Pancreatitis — inflammation of the pancreas.

6. Perinephric abscess — collection of pus within the fatty tissue around the kidneys.

7. Renal abscess — collection of pus in the parenchyma of the kidneys.

8. Peritonitis — inflammation and infection of the lining of the abdominal cavity.

CV. Pathology of the Abdomen and Pelvis

CVI. MRA Renals

CVII. Pathology of the Abdomen and Pelvis

1. Undescended testicles
2. Prostate cancer and cancers of the bladder, uterus and cervix
3. Rectal, cervical and uterine lesions
4. Benign uterine tumors called adenomyoses
5. Polyps Leiomyomas
6. Fibroids

CVIII. Pathology of the Abdomen and Pelvis

1. Polycystic kidneys, which are multiple cysts in the kidneys
2. Renal cell carcinoma, which is a malignancy affecting the kidneys
3. Fatty infiltration of the liver
4. Hepatoma, which is a malignant liver tumor
5. Cavernous hemangioma, which is a benign hepatic tumor
6. Hepatic metastases, which are the spread of cancer to the liver
7. Ovarian cysts

CIX. Polycystic Kidney

CX. Tumor in the Kidney

CXI. Imaging Protocols of the Abdomen and Pelvis

CXII. MR of the Thorax

CXIII. Pathology of the Thorax

1. Pulmonary embolism, which is an obstruction of the pulmonary arteries or one of their branches, usually because of an air bubble.
2. Bullous emphysema, which is a pulmonary disease that allows free air to collect in the lung tissues.
3. Pulmonary metastatic disease, which is the spread of a primary cancer into the lungs.
4. Hodgkin disease, which is a malignancy of the lymphatic system.

CXIV. Imaging Protocols of the Breast

CXV. Breast Pathology

CXVI. Imaging the Brachial Plexus

1. Brachial plexus lesions, especially those secondary to carcinoma of the breast and bronchus.

2. Thoracic outlet syndrome, which is a rare condition in which blood vessels and nerves that run from the spine through the rib cage and clavicle to the shoulder are compressed. Symptoms typically include pain and numbness in the arms, along with a weak grip and tingling in the fingers.

3. Trauma to the brachial plexus region.

CXVII. Brachial plexus pathology

Contents

➢ Lecture 33: MR Pathology (Part I)

Time: 30 minutes

Keywords: Imaging Planes, The Spleen, The Shoulder Girdle

Objectives:

- Differentiate between Labral Tear and the Rotator Cuff
- Understand all the case studies
- Locate pathology as demonstrated on MR images.
- Describe the functions of Endometriosis
- List symptoms associated with each condition
- Describe Abdominal and Pelvic Regions
- Define Magnetic Resonance Imaging

Content:

I. Magnetic Resonance Imaging

II. Pulse Sequences

III. Imaging Planes

IV. The Brain

V. Brain Anatomy

VI. The Brain Stem

VII. The Diencephalon

VIII. The Cerebrum

IX. The Cerebellum

X. Cavernoma

XI. Case Study: Cavernoma

XII. Neuroglial Cyst

XIII. Case Study: Neuroglial Cyst

XIV. Meningioma

XV. Case Study: Meningioma

XVI. Encephalomalacia

XVII. Case Study: Encephalomalacia

XVIII. Leukoencephalopathy

XIX. Case Study: Leukoencephalopathy

XX. Cerebral Infarction

XXI. Case Study: Cerebral Infarction

XXII. Small Vessel Occlusive Disease

XXIII. Case Study: Small Vessel Occlusive Disease

XXIV. Arnold-Chiari Malformation

XXV. Case Study: Arnold-Chiari Malformation

XXVI. Dandy-Walker Syndrome

XXVII. Case Study: Dandy-Walker Syndrome

XXVIII. Acoustic Neuroma

XXIX. Case Study: Acoustic Neuroma

XXX. Pituitary Adenoma

XXXI. Case Study: Pituitary Adenoma

XXXII. Brain Metastasis

XXXIII. Case Study: Brain Metastasis

XXXIV. Subarachnoid Hemorrhage

XXXV. Case Study: Subarachnoid Hemorrhage

XXXVI. Subdural Hemorrhage

XXXVII. Case Study: Subdural Hemorrhage

XXXVIII. Sinusitis

XXXIX. Case Study: Sinusitis

XL. Cranial Vessels

XLI. Magnetic Resonance Angiography

XLII. Cerebral Aneurysm

XLIII. Case Study: Cerebral Aneurysm

XLIV. Cervical Arteries

XLV. Vertebral Artery Stenosis

XLVI. Case Study: Vertebral Artery Stenosis

XLVII. The Vertebral Column

XLVIII. Vertebral Column Anatomy

XLIX. Vertebral Column Curvatures

L. Cervical Vertebrae

LI. Thoracic and Lumbar Vertebrae

LII. Sacrum and Coccyx

LIII. Herniated Cervical Disc

LIV. Case Study: Herniated Cervical Disc

LV. Syringomyelia

LVI. Case Study: Syringomyelia

LVII. Herniated Lumbar Disc

LVIII. Tethered Cord

LIX. Case Study: Tethered Cord

Contents

➢ Lecture 34: MR Pathology (Part II)

Time: 30 minutes

Keywords: The Spleen, Gallstones, Endometriosis, Meniscus Tear

Objectives:

- Differentiate between the the Adrenal Glands and the the Adrenal Tumor
- Define Magnetic Resonance Cholangiopancreatography
- Describe Labral Tear as well as the case study
- List symptoms of Arterial Stenosis and Sclerosis
- Describe the disease progression for specific pathologies
- Discuss how Liver Hemangioma is discovered

Content:

I. Magnetic Resonance Imaging

II. Pulse Sequences

III. Imaging Planes

IV. The Abdominopelvic Cavity

V. Abdominal and Pelvic Quadrants

VI. Abdominal and Pelvic Regions

VII. The Spleen

VIII. Splenomegaly

IX. Case Study: Splenomegaly

X. The Adrenal Glands

XI. Adrenal Tumor

XII. Case Study: Adrenal Tumor

XIII. The Liver

XIV. Liver Hemangioma

XV. Case Study: Liver Hemangioma

XVI. Magnetic Resonance Cholangiopancreatography

XVII. The Biliary System

XVIII. Gallstones

XIX. Case Study: Gallstones

XX. Magnetic Resonance Angiography

XXI. The Celiac, Superior Mesenteric and Iliac Arteries

XXII. Arterial Stenosis and Sclerosis

XXIII. Case Study: Arterial Stenosis

XXIV. Uterus and Ovaries

XXV. Endometriosis

XXVI. Unicornuate Uterus

XXVII. Case Study: Unicornuate Uterus

XXVIII. Case Study: Ovarian Cyst

XXIX. Ovarian Teratoma

XXX. Case Study: Ovarian Teratoma

XXXI. The Appendicular Skeleton

XXXII. The Shoulder Girdle

XXXIII. The Rotator Cuff

LXVI. Case Study: Lateral Collateral Ligament Tear

LXVII. The Ankle and Foot

LXVIII. Osteomyelitis

LXIX. Case Study: Osteomyelitis

LXX. Fetal Magnetic Resonance Imaging

LXXI. Advantages of Fetal Magnetic Resonance Imaging

LXXII. Common Uses of Fetal Magnetic Resonance Imaging

LXXIII. Congenital Cystic Adenomatoid Malformation

LXXIV. Case Study: CCAM

LXXV. Sacrococcygeal Teratoma

LXXVI. Case Study: Sacrococcygeal Teratoma

LXXVII. Diastematomyelia

LXXVIII. Case Study: Diastematomyelia

LXXIX. Cystic Hygroma

LXXX. Case Study: Cystic Hygroma

Contents

➢ Lecture 35: MR Spectroscopy and Functional Imaging

Time: 120 minutes

Keywords: Larmor frequency, Photons, Alzheimer's Disease, Ischemic lesions

Objectives:

- Differentiate between the single voxel and multi-voxel
- Define what STEAM stand for
- Describe the electron shielding phenomenon
- List different types of metabolites
- Describe the + and - Frequency Problem
- Explain what spin is and what it is equal to

Content:

I. Introduction

II. MR Spectroscopy

III. Birth of NMR

IV. Nuclear Magnetic Resonance (NMR)

V. Brain and Water

VI. Spectroscopy

1. Resonance

VII. Nuclear Paramagnetism

VIII. Spin

IX. Some facts about Spin

X. Interaction of Spin with External Magnetic Field

XI. Resonance

XII. Resonance of a single spin I=1/2

1. The absorption of radiation by a nucleus in a magnetic field

XIII. Larmor Frequency

XIV. Relaxation processes

1. Spin - lattice (longitudinal) relaxation
2. Spin - spin (transverse) relaxation

XV. Bloch Equations

XVI. Energetics!

XVII. Bulk Magnetization

XVIII. Alignment of Nuclear Magnetic Moments

XIX. Setting the Context

XX. Typical Proton NMR Spectrum

XXI. Electron shielding

XXII. Chemical Shift

XXIII. J-coupling

XXIV. Echo Time and Repetition Time

XXV. Editing

XXVI. The Time Domain NMR Signal

XXVII. The +/- Frequency Convention

XXVIII. Fourier Transforms

1. The + and - Frequency Problem
2. The Digital FT
3. Sampling Error

4. The Two-Dimensional FT

XXIX. NMR Hardware Overview

1. Magnet
2. Field Lock
3. Field Strength
4. Shimming
5. Shim Coils
6. Head Coil
7. RF Coils
8. Gradient Coils
9. Voxel Positioning
10. Quadrature Detector
11. Digital Filtering
12. Safety

XXX. Basics of MRS

XXXI. Line widths, Line shapes, Integrals

XXXII. Scalar Coupling

XXXIII. Coupling Pattern vs Chemical Shift Difference

XXXIV. 2π or not 2π

XXXV. Photons

XXXVI. Some Important Constants

XXXVII. What a MR spectroscopy shows

XXXVIII. How MR spectroscopy works

1. Amino acids
2. Lipid
3. Lactate
4. Alanine
5. N-acetyl aspartate
6. Choline
7. Creatine
8. Myoinosito

XXXIX. Basic in Vivo Localization Techniques

1. Single voxel spectroscopy (SVS)
2. Water signal suppression
3. Principles of volume selection
4. PRESS and STEAM sequences
5. PRESS (Point Resolved Spectroscopy)
6. Point Resolved Spectroscopy
7. The STEAM (Stimulated Echo Acquisition Mode)
8. Chemical Shift
9. Chemical Shift value: ωm, ωref, dm
10. Binomial Pulses
11. Chemical Shift Imaging
12. Chemical Shift Selective Imaging Sequence
13. Depth Resolved Spectroscopy

XL. What Magnetic Resonance Spectroscopy measures

XLI. Compounds

XLII. N-Acetylaspartic acid

1. N-acetylaspartate (NAA)
2. Function
3. Applications

XLIII. Choline

XLIV. Creatine

XLV. Lactate

XLVI. Glutamate and glutamine

XLVII. Myo-inositol

XLVIII. Less commonly detected compounds

XLIX. Preparation/Procedure for NMR Spectroscopy

1. How to prepare for the test
2. During the test
3. Risks

L. Data Acquisition

1. Planning a Magnetic Resonance Spectra
2. Acquisition Methods: Single-Voxel Versus Chemical Shift Imaging

3. When to Use What Method
4. Signal-to-Noise Ratio
5. Rules (and Qualifiers) for Signal-to-Noise Ratio
6. Selecting the Region of Interest
7. How to Acquire Good Quality Spectra
8. Processing and Quantitation
    a. Line broadening
    b. Fourier transform:
    c. Phasing
    d. 9. Absolute Quantitation
    e. Shimming the magnetic field
    f. Suppressing the water signal
    g. Single Voxel Spectroscopy (SVS)
    h. Chemical Shift Imaging (CSI)
    i. Magnetic Resonance Spectroscopic Imaging (MRSI)
10. Spectroscopy Evaluation
11. Step by step for basic functionality (SVS)
12. Step by step for basic functionality (CSI)
13. Single Voxel Spectroscopy
14. Step by step
15. Grace
16. 3D CSI (Chemical Shift Imaging)
    a. Features

LI. Miscellaneous

1. Safety
    a. Static magnetic field B0
    b. Gradient fields for localization purposes
    c. RF fields to excite the magnetization

LII. Magnetic Resonance Spectroscopy at 3T

LIII. Clinical Applications

1. Brain Tumors
2. Cerebral Ischemia and Infarction

3. Trauma
4. Infectious Diseases
5. Pediatric Metabolic Disorders
6. Alzheimer's Disease
7. Ischemic lesions
8. Hepatic encephalopathy

LIV. Basic Questions/Answers

Contents

➢ Lecture 36: MR Protocols

Time: 120 minutes

Keywords: Steps of Performing an MR Scan; Automatic Pre-scan; Protocols of Abdomen, Pelvis, Adrenal, Female pelvis, Liver, Pancreas, Pelvimetry, Perineal fistula, Rectum, Renal, Stenosis, Breast, Upper extremities, Lower extremities, Brain, ENT, Spine

Objectives:

- Discuss 5 steps of MRT protocols and automatic pre-scan
- Describe general principles of adult MSK MRI protocols
- Define protocols for abdomen, pelvis, adrenal, liver, pancreas, pelvimetry, perineal fistula, rectum, renal, stenosis
- Explain the types of protocols for MR upper and lower extremities, breast, brain, ENT, spine

Content:

I. Performing an MR Scan
   1. Steps
      a. Patient preparation
      b. Screening
      c. Patient positioning
      d. Protocol selection
      e. Localizer scans
      f. Calibration scans for parallel imaging
      g. Position slices and saturation bands
      h. Automatic prescan (6 steps)

i. Acquire images
j. Post-processing
k. Data archiving

II. Automatic Pre-scan
1. Quick shimming
2. Coil tuning and matching
3. Center frequency adjustment
4. Transmitter attenuation/gain adjustment
5. Receive attenuation/gain adjustment
6. Dummy cycles

III. Protocols
1. MR Adult Abdomen and Pelvis W/WO Body Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
2. MR Adult Adrenal Mass W/WO Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
3. MR Adult Female Pelvis W/WO for Cervical Cancer Staging Body Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV

f. Scan range

4. MR Adult Female Pelvis W/WO for Uterine Cancer Staging Body Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
5. MR Adult Female Pelvis W/WO Body Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
6. MR Adult Female Pelvis W/WO UAE Body Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
7. MR Adult Liver Mass W/WO Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
8. Adult Liver Mass WO with MRCP Protocol (scan time is approximately 45 minutes)
    a. Mod

b. Slice
c. Gap
d. FAT / SAT
e. FOV
f. Scan range

9. MR Adult Liver Mass W/WO with MRCP Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
10. MR Adult Liver Mass with Eovist W/WO Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
11. MR Adult Liver Iron Quantification Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
12. MR Adult Pancreas W/WO with MRCP Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV

f. Scan range

13. MR Adult Pancreas W/WO with Secretin Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
14. MR Adult Pelvimetry WO Protocol. No IV contrast. Patient will be pregnant. Obtain informed consent. Supine position. Do not draw measurements (techs are not qualified) 1.5T ONLY
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
15. MR Adult Perineal Fistula W/WO Body Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
16. MR Adult Rectum W/WO Body Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
17. MR Adult Renal Mass W/WO Protocol (scan time is approximately 45 minutes)
    a. Mod

b. Slice
c. Gap
d. FAT / SAT
e. FOV
f. Scan range

18. MR Adult Renal Arterial Stenosis W/WO Protocol (scan time is approximately 45 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
19. MR Adult Scrotum W/WO Protocol. Charge as Pelvis W/WO
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
20. Breast MRI Protocol
    a. Six steps for high quality scans
    b. Immobilization devices
    c. MRI guided wire localization
    d. ISPY-2 breast (general requirements and contrast agent administration)
21. Adult MSK MRI Protocols
    a. General principles
22. Upper Extremities
    a. MR Adult Elbow W/WO Protocol. 3T Scanner Only
    b. MR Adult Elbow WO Protocol. 3T Scanner Only
    c. MR Adult Elbow Arthrogram WO Protocol. Charge as Elbow Arthrogram WO
    d. MR Adult Finger (NOT Thumb) WO and W/WO Protocol. Charge as 3T Scanner Only
    e. MR Adult Forearm W/WO Protocol. Charge as Forearm W/WO, 1.5T Scanner Only

f. MR Adult Forearm WO Protocol. Charge as Forearm WO, 1.5T Scanner Only
g. MR Adult Hand WO Protocol. Localizer (REF scan). 3T Scanner Only
h. MR Adult Hand W/WO Protocol. 3T Scanner Only
i. MR Adult Hand Rheumatology W/WO Protocol. MCP thru DIP. 3T Scanner Only
j. MR Adult Humerus WO Protocol. 1.5T Scanner Only
k. MR Adult Humerus W/WO Protocol. 1.5T Scanner Only
l. MR Adult Scapula WO Protocols
m. MR Adult Scapula W/WO protocols
n. MR Adult Shoulder WO Protocol. 3T Scanner Only
o. MR Adult Shoulder W/WO Protocol
p. MR Adult Thumb WO and W/WO Protocol. 3T Scanner Only
q. MR Adult Shoulder Arthrogram Protocol. Patients are injected in X-ray and are brought to MRI in a wheelchair by the x-ray tech. The screening form should be filled out. Images must be checked by the MSK radiologist before the patient gets up off the table. 3T Scanner Only
r. MR Adult Wrist WO Protocol. 3T Scanner Only
s. MR Adult Wrist W/WO Protocol. 3T Scanner Only
t. MR Adult Wrist Arthrogram WO Protocol
u. MR Adult Wrist Rheumatology W/WO Protocol. Wrist Thru MCP. 3T Scanner Only

23. Lower Extremities
    a. MR Adult Ankle WO Protocol
    b. MR Adult Ankle W/WO Protocol
    c. MR Adult Ankle Bilateral R/O AVN WO Protocol
    d. MR Adult Ankle Plantar Flexion WO Protocol
    e. MR Adult Ankle Achilles Tendon WO Protocol
    f. MR Adult Femur WO Protocol
    g. MR Adult Femur W/WO Protocol
    h. MR Adult Forefoot W/WO Protocol
    i. MR Adult Forefoot WO Protocol
    j. MR Adult Hip WO Protocol
    k. MR Adult Hip WO Ortho Detail Protocol
    l. MR Adult Hip Unilateral W/WO Protocol

m. MR Adult Hip Bilateral W/WO Protocol
n. MR Adult Knee WO Protocol. 3T Scanner ONLY
o. MR Adult Knee W/WO Protocol
p. MR Adult knee Arthrogram WO protocol
q. MR Adult Knee Quad Rupture WO protocol

24. MR Adult Pelvimetry WO Protocol. No IV contrast. Patient will be pregnant. Obtain informed consent. Supine position. Do not draw measurements (techs are not qualified). 1.5TH ONLY
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
25. MR Adult Pelvis WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
26. MR Adult Pelvis W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
27. MR Adult Pelvis WO - Sports Hernia Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT

e. FOV
f. Scan range

28. MR Adult Pelvis WO - Sacroiliitis Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
29. MR Adult SI Joints W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
30. MR Adult Tib/Fib WO protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
31. MR Adult Tib/Fib W/WO protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
32. MR Adult Toe WO or W/WO Protocols
    a. Mod

b. Slice
c. Gap
d. FAT / SAT
e. FOV
f. Scan range

33. Miscellaneous MSK: MRI protocols, documents, procedures and other information for techs
    a. Adult MSK Protocol SI Joints W/WO
    b. Adult MSK Protocol Chest WO or W/WO (MSK)
    c. Adult MSK Protocol Sternum WO or W/WO
    d. MR Adult Lumbosacral Plexus Protocol

IV. Brain

1. MR Adult Trauma Brain WO
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
2. MR Adult Brain WWO
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
3. MR Vasculitis Brain W & WO, MRA COW WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range

4. Special Technologist Instructions
5. MR Adult Brain Tumor Follow Up W/WO
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
6. MR Adult Brain Tumor Follow Up W/WO plus DCE & DSC Perfusion
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
7. MR Adult Brain Tumor Follow Up W/WO plus DCE/DSC Perfusion & Spectroscopy (aka The Big Enchilada)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
8. MR Adult Brain & Orbits W/WO
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
9. MR Adult Cine WO Protocol
    a. Mod

b. Slice
c. Gap
d. FAT / SAT
e. FOV
f. Scan range

10. MR Dementia Brain W/WO Protocol (3T only)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
11. MR Adult/ Pediatric Frameless Brain W, WO, or W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
12. Cover the entire brain - NO Angles
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
13. MR Adult Frameless Brain W,WO, or W/WO plus DCE/DSC Perfusion Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV

f. Scan range

14. MR Adult/ Pediatric MRA Brain WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
15. MR Adult/ Pediatric Neuro Carotid Dissection WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
16. MR Adult/ Pediatric Neuro Carotid Dissection W/WO. Use Adult protocol with smaller FOV/S/G for Pediatric
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
17. MRA Adult/ Pediatric Neuro Neck WO
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
18. MRA Adult/ Pediatric Neuro Neck W/WO
    a. Mod

b. Slice
c. Gap
d. FAT / SAT
e. FOV
f. Scan range

19. MR Adult MS Brain W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
20. MR Adult/ Pediatric Dynamic Pituitary W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
21. MR Pituitary W/WO plus Radiation Therapy Planning Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
22. MR Adult Brain PRE DBS - VIM and Thalamotomy Protocol (3T only)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV

f. Scan range

23. MR Adult Brain PRE DBS - GPI Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
24. MR Adult Brain PRE DBS - STN Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
25. MR Adult Epilepsy/ Seizure Brain WO Protocol. Allowed on the 3T ONLY unless patient has an implanted device
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
26. MR Adult Epilepsy/ Seizure Brain W/WO Protocol. Allowed on the 3T ONLY unless patient has an implanted device
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
27. MRI Spectroscopy Protocol – Multi (Spectroview with Gausian Filter)

28. MR Adult Stroke Brain WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
29. Adult/ Pediatric ETV WO Protocol. Allowed on the 3T ONLY unless patient has an implanted device
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
30. MR Adult MVD/ Trigeminal Neuralgia Brain WO. Scan on 1.5T or 3T, perferably the 3T
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
31. MR Adult/Pediatric 5th & 7th Nerve Trigeminal Neuralgia W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
32. MR Adult Brain Venous Thrombosis / MRV W/WO Protocol
    a. Mod
    b. Slice

c. Gap
d. FAT / SAT
e. FOV
f. Scan range

33. MR Adult/ Pediatric Quick Brain WO Protocol (Scan time approximately 3 minutes)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range

V. ENT

1. MR Adult Orbits W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
2. MR Adult Orbits WO with Cine Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
3. MR Adult Orbits WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV

f. Scan range

4. MR Adult/ Pediatric IAC Pre Cochlear Implant WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
5. MR Adult/ Pediatric IAC W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
6. MR Adult/ Pediatric Brachial Plexus Bilateral WO Protocol (Use adult protocol with smaller FOV/S/G for pediatric)
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
7. MR Adult/ Pediatric Brachial Plexus Bilateral W/WO Protocol (Scan times: 45 min to 1 hr on 1.5T: at least 1hr 15 min on 3T) Use adult protocol with smaller FOV/S/G for pediatric
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range

8. MR Adult/ Pediatric Parotid, Face, Sinus or Skull Base WO Protocol (1.5T preferred except for trigeminal neuralgia 3T is preferred) If indication includes "trigeminal neuralgia," add BFFE (skull base to top of pons) and MRA COW wo
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
9. MR Adult/ Pediatric Parotid, Face, Sinus or Skull Base W/WO Protocol (1.5T preferred except for trigeminal neuralgia 3T is preferred) If indication includes "trigeminal neuralgia," add BFFE (skull base to top of pons) and MRA COW wo
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
10. MR Adult/Pediatric 5th & 7th Nerve Trigeminal Neuralgia W/WO Protocol. Scan on 1.5T or 3T, perferably the 3T
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
11. MR Soft Tissue Neck WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV

f. Scan range

12. MR Soft Tissue Neck W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
13. MR Adult/ Pediatric TMJ WO Protocol. Scan Right and Left sides separately. Label Right and Left sides
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range

VI. Spine

1. MR Adult CSP WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
2. MR Adult CSP WO Trauma Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
3. MR Adult CSP Felxion/Extension WO Protocol

a. Mod
b. Slice
c. Gap
d. FAT / SAT
e. FOV
f. Scan range

4. MR Adult CSP W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
5. MR Adult LSP WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
6. MR Adult Lumbar Spine W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
7. MR Adult Lumbar-Sacral Plexus W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT

e. FOV
f. Scan range

8. MR Adult TSP WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
9. MR Adult TSP W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
10. MR Adult Total Spine WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
11. MR Adult Total Spine W/WO Protocol
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range

12. MR Adult Total Spine Limited Survey WO Protocol. This protocol should read "for patients who cannot tolerate the full total spine exam". Axial images only obtained through areas of pathology and the cervical/ thoracic spine.
    a. Mod
    b. Slice
    c. Gap
    d. FAT / SAT
    e. FOV
    f. Scan range
13. MR Adult Total Spine Chiari/Tethered Cord WO Protocol. Use an appropriate FOV for the patient's size for the best quality. Charge as Total Spine WO
    a. Cervical Spine
    b. Thoracic Spine
    c. Lumbar Spine

Contents

Module III: Introduction to PET/MR

➢ Lecture 37: Cellular Anatomy and Physiology

Time: 90 minutes

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

Objectives:

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

Content:

I. The basics of organic and inorganic chemistry
    1. Four major categories of compounds
        a. Carbohydrates (Breads and Starch)
        b. Lipids (Fats, Oils and Waxes)
        c. Nucleic Acids (DNA and RNA)
        d. Proteins (Meat and Nuts)
    2. Carbohydrates “Carbs”
        a. Function of Carbs
        b. Simple Sugar: Glucose
        c. Double sugar: Sucrose
        d. Starch: Complex Sugar
    3. Lipids
        a. Function of Lipids
        b. Formation of Lipids
        c. Saturated and Unsaturated fats
        d. Cholesterol
    4. Nucleic Acids
        a. DNA
        b. Nucleotides
        c. RNA
    5. Proteins
        a. Function of Proteins
        b. Amino Acids
        c. Denaturation
    6. Enzymes
        a. Function of Enzymes
        b. Lock and Key Model

II. Cellular Anatomy and Physiology
    1. Cell Membrane
    2. Cytoplasm
    3. Endoplasmic Reticulum
    4. Ribosomes

5. Golgi Apparatus
6. Mitochondria
7. Lysosomes
8. Peroxisomes
9. Microfilaments and microtubules
10. Centrosome
11. Cilia and flagella
12. Vesicles
13. Nucleus, nuclear envelope
14. Nucleolus
15. Chromatin

III. Cellular Reproduction

1. Mitosis
    a. Interphase
    b. Prophase
    c. Prometaphase
    d. Metaphase
    e. Anaphase
    f. Telophase
    g. Cytokinesis
2. Meiosis
    a. Interphase
    b. First division of meiosis (Prophase1, Metaphase1, Anaphase1, Telophase1)
    c. Second division of meiosis: Gamete formation (Prophase2, Metaphase2, Anaphase2, Telophase2)
    d. Meiosis in Males and in Females
3. Mutations
    a. Genotype
    b. Phenotype
    c. Recessive Gene
    d. Dominant Gene
    e. Alleles

IV. Celera Genomics. The Human Genome Project

V. Scientific Breakthroughs

Contents

➢ Lecture 38: Cellular Effects of Radiation Exposure

Time: 60 minutes

Keywords: Effects of Radiation Exposure, Radiolysis of Water, Free Radicals, Biochemical Damage (DNA Damage, Chromosome Damage, Membrane Damage), Cell Cycle, Bergonie and Tribondeau Law, Dose Response Relationships, Types of Dose Response Curves, Target Theory and Cell Survival Curves, Cell Death.

Objectives:

- Discuss Direct and Indirect Effects of Radiation Exposure
- Describe Biochemical Damage From Ionizing Radiation and Cell Cycle.
- Define Dose Response Relationship and the Types of Dose Response Curves
- Explain the Law of Bergonie and Tribondeau, Target Theory and Cell Survival Curves

Content:

I. The Effects of Radiation on the Cell at the Molecular Level
   1. Direct Effects
   2. Indirect Effects
      a. Radiolysis of Water
      b. The Lifetimes of Free Radicals
      c. Free Radicals

II. Biochemical Damage From Ionizing Radiation
   1. Molecular Level
      a. DNA Damage
   2. Submolecular Level
      a. Chromosome Damage
      b. Membrane Damage

III. Cell Cycle

IV. Bergonie and Tribondeau Law

V. Dose Response Relationship
    1. Linear or Nonlinear
    2. Threshold or Nonthreshold
    3. Types of Dose Response Curves
        a. Linear Quadratic Dose Response
        b. Linear Nonthreshold Dose Response
        c. Linear Threshold Dose Response
        d. Nonlinear Dose Response (sigmoid curve)
    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

Contents

➢ Lecture 39: Effects of Initial Exposure of Radiation

Time: 90 minutes + video-lecture

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

Objectives:

- Discuss the effects of radiation, the relative tissue and organ radiosensitivity

- Describe the effects of radiation on specific tissue and organs
- Explain Hematologic and Cytogenetic Effects
- Define the Acute Radiation Syndromes and the Response Stages
- Review the dose response curves

Content:

I. Justification
   1. Reasons of Potential Biological Effects
      a. Quality of Radiation
      b. Quantity of Radiation
      c. Received Dose of Radiation
      d. Exposure Conditions (Spatial Distribution)
   2. Relative Biological Effectiveness (RBE)

II. Biological Effects of Radiation
   1. Types Effects
      a. Radiation Sickness
      b. Cancer
      c. Genetic Effects
   2. Action of Radiation
      a. Direct
      b. Indirect
   3. Short and Long Term Effects of Radiation
      a. Time Frame for Effects of Ionizing Radiation
      b. Data on Radiation Exposure to Humans
      c. The Risk Assessment of Cancer

III. Relative Tissue and Organ Radiosensitivity
   1. Skin Effects
      a. Spectrum of Effects on Skin
      b. Dose/Time-response Relationship
   2. Tissue Types
      a. Vegetative intermitotic tissue cells (VIMs)
      b. Differentiating intermitotic cells (DIMs)

c. Multiple connective tissue cells (MCTs)
d. Reverting post mitotic cells (RPMs)
e. Fixed post mitotic cells (FPMs)

3. Organs Types
    a. Acutely Responding Organs
    b. Late-responding Organs

IV. 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

V. Hematologic Effects of Radiation
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. Low radiation dose
    b. Moderate to high dose
    c. Stem cell sensitivity
4. Lymphocytes
5. Spleen

VI. Cytogenetic Effects of Radiation
1. Structural changes
2. Chromosomal aberration
    a. Types of Chromosomal Aberrations
    b. Factors that Influence the Repair of Chromosomal Aberrations
    c. Karyotype

VII. 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
    a. Syndrome
    b. Dose Range
    c. Prodromal Effects
    d. Manifest-illness Effects

e. Survival without treatment
f. Survival with treatment

4. Consequences of Acute Radiation
5. Acute Exposure

VIII. Dose Response Curve

1. Radiation Doses and Expected Effects
2. Commonly Encountered Radiation Doses
    a. Effective Dose
    b. Radiation Source
3. Radiation Effects on Embryo/Fetus
4. Cell Sensitivity

IX. Response Stage

1. Bone Marrow Syndrome
    a. Signs and Symptoms of Bone Marrow
2. Gastrointestinal Syndrome
    a. Signs and Symptoms of Gastrointestinal
3. Central Nervous System Syndrome
    a. Signs and Symptoms of Central Nervous System

Contents

➢ Lecture 40: Effects of Long-Term Exposure to Radiation

Time: 90 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

Contents

➢ Lecture 41: Radiation Protection of Personnel (Part I, II and III)

Time: 90 minutes

Keywords: Radiation Protection Program, 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

Content:

✓ <u>Part I</u>

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
    c. Laboratory technique
    d. Administrative and procedural controls
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

✓ <u>Part II</u>

1. Responsibilities Of Badge Users

1. Landauer dosimeter

✓ Part III

1. Society of Nuclear Medicine Performance and Responsibility Guidelines for NMT
2. Revision 2003
3. Nuclear Medicine Technology
4. Patient Care
5. Nuclear Instrumentation—Quality Control
6. Diagnostic Procedures
7. Radiopharmaceuticals
8. Radionuclide Therapy
9. Radiation Safety
10. References

Contents

➢ Lecture 42: Patient Care, safety, preparation and infection control

Time: 120 minutes

Keywords: Hybrid PET/MR, Safety issues, Access Restriction, Zoning, Shielding requirements, Radiation safety, Hot-lab considerations, Patient Preparation, Workflow, Patient Care, The Clinical Performance Standards, Infection control, Technologist responsibilities, Patient management

Objectives:

- Discuss hybrid PET/MRI, safety Issues when Installing PET/MR and code of ethics for technologists responsible for maintaining the highest possible standards
- Explain the preparation of patient, patient care and safety
- Describe workflow and infection control in PET/MR
- Define the clinical performance standards
- Review shielding requirements and radiation safety patient from ionizing and non-ionizing radiation
- Illustrate access restriction, zoning and hybrid PET/MR zones

Content:

I. Hybrid PET/MRI

1. Introduction

II. Safety Issues when Installing PET/MR
    1. Effects on facilities
    2. Construction

III. Access Restriction and Zoning
    1. Zone 1
    2. Zone 2
        a. Security and Safety
    3. Zone 3
    4. Zone 4

IV. Hybrid PET/MR Zones
    1. Zone 1
    2. Zone 2
    3. Zone 3
    4. Zone 4

V. Dedicated Shielding Requirements for Simultaneous Hybrid System

VI. Radiation Safety & Hot-lab Considerations

VII. Patient Preparation
    1. Resting Phase
    2. Patient Preparation before Examination
        a. Sedation and Anesthesia Preparation Instructions
        b. Other Preparation Instructions
    3. IN-BED Patient Preparation
    4. Instructions for the 24 hours prior to PET/MR Scan Time
    5. Day of the Exam
    6. Follow up Care

VIII. Workflow and Logistic Considerations
    1. Patient schedule
        a. PET
        b. MRI
    2. Pre scan preparation
        a. PET

b. MRI

3. In-bed patient preparation
    a. PET
    b. MRI
4. Field of view
    a. PET
    b. MRI
5. Planning
    a. PET
    b. MRI
6. Acquisition
    a. PET
    b. MRI
7. Respiratory motion
    a. PET
    b. MRI

IX. Patient Care

1. The need for High-Quality Imaging
2. Reducing Health Care Costs
3. Improving Medical Imaging
4. The Scope of Practice for Patient Care
5. Quality control
    a. Nuclear medicine and PET imaging systems
    b. Non-imaging instrumentation

X. The Clinical Performance Standards

1. Patient Care
2. Diagnostic Procedures
3. Adjunctive Medications
4. Radiopharmaceuticals
5. Radiation Safety

XI. Infection control in PET/MR

1. Methicillin Resistant Staphylococcus Aureus (MRSA)
2. Center for Disease Control (CDC)
3. The MRI Suite
4. Bacteria and Table Pads
5. The American College of Radiology Safe PET/MRI Practices
6. Infection Control (Zone IV)
7. Black (ultraviolet) Light Detection of Body Fluid Contamination
8. PET/MR Magnet Bore
9. Suggestions for Infection Control Procedures for Free-Standing Imaging Centers end Hospital Radiology Departments

XII. Technologist responsibilities for patient care, safety and Patient Management

1. Code of Ethics
   a. Principle 1
   b. Principle 2
   c. Principle 3
   d. Principle 4
   e. Principle 5
   f. Principle 6
   g. Principle 7

Contents

➢ Lecture 43: Radiation Safety in PET Imaging (Part I, II and III)

Time: 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
- 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. Thermo 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**

I. Safety Definitions and Symbols Used

1. Labels

a. Danger
b. Warning
c. Caution

2. Symbols
    a. IEC standards

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

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

IV. CT Scan Acquired at the Same Tomographic Plane
1. Scan Types
    a. Smart View
    b. Smart Prep Baseline and Monitor Scans
    c. Cine Scans
    d. Axial Scans with zero table increment

V. Weighted CT Dose Index (CTDlw)
1. Dose Length Product
2. Accumulated Exam DLP

VI. Emergency Stop Buttons

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

VIII. Safety Labels and Rating Plates

1. Radiation Emission Warning
2. Pinch Hazard Label
3. Shock Hazard
4. Do Not Touch

IX. Laser Safety

1. Warning

X. Gamma Radiation

XI. Prevention of Harmful Cumulative Dose

XII. Data Safety

XIII. Safe Operation Guidelines

XIV. Compliance and Regulatory Information

XV. Operator's Safety

XVI. Safe Patient Handling

1. Before starting the scan procedure

- ✓ **Part III**

I. Radiation Protection Programs

1. PET/CT Regulators
2. Helpful Organizations

II. Principle of "ALARA"

III. Annual Radiation Dose Limits

1. Rad. Workers
2. Occasion. Exposed
3. Gen. Public
4. Minor Trainees
5. Fetus

IV. Radiation Warning Signs

1. Cyclotron
2. "Hot" Lab

3. PET/CT Scanner

V. 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

VI. Criteria for Personnel Monitoring

VII. Survey Meter Quality Assurance

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

IX. Differences of PET/CT
    1. Differences of PET
        a. Higher Exposure Rate Constants
        b. Higher Dose Rate From Patients
        c. PET Shielding: Tenth Value Layers
        d. Shorter Physical Half-Life
        e. Shorter Half-Life: Lower Dose

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

XI. 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

XII. 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

XIII. 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

XIV. Internet Resources

Contents

Module IV: Applications of PET/MR

➢ Lecture 44: PET/MR Instrumentation

Time: 60 minutes

Keywords: instrumentation; PET; PET/MRI; MRI; optical 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

III. Scintillation Materials Used in Nuclear Medicine Instrumentation

1. NAl(TI)
2. BGO
3. LSO
4. YSO
5. GSY
6. BaF
7. LaBr3
8. LYSO
    a. Density (g/cm3)
    b. Effective Z
    c. Attenuation length
    d. Decay constant (ns)
    e. Relative light output (%)
    f. Wavelength (l [nm])
    g. Index of refraction
    h. Hygroscopic

IV. Advances in PET Reconstruction Algorithms.

V. TOF PET

VI. CT AND PET/CT

VII. OPTICAL IMAGING

VIII. MRI

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

IX. MULTIMODALITY IMAGING: PET/MRI

1. We Have PET/CT vs. PET/MRI
2. Technical Aspects

3. Applications: from Combining Function with Anatomy to Multifunctional Imaging

Contents

➢ Lecture 45: PET/MR Systems

Time: 120 minutes

Keywords: Side-by-side; PET- insert; Integrated PET/MRI; High-resolution; High-contrast morphologic imaging of soft tissues; Sequential systems; Insert systems; Integrated systems; Magnet; Nuclear spin ;T1 and T2 relaxation; Optical reflector, PMT; Scintillator; Photomutiplier; PET impacting MR; Positron; Transmission scan.

Objectives:

- This lecture provides detail of 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

III.PET-MRI 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

1. Scanner construction and operation

    Magnet

    a. Permanent magnet

    b. Resistive electromagnet

c. Superconducting electromagnet

d. Shims

e. Gradients

f. 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

1. PET Detectors

a. Coincidence Detection

b. How it works: Timing coincidence

2. Typical PET Scanner Detector Ring

3. Anatomy: PET gantry

4. Prototypical PET Detector

5. PET Block Detector Design

6. PET Detector Requirement

7. PET Detectors

a. How it works: Scintillation

b. Scintillation Crystals

VI. Motivation for PET/MR

VII. Brief history of PET/MR development

VIII. Challenges in the integration of PET and MRI

1. Attenuation Correction

IX. MRI compatible PET detectors

1. Light Fiber Based PET/MRI Systems

d. a. First approach to acquire PET data inside an MRI scanner (1997)

2. Light Fiber Based PET/MRI Systems

a. West Virginia University, USA – Optical Fibers

X. Avalanche Photodiode Arrays

1. University of Tuebingen, Germany.

a. Advantages

b. Challenges

2. Solid-state photodetectors

3. APD based detectors

4. SiPM based detectors

5. Silicon Photo Multipliers (SiPM, Geigermode-APD)

XI. Strategies for PET/MR

1. Use of MR-friendly materials

2. Reducing magnetic fields seen by photomultiplier tubes

3. Using PET detectors that are insensitive to magnetic fields

4. Reducing PET signal interference with MR

5. Attenuation correction

XII. 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.

a. MRI parameter

b. Description

5. PET characteristics of the Philips Ingenuity TF system.

a. PET parameter

b. PET description

XIII. 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

a. System Design

5. 60 cm Patient Bore
6. High Resolution in-Room Operator Control (iROC)
7. Sleek dual-sided controls
8. IntelliTouch Patient Positioning
9. Sophisticated LED accent lights

XIV. 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

b. Field strength

c. Bore size

d. System length

e. System weight (in operation)

f. Minimum room size

g. RF Tim

h. Gradient strength

i. Helium consumption

8. Siemens' technologies
9. MR-compatible PET detectors
10. Tim
11. Gradient System
12. RF Technology

XV. 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

XVI. 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

Contents

➢ Lecture 46: PET/MR Image Distortion in Clinical Imaging

Time: 120 minutes

Keywords: PET/MRI; MR-AC; SPECT; PET; Philips Healthcare; Siemens; SIGNA PET/MR;CT AC Artifact From Port; Non-rigid registration; initial estimation of motion information; simultaneous estimation of motion parameters and images; DWI; Truncation artifacts; MLAA; Inhomogeneity; Truncation artifacts; Soft Tissue.

Objectives:

- To understand the risk and artifact using PET/MRI in diagnostic imaging.
- To gain awareness about the presence and causes of potential artifacts in PET/MRI
- To understand the Dual-modality imaging and attenuation effect.
- What is the source of image distortion and image bias in hybrid PET/CT and PET/MR
- Explain how to minimize the attenuation effect in clinical PET/MR imaging

Content:

I. Attenuation Correction

III. PET/CT Imaging

1. PET/CT offers two major advantages over separate PET and 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

VI. Source of image distortion and image bias in hybrid PET/CT and PET/MR

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

VIII. Workflow and Scan Protocol Considerations for Integrated Whole-Body PET/MRI Fundamentals of MRI

1. Patient Preparation Before Examination
2. In-Bed Patient Preparation
3. OPTIMIZATION OF PET/MRI PROTOCOLS

IX. PET/MR Artifact

X. MRI-guided attenuation correction in PET/MRI

XI. MRI-guided image reconstruction in PET/MRI

1. partial-volume effect (PVE).

XII. MRI-guided motion compensation in PET/MRI

XIII. Clinical workflow and protocols

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

XV. Hybrid PET/MR Pitfalls and artifacts

1. Truncation artifacts

XVI. Potential new artifacts by MR-AC: truncation

XVII. Hybrid PET/MR Pitfalls and artifacts

1. Solution
2. Inhomogeneity
3. Truncation artifacts
4. Fold-over artifacts
5. Pulsation artifacts
6. Possible solutions

7. Eddy currents and standing wave
8. Motion artifacts
9. Susceptibility artifacts
10. Geometric distortion
11. Motion artifacts
12. Motion correction
13. Bone
14. Metallic Implants
15. Metals
16. PET images and profiles through lung lesion
17. Transformation of attenuation coefficients
18. Soft Tissue
19. Contrast Agent
20. PET/MRI Misregistration
21. Non-recognition of Lung Compartment
22. Attenuation Correction in PET/MRI
23. Software-based algorithms
24. AC-specific sequences

Contents

➢ Lecture 47: PET/MR Attenuation Correction

Time: 90 minutes

Keywords: Aliasing; temporal aliasing; spatial aliasing; Wraparound; FOV

Objectives:

- Describe What is Aliasing
- Explain What is Artifact (error) VCH VGV
- Describe MRI Artifact
- Explain MRI Artifact
- Define PET/MR Motion Correction
- Define PET/MR Implanted Material Artifacts

- Explain PET/MRI Respiratory motion Artifact

Content:

I. Atlas Based Attenuation Correction
II. Direct Segmentation Attenuation Correction
III. Special Bone Representing Sequencing

1. What PET is
    a. PET stands for Positron Emission Tomography, imaging test that helps to measure the functionality of tissues and organs within the body.
    b. PET is a noninvasive, diagnostic imaging technique for measuring the metabolic activity of cells in the human body.
    c. It was developed in the mid-1970s and it was the first scanning method to give functional information about the brain.
    d. PET module examines the function of human body organs by tracing the metabolism and movement of chemoical radiolabel which is administered intravenously.
    e. The most commonly used substance is fluorodeoxyglucose (FDG) labeled with Fluorine 18 radioactive element, it accumulates in the changes with increased glucose metabolism.
2. What a Positron is
    a. A Positron is an anti-matter electron, it is identical in mass but has an opposite charge of +
    b. Positron can come from different number of sources, but for PET they are produced by nuclear decay
    c. Nuclear decay is basically when unstable nuclei are produced in a cyclotron by bombarding the target material with protons, and as a result a neutron is released
    d. 18-O + proton => 18-F + neutron
    e. In PET the target material is chosen so that the product of the bombardment decays to a more stable state isotope by emitting a positron, for instance 18-F has too many protons, so one of these protons decays into a neutron emitting in the process a positron and a neutrino
    f. proton (+1 charge) => neutron (0 charge) + positron (+1 charge) + neutrino (0 charge)

g. After decay, we're left with 18-O

3. What happens after the positron is obtained
    a. Leftover energy from the nuclear decay process is shared between the positron and the departing neutrino. Kinetic energy
    b. Because of conservation of energy and momentum the positron is forced to stay and thus become useful
    c. Positron begins its activity in colliding with other particles and gradually losing its kinetic energy and thus slowing down
4. PET - Positron Emission Tomography
    a. What we want to detect in PET
    b. 2 photons of 511 keV in coincidence, coming in a straight line from the same annihilation
5. Annihilation of a positron and electron
    a. The positron will encounter an electron and completely annihilate each other resulting in converting all their masses into energy. This is the result of two photons, or gamma rays
    b. Because of conservation of energy and momentum, each photon has energy of 511keV and head in an almost 180 degrees from each other
    c. 511keV is the ideal rest state annihilation value
6. How we detect Photons (Gamma Rays)
    a. PET detects these photons with a PET camera which allows to determine where they came from, where the nucleus was when it decayed, and also knowing where the nucleus goes in the body
7. Limitations
    a. PET can give false results if a patient's chemical balances are not normal. Specifically, test results of diabetic patients or patients who have eaten within a few hours prior to the examination can be adversely affected because of blood sugar or blood insulin levels
    b. Also, because the radioactive substance decays quickly and is effective for a short period of time, it must be produced in a laboratory near the PET scanner

c. Finally, the value of a PET scan is enhanced when it is part of a larger diagnostic work-up. This often entails comparison of the PET scan with other imaging studies, such as CT or MRI

8. What MRI is
    a. MRI stands for Magnetic Resonance Imaging, a scan that uses magnetic and radio waves to produce detailed morphological information of the organs, tissues and structures within the body
    b. Magnetic resonance imaging (MRI) is an imaging technique used primarily in medical settings to produce high quality images of the soft tissues of the human body
    c. It is based on the principles of nuclear magnetic resonance (NMR), a spectroscopic technique to obtain microscopic chemical and physical information about molecules MRI has advanced beyond a tomographic imaging technique to a volume imaging technique
    d. MRI module uses radio waves and magnetic field to create detailed, more accurate than CT, images of internal body parts such as soft tissue, organs and bones, which allows to detect even small tumors, not visible while using other imaging methods
    e. MRI scan also provides detailed information about the accumulation of the radiolabel
9. Magnetic Principles
    a. The spinning hydrogen protons act like small , weak magnets.
    b. hey align with an external magnetic field (Bø).
    c. There is a slight excess of protons aligned with the field. (for 2 million , 9 excess) ~6 million billion/voxel at 1.5T
    d. The # of protons that align with the field is so very large that we can pretty much ignore quantum mechanics and focus on classical mechanics.
    e. The spinning protons wobble or “precess” about that axis of the external Bø field at the precessional, Larmor or resonance frequency.
    f. Magnetic resonance imaging frequency $\nu = \gamma B_o$ where γ is the gyromagnetic ratio.
    g. The resonance frequency ν of a spin is proportional to the magnetic field, B_o
10. MRI and Radio Frequencies
    a. The RF coil produces a radio frequency simultaneously to the magnetic field

b. This radio frequency vibrates at the perfect frequency (resonance frequency) which helps align the atoms in the same direction
c. The radio frequency coil sent out a signal that resonates with the protons.
d. The radio waves are then shut off.
e. The protons continue to vibrate sending signals back to the radio frequency coils that receive these signals

11. Gradient Coils Principle
    a. These are room temperature coils.
    b. A gradient in B o in the Z direction is achieved with an antihelmholtz type of coil.
    c. Current in the two coils flow in opposite directions creating a magnetic field gradient between the two coils.
    d. The B field at one coil adds to the B o field while the B field at the center of the other coil subtracts from the B o field.
    e. The X and Y gradients in the B o field are created by a pair of figure-8 coils. The X axis (figure below) coils create a gradient in B o in the X direction due to the direction of the current through the coils.
    f. The Y axis (figure below) coils provides a similar gradient in B o along the Y axis
12. RF Coils

IV. What Hybrid Imaging is
1. Hybrid PET/MRI Scanner
    a. MRI/PET is a hybrid scanner that combines of the two modalities into a single scan.
    b. Capturing metabolic activity and anatomy together offers doctors a more precise and accurate assessment of disease, as well as an improved understanding of the physiologic process.
    c. This allows for easier and faster detection, characterization, staging and treatment of oncological, neurological and cardiovascular diseases, and exposes patients to lower levels of radiation.
2. PET/MR Advantages
3. Why MRI-PET Hybrid Imaging
    a. Want true simultaneous data acquisition in a single device
    b. Want combined functional and morphological data acquisition at the same time
    c. Want multi modal functional acquisitions at the same time (fMRI / MRS - PET)

d. Want to cross-validate activations measured with PET and fMRI under the same conditions, at the same time, in the same status

V. Why PET/MR

1. How MRI/PET work
    a. For the PET portion of the study, a small amount of radioactive material is injected into the body.
    b. The type of radioactive material depends on the organ or tissue being studied.
    c. Once the injection is completed, the patient will wait approximately 60 minutes in a quiet area with limited movement to allow the body to absorb the radioactivity.
    d. More of the radiotracer material will accumulate in the cells with higher chemical activity, which generally corresponds to the areas of disease.
    e. For the MRI portion, magnetic fields and radio frequency bursts will move the molecules in the patient's body out of their normal alignment or their normal spinning pattern.
    f. As the molecules return to their natural positions, the machine records that activity and uses the information to create detailed images of the organs, tissues and other structures inside the body.
    g. How
2. Advantage of PET/MR
    a. By using this scanner it is possible to perform simultaneous PET and MRI using much lower doses of radiation than in PET-CT (computed tomography).
    b. It is a very modern diagnostic tool that allows performing just one scan instead of two separate ones.
    c. Hybrid PET-MR scanner has several advantages over PET/CT scanners, including improved soft tissue contrast and reduced radiation dose.
    d. The latter also provides the potential for motion compensated PET reconstruction to be performed.
    e. However, deriving attenuation maps using hybrid PET-MR systems remains challenging.
    f. Accurate attenuation correction (AC) is of great importance in PET, especially for lesions near bones.

g. In hybrid PET/CT systems, AC maps can be derived from CT images by scaling Hounsfield units (HU) to the equivalent attenuation coefficients at 511 keV.
h. However, deriving AC maps using MR imaging requires more sophisticated methods because no direct relationship exists between MR signal intensity and PET attenuation coefficients.
i. In particular, cortical bone and air have low intensity in conventional MR sequences, but have very different attenuation coefficients in PET.

3. Key information about the Biograph scanner
    a. The scanner is adapted to scan the entire body in a magnetic field of 3 T.
    b. The diameter size of the gantry is equal to 60 cm, and the length of the bed is equal to 199 cm.
    c. The system is equipped with 18 independent RF modules.
    d. PET detector contains 56 blocks of detectors in each of the 8 rings.
    e. The field of vision of the axis "z" is equal to 26 cm.
    f. The matrix of detector blocks is made of LSO crystal, and light pulses are recorded by avalanche photodiodes (APD)
4. PET Detectors
    a. Traditional PET detectors, based on PMTs, are sensitive to magnetic fields
    b. MRI FOV should not be obstructed with materials of high magnetic susceptibility
    c. MRI uses high frequency and high power RF which can interfere with PET signal
5. 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
6. RF Induced Distortions in the PET Data
    a. PET Detectors and electronics have to be shielded sufficiently
    b. Change of Magnetic field (gradient) cannot be shielded
7. How to Combine MRI with a PMT Based PET
    a. Keep PET and MRI away from each other
    b. (side-by-side)
    c. Only the PMT needs to be protected from the magnetic field

d. The scintillator, which detects the gamma rays can be kept inside the magnetic field

8. Light Fiber Based PET/MRi Systems
    a. If the scintillation light is transported away from the high magnetic field, PMT detectors may be used. •
    b. Light loss due to fiber coupling is significant and degrades PET performance
    c. MR field of view is free from metallic materials which preserves good MR performance
9. Field Cycled MRI-PET
    a. B0 field generated by large electro magnet (1T)
    b. PMT based PET detectors can be used
    c. During PET images, MRI field is switched off
    d. Requires dedicated MRI coils and gradients
10. Other Potential Approaches for a Combined PET/MR
11. Novel Detectors for PET/MRI
12. Typical Topology of an Integrate PET/MRI
    a. PET Inside an MRI System
    b. RF coil is located inside the MRI to do MR imaging
    c. PET is inside the Gradient System
    d. The PET needs to allow for the gradients to penetrate
13. APD Based PET/MRi Systems
    a. Hybrid approach using short fibers and position sensitive APDs
    b. Operated inside a 7 T MRi
    c. Excellent MR performance due to absence of metallic materials at the center FOV
14. Avalanche Photodiode (APD)
    a. Avalanche photodiode (APD) technology has made big advances over the last few years.
    b. These compact and reliable silicon-based devices have successfully been used to replace bulky photomultiplier tubes in high-resolution PET systems.
    c. APDs have been tested in high magnetic fields of up to 9.4 T without showing any performance degradation.
    d. Hence, compact APD-based detectors offer new possibilities in merging PET and MRI.

e. APD based LSO Block detector (4x4mm2)
f. Fully integrated with MRI system
g. Shared cooling system

15. First small Animal Studies with PET/MRI
16. Hybrid PET/MR Advantage
    a. One of the main advantages of PET/MR scanners compared to PET/CT systems is the reduced ionizing radiation received by the patient.
    b. Another one is that PET/MR scanners not only provide high resolution anatomical images with high soft-tissue contrast, but also functional information.
    c. As PET and MR are acquired simultaneously, the patient's physiological state is identical for both modalities, which allows dynamic PET/MR studies and new opportunities to correct for motion.
17. Hybrid PET/MR Challenges
    a. In current combined PET/MR systems, PET attenuation correction is based on MRI, since the small bore inside MRI systems and the strong magnetic field do not permit a rotating PET transmission source or a CT device to be integrated.
    b. Unlike CT measurements in PET/CT scanners, the MR signal is not directly correlated to tissue density and thus cannot be converted by a simple transformation of intensity values.
    c. Various approaches have been developed based on templates, atlas information, direct segmentation of T1-weighted MR images, or segmentation of images from special MR sequences.
    d. The advantages and disadvantages of these approaches as well as additional challenges will be discussed.
18. Quantitative image reconstruction in PET-MRI
    a. Besides the integration of the hardware components, there is also a need for reconstruction algorithms with the necessary corrections.
    b. As one of the important advantages of PET-CT compared to standalone PET is the fast acquisition and easy transformation of CT data into attenuation correction factors for PET image reconstruction.
    c. In PET-MRI the attenuation correction seems to be one of the major barriers to the full acceptance of PET-MRI as an established clinical imaging modality.

d. The different methods investigated to overcome this limitation are described in this section.

19. Attenuation
    a. Attenuation is defined as the reduction in intensity of the electromagnetic radiation as it travels through a medium and interacts with matter.
    b. Photons emitted from the center of the patient will be more attenuated than the ones emitted in the periphery, which results in an underestimation of the radionuclide uptake in the center of the PET image.
    c. In the absence of a transmission source, CT image or timeof-flight PET, the attenuation information can only be derived from MRI images.
    d. However, MRI image intensities do not reflect the electron density, which prevents a direct estimation of the attenuation coefficients
20. Requirements for attenuation correction
    a. The effect of attenuation and the requirements for the accuracy of the attenuation map depends strongly on the object size.
    b. For small animal imaging the effect of attenuation is much smaller and methods like contour based attenuation correction derived from MRI will have sufficient accuracy for most studies.
    c. Three different groups of attenuation correction techniques are currently being investigated for PET-MRI: MRI based, emission based and transmission based
    d. The main requirement for the implementation of an attenuation correction method in clinical practice is the robustness of the method, i.e. the guarantee that no error that could lead to an incorrect diagnosis will be present in the attenuation map.
    e. To enable this, it is required that all attenuating objects (also the ones on the path between the emitting object and detectors) inside the FOV are included in the attenuation measurement.
    f. A specific problem for PET-MRI is the attenuation caused by MRI coils and other hardware within the field of view typically positioned close to the object of interest.
    g. Such objects contribute to the total attenuation, thus reducing the PET signal, and can result in artefacts if not accurately corrected for.
    h. Any attenuation correction method should also have a reasonable acquisition time: ideally the attenuation map is acquired simultaneously with the PET data (to avoid

misalignment) and it should only lead to a minimal increase of the total acquisition time and very limited additional dose to the patient.

21. Hybrid PET/MR Challenges
    a. Attenuation and PET/MR imaging In order to obtain qualitatively and quantitatively accurate PET images, the emission data recorded during a PET scan do not only have to be reconstructed, but must also undergo different corrections.
    b. These corrections refer to normalization for different detector efficiencies, random and scattered coincidences, dead time, decay, and, last but not least, tissue attenuation of the 511 keV photons which are emitted as pairs of opposing photons upon positron annihilation
22. Attenuation and PEt/MR imaging
    a. Photon attenuation is due to photoelectric interactions resulting in complete photon absorption or scattering with energy loss.
    b. The percentage of photons attenuated within the tissue is independent of the annihilation location, but dependent on the total intrabody travel length of the two 511 keV photons along a line-of-response (LOR)
    c. A length of, for example, 15 cm (medium diameter of the head) leads to an attenuation factor of 4.5, whereas a length of 35 cm such as found in the abdomen results in a factor of 18.
    d. Thus, only 22 and 5.5 %, respectively, of the radiation emitted by the radiolabelled tracer in the direction of an LOR is recorded by the PET detector. These numbers illustrate that even a minor error in measuring or determining the attenuation factor may lead to an erroneous correction for tissue attenuation
    e. One of the most challenging issues of PET imaging in hybrid PET/MR systems is attenuation correction since the small bore inside MRI systems and the strong magnetic field do not allow PET transmission scans to be implemented with positron-emitting rod sources or additional computed tomography (CT) devices.
    f. Thus, present solutions for PET- or CT-based transmission systems are not compatible with the MR environment.
23. Attenuation correction can be performed in two different ways
    a. Before applying the conversion procedure, the CT images must be adapted to the PET resolution by Gaussian filtering and down sampling.

b. The second method of correcting for tissue attenuation is to incorporate the knowledge on the μ-map directly into the iterative reconstruction as, for example, the 3D attenuation-weighted ordered subset expectation maximization (OSEM) algorithm
c. In hybrid scanners combining PET and MRI, it is not possible to derive μ-maps valid for PET from MR images using simple piece-wise linear calibration curves. Commonly, MR signals are related to the proton density and longitudinal (T1) and transverse (T2) magnetization relaxation properties of the tissue under investigation, but they are not related to tissue attenuation in regard to ionizing radiation. This becomes obvious with respect, for example, to bone and cavities which show similar signal intensities in MRI, but cause the highest and lowest tissue attenuation in PET.
d. Photon attenuation in PET/MR systems is due to the patient tissue itself and MRI system components such as the patient bed, immobilization devices, and radiofrequency (RF) coils.
e. In brain imaging, bone, air-filled cavities, and soft tissue are the most relevant classes for attenuation correction.
f. In whole-body applications, lung tissue must also be taken into account.
g. Whereas bone may be regarded as less relevant as in brain imaging.
h. Furthermore, the usable MR field of view (FOV) in present whole-body PET/MR scanners is too small to image the patient completely thus leading to truncation artefacts, which have to be considered in attenuation correction procedures.

24. MRI-based attenuation correction
25. Challenges in Implementation
    a. There are three major concerns while creating a combined PET MRI unit;
    b. first is putting a PET system with photomultiplier tubes (PMTs), which are extremely susceptible to magnetic fields, into a high magnetic field (and having PET detector units that do not interfere with magnetic fields),
    c. second, creating attenuation maps for PET images,
    d. third, a proper construct for the PET-MRI system
26. Attenuation correction based on data from PET

a. An alternative for MRI based attenuation correction is to derive the attenuation information from the data collected by the PET scanner.
b. As the acquisition time in PET is shorter than the typical acquisition time of the MRI part, this method is interesting for patient throughput.
c. Several methods have been developed that rely on emission and/or transmission data.
d. The main difficulties of transmission and emission based methods are clearly different from MRI based methods.

27. Attenuation correction based on data from PET
    a. An alternative for MRI based attenuation correction is to derive the attenuation information from the data collected by the PET scanner.
    b. As the acquisition time in PET is shorter than the typical acquisition time of the MRI part, this method is interesting for patient throughput.
    c. Several methods have been developed that rely on emission and/or transmission data.
    d. The main difficulties of transmission and emission based methods are clearly different from MRI based methods
28. Transmission based attenuation correction
    a. Transmission imaging has been used extensively in standalone PET scanners and has a clear advantage because it results directly in the linear attenuation coefficient at 511 keV (or a nearby energy for singles transmission).
    b. Another advantage (compared to MRI based methods) is its general applicability: with this method it is possible to determine the linear attenuation coefficient of any object (also coils) inserted in the FOV.
    c. There is however also some challenges in the development of an attenuation correction method based on transmission data for PET-MRI.
29. PET detector element related issues
    a. In terms of the ideal detector crystal, Lutetium oxyorthosilicate (LSO) and Bismuth germinate (BGO) have been shown to be least susceptible to MR artifacts.
    b. At present, there are a few major strategies to limit the interference of the magnetic field of the MRI scanner, with the detection of the PET signal.

c. The first involves using optical fibers that guide light away from the magnetic field, for detection, another involves replacing the PMT with avalanche photodiode devices (APDs), and yet another involves shielding the PMT from the surrounding magnetic field.

30. Attenuation Correction for PET/MR
    a. For PET to be quantitative, attenuation correction is a mandatory step
    b. Use of conventional transmission scan is not feasible due to space constraints
    c. Simple derivation of attenuation data from MR images is difficult since the MR signal is not directly correlated to material density
    d. More sophisticated image processing approaches are needed
    e. Image segmentation
    f. Atlas based approaches
    g. Dedicated MR sequences which provide contrast rich signal for different materials (e.g. UTE for bone)
31. Attenuation Correction
    a. Attenuation correction is an essential requirement for quantification of PET data. In PET/CT acquisition systems, attenuation maps are derived from Computed Tomography (CT) images.
    b. However, in hybrid PET/MR scanners, MRI images do not directly provide a patient-specific attenuation map. Our approach is to synthesize a CT from an MRI image.
    c. The synthetic images are generated through a multi-atlas information propagation scheme, locally matching the MRI-derived patient's morphology to a database of MRI/CT pairs, using a local image similarity measure
32. MR-based attenuation correction approaches
    a. MR-based attenuation correction (AC) approaches consist of distinguishing the regions with different attenuation properties, assigning the correct linear attenuation coefficients to them and utilizing the resultant attenuation map to correct the PET emission data during reconstruction. MR-based approaches were first developed for multimodal PET/MR acquisitions of the brain.
    b. Multimodal brain and whole-body studies can be performed with hybrid whole-body PET/MR systems.

c. Thus, the correction methods for brain data acquisition are also relevant for brain studies with whole-body PET/MR, especially because such methods are not presently available in whole-body PET/MR systems.
d. The need has also arisen for additional MR-based attenuation correction approaches for whole-body applications, and some of the existing methods for brain imaging have been adapted for whole-body imaging.
e. Other methods cannot be applied for the whole body because of the nonrigidity of the body, organs, and MR equipment which is particularly challenging.
f. Four categories can be distinguished:
g. Template-based
h. Atlas-based
i. Direct segmentation approaches
j. Methods based on special bone-representing sequences.

33. Template-based approaches
    a. Template-based methods were initially suggested for situations where a transmission scan of the subject investigated is not available in PET.
    b. The attenuation map template is constructed as an average image from a number of available transmission scans.
    c. In template-based methods utilizing PET and MRI, an attenuation map template and a co-registered MR template are generated.
    d. After adapting the MR template to the patient MR image with nonlinear registration, the same nonlinear transformation can be applied to the attenuation map template to adapt it to the PET image of the patient investigated.
    e. The average attenuation map template was generated from 68Ge-based transmission scans (HR+-PET) of 10 healthy subjects (females and males) via spatial normalization to the standard brain of SPM2.
    f. Using the co-registered T1-weighted MR template of SPM2 for nonlinear registration with the MR image of the patient investigated, the transformation matrix obtained is applied to the attenuation map template to generate an individualized attenuation map.
    g. In a second version, one of the measured image pairs is used as a reference instead of the SPM standard brain and the other data sets are nonlinearly registered to it .

h. In separate female and male templates averaged over four volunteers each are generated.
i. In the latest version, a mixed-gender template is constructed as an average of the eight subject data sets.
j. Finally, the attenuation map of the MR head coil measured in the HR+-PET is added so that the method can be applied in the PET/MR scanner.

34. Atlas-based approaches
    a. Atlas-based approaches were developed to integrate global anatomical knowledge derived from a representative intensity-based or segmented reference data set into the segmentation procedure.
    b. Atlas data can provide exactly matched attenuation data
    c. However, exact co-registration of the data may not always be achieved Atlas data base needs to cover large range of ages and genders to provide good match
    d. Atlas may not include or match pathological features (e.g. tumor mass)
    e. Good matching pairs of MRI and corresponding attenuation data may not be easily to obtain
35. Direct segmentation-based approaches
    a. These approaches work directly on the standard T1-weighted MR images routinely acquired for each patient.
    b. The most challenging task in using these images is distinguishing bone tissue from air-filled cavities since both tissue types appear in the same intensity range.
    c. The T1-weighted MR image slice shows an air-filled nasal cavity, the mastoid process as a mixture of lamellar bone and small cavities, and the skull. The dark areas representing bone and air appear in the same intensity rang
36. Attenuation Correction for PET/MRI
    a. Segmentation can be achieved with moderate computational effort Challenges using segmentation:
    b. MR data is often truncated and not acquired for the same PET FOV
    c. However, the success of the segmentation will depend highly on the available contrast of the MR sequence
    d. Often tissues may not be unambiguously identified or misclassified
37. Joint kinetic modelling and motion correction of dynamic PET data

a. Kinetic modeling of dynamic PET data allows for the quantification of the underlying biological/physiological processes for disease understanding and drug development.
b. We developed a unified framework to address two of the fundamental problems, namely subject motion and noise statistics to improve the pharmacokinetic analysis for clinical decision making.

38. System construction
    a. The ideal construct for a PET-MRI system is not yet entirely clear and at present, three models are considered, sequential, insert, and integrated.
    b. In the sequential construct, the PET and MRI scanner are placed in sequence, just as with the PET-CT systems and the currently available PET-MRI systems are of this type.
    c. The advantages of this method are, minimal adjustment to existing technology, but magnetic shielding and certain front-end software changes would be required.
    d. Furthermore, the disadvantage of non-simultaneous acquisition remains
    e. The insert construct system involves building a removable PET detector ring that can be placed within the MR gantry or around the subject, when simultaneous acquisition is needed. In this situation, the PET ring must produce minimal disturbance to the magnetic field, the PET detector must be resistant to magnetic field fluctuations or have an external read-out and all parts must be shielded to prevent electromagnetic interference. Various options, which include using optical fibers or Avalanche photodiodes (APDs) are presently under development.
    f. This system has the advantage of allowing simultaneous PET-MRI acquisition and the opportunity for it to be adapted to any center that already has an MRI system.
    g. The drawback, besides developing the technology to create excellent quality images with excessive interference, is a further decrease in the space within the bore of the MRI scanner.
    h. Integrated systems presently rely on three major technologies;
    i. the first is a split superconducting magnet, where the PET detector ring lies in the space between a split superconducting magnet and optical fibers carry the scintillation light to an area outside the 1 mT fringe field for processing.
    j. At present, this can only be used at a low magnetic field, with a specialized gradient set, limiting its utility somewhat.

k. Second (field cycled acquisition), using two separate and dynamically controllable magnets (one for excitation of protons on the MR and the other for reading the MR signal), an interleaved acquisition can be created that allows a window for PET data acquisition.

l. In the third method, the crystals and photomultiplier components are located between the MRI's send and receive coils, which naturally again leads to space constraints and electromagnetic as well as heat-related issues.

m. Finally, there is some work being done on integrating some of these solutions to produce a more comprehensive solution.

39. Quality Control of PET/MR
40. Conclusion

Contents

➢ Lecture 48: PET MR QC Standards

Time: 90 minutes

Keywords : Quality Assurance; Quality Assessment; Quality Control; Spatial Esolution; Readout Bandwidth; Scatter Fraction; GE; NEMA; DICOM.

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. "META" QC:

1. What is the Quality of your Quality Control?

Ii. Need for quality management in diagnostic imaging

Iii. Need for quality management in radiology

1. Sub quality images can result in
2. This in turn can result in

Iv. The purpose of a quality management program

1. To Control or minimize the errors in following variables as much as possible

V. Levels of quality of patient care & diagnostic images

1. Expected quality
2. Perceived quality
3. Actual quality

VI. Quality assurance (QA)

VII. Quality assessment

VIII. Quality control (QC)

IX. Types of QC tests

1. Acceptance testing
2. Routine performance evaluations
3. Error correction tests

X. Continuous quality improvement

XI. Quality assurance MRI

XII. Quality control MRI

XIII. Quality control testing frequency

XIV. Image artifacts

XV. Spatial resolution

XVI. SNR

XVII. Magnetic field inhomogeneity

XVIII. Mage quality MRI

1. ACR MRI Large Phantom

IXX. Spatial accuracy

1. Large FOV Phantom

XX. 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
8. Sinogram (uniformity) check
9. Weekly Quality Control Tests

a. Performance data of different pet scanners

10. Spatial Resolution
11. Scatter Fraction
12. Sensitivity

XXI. Image distortion in clinical PET/MRI

XXII. Current design of PET/MR system

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

XXIII. Overview of some functionality on various commercially available whole body PET/MRI systems

XXIV. NEMA national electrical manufacturers association

XXV. NEMA standards "DICOM"

XXIV. NEMA standards medical imaging & technology alliance (MITA)

XXVI. Technical PET performance of commercially available systems

XXVII. Overview OF NEMA NU-2 2007 performance characteristics for commercially available whole body

XXVIII. PET/MRI quality control and NEMA standards

XXIX. 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

XXX. 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

XXXI. Performance measurements of the siemens MR 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)

XXXII. Systematic evaluation of phantom fluids for simultaneous PET/MR hybrid imaging

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

Contents

➢ Lecture 49: PET MR Artifacts

Time: 90 minutes
Keywords: Aliasing ; Artifact ; MRI Artifact ; MRI Motion Artifact ; Integrating PET/MR System; PET/MR Motion Correction; PET/MR Implanted Material Artifacts; PET/MRI Respiratory motion Artifact;

Objectives:

- Explain what Aliasing is
- Understand MRI Artifact
- Explain PET/MR Implanted Material Artifacts
- Describe PET/MRI Respiratory motion Artifact
- Describe What MR can do for PET
- Define What PET can do for MR

Content:

I. What is Aliasing?

1. Temporal aliasing
2. Spatial aliasing

II. What is Artifact (error)

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

III. Artifact in Medical imaging

IV. MRI Artifact

1. Patient Related

V. Motion Artifact

1. Motion Respiratory Motion Artifact
2. Respiratory motion – Remedy
3. Mechanical methods

VI. Signal Averaging

VII. Motion Artifacts

1. Respiratory Triggering/Gating
2. Drawback
3. Gradient moment nulling
4. Disadvantage
5. Advantage
6. Fat Suppression Methods
7. Cardiac Motion
8. Electrocardiographic Triggering / Gating

VIII. Zipper artifact MRI

1. Remedy

IX. Zebra Stripes MRI

1. Moire fringes
2. Zero-fill artifact
3. Spike in k-space

X. Moire fringes MRI

XI. Zero fill artefact MR

XII. Magic Angle Effects MRI

XIII. Magnetic susceptibility artifact

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

XIV. Black boundary artifact

1. Remedy

XV. DC Offset and Quadrature Ghost

XVI. RF Noise

XVII. Bo Inhomogeneity

XVIII. Gradient

XIX. Flow Artifact

XX. Chemical Shift

XXI. Image Distortion in Clinical PET/MRI

1. Source of image distortion and image bias in hybrid PET/MRI
2. Source of Artifacts
3. Observation
4. Solution

XXII. PET/MR Imaging artifacts

XXIII. Integrating PET/MR System

1. PET effects on the MR
2. PET/MR Motion Correction
3. PET/MR Implanted Material Artifacts

XXIV. Different appearances of artifacts

XXV. Effect of MRI-based PET AC

XXVI. Whole body [18 F]-FDG PET/MRI study with truncation artifact

XXVII. Coronal [18 F]-FDG PET/MRI of a Dementia Patient

XXVIII. PET/MRI Respiratory motion Artifact

XXIX. Partial volume effects (PVE) affect PET data quantification.

XXX. The high resolution morphological MRI data can be used for PET PVE correction

XXXI. PET/MRI Respiratory Motion Artifact

XXXII. 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

XXXIII. What PET can do for MR

XXXIV. Ways in Which PET Can affect MRI

XXXV. MR and PET Can Help Each Other

Contents

➢ Lecture 50: PET MR Workflow

Time: 120 minutes

Keywords: Whole-Body MRI;PET/CT; Hybrid Imaging; Workflow; Technical Aspect; contraindications; Cardiac pacemakers; ferromagnetic metallic materials; Gadolinium ; Nephrogenic systemic fibrosis; GBCA; NSF;18F-FDG;Biograph mMR; Simultaneous acquisition timeline; Sequential acquisition timeline; Sequential acquisition timeline; Partial Volume Effect Correction; Neurodegeneration.

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. General Aspects of Workflow in Imaging

1. Whole-Body MR
2. PET/CT

II. Options for Time Savings in Hybrid Imaging

III. Workflow and Logistic Considerations

IV. Patient Preparation Before Examination

V. 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
5. Nephrogenic systemic fibrosis (NSF)
6. GBCA stratify into three levels of apparent NSF-related risk
7. Group 1: Agents associated with the greatest number of NSF cases
8. Group 2: Agents associated with few, if any, unconfounded cases of NSF
9. Group 3: Agents that have only recently appeared on the market
10. Risk classification for contrast agents containing gadolinium
11. Gadolinium in Patients with Impaired Renal Function
12. PET/MR in Pregnant Patients
13. Gadolinium in Pregnant Patients
14. Standard tracer for 18F-FDG

VI. In-Bed Patient Preparation

VII. 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

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

1. Sequential PET/CT‑MR Imaging
2. 0 min: 18F-FDG injection
3. 25 min: uptake and placing of the patient in the MR scanner
4. 30‑60 min: MR scanning of the patient
5. 60‑90 min: PET/CT scanning of the patient, injection of the second patient at 30 min, and so forth
6. Sequential PET/CT‑MR Imaging

7. Simultaneous PET/MR Imaging

8. Current Literature

IX. 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

X. PET/MRI and Workflow

1. Imaging workflow for Biograph mMR

XI. Data Visualization, Analysis, and Reporting

1. Noise Equivalent Count Rate

2. Scatter Fraction

3. Contrast

4. Daily Quality Control Tests

5. Sinogram (uniformity) check

6. Weekly Quality Control Tests

a. Performance data of different pet scanners

10. Spatial Resolution

11. Scatter Fraction

12. Sensitivity

XXI. Image distortion in clinical PET/MRI

XXII. Current design of PET/MR system

1. General Electric (GE)

1. Ingenuity TF PET/MRI

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XXX. 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

XXXI. Performance measurements of the Siemens mMR integrated Whole-body PET/MR scanner

1. SIEMENS mMR 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)

XXXII. Systematic evaluation of phantom fluids for simultaneous PET/MR hybrid imaging

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

Contents

➢ Lecture 51: PET MR Fusion Imaging

Time: 60 minutes

Keywords: Clinical multimodality imaging; PET; CT; PET/CT; Arterial spin labeling (ASL); fMRI; Spectroscopy; Magnetic resonance tomograph (MRT); PET/MRI; Positron emission tomography; MR/PET

Objectives:

- Discuss Technical Evolution PET/MRI
- Explain Clinical Potential of PET/MRI
- Describe Clinical studies comparing 18F-FDG PET/CT and whole-body MRI
- Define where MRI is more sensitive than PET/CT, but where PET/CT is more accurate

Content:

I. PET/MRI: Technical Evolution
    1. Preclinical PET/MRI work
    2. The PET/MRI combination
        a. Technologic steps that modify state-of-the-art PET and MRI
    3. Prototype PET/MRI designs
        b. Philips
        c. Siemens

II. Clinical Potential of PET/MRI
    1. Criticism of PET/MRI
    2. The need for balance between opportunities and limitations of PET/MRI
    3. Arguments for replacing CT with MRI

III. Whole-Body PET/MRI

1. Clinical studies comparing 18F-FDG PET/CT and whole-body MRI
    a. PET/CT
    b. PET/MRI

IV. Conclusion

Contents

➢ Lecture 52: Cross Sectional Anatomy

Time: 90 minutes

Keywords: Thorax, Female Breast, Abdomen, Male and Female Pelvises.

Objectives:

- Discuss Cross Sectional Anatomy of Thorax
- Explain Cross Sectional Anatomy of Abdomen
- Describe Cross Sectional Anatomy of Female Breast
- Define Cross Sectional Anatomy of Female's and Male's Pelvis

Content:

I. Thorax

1. Axial
2. Sagittal
3. Coronal

V. Female Breast

VI. Abdomen

1. Axial
2. Sagittal
3. Coronal

VII. Pelvis

1. Female
    a. Axial

b. Sagittal
c. Coronal

2. Male
   a. Axial
   b. Sagittal
   c. Coronal

Contents

➢ Lecture 53: PET MR Site Planning

Time: 120 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, Anaesthesia 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

2. Zone II
3. Zone III
4. Zone IV

VI. Dedicated shielding requirements for simultaneous hybrid system

VII. Radiation safety & Hot-lab considerations

Contents

➢ Lecture 54: PET MR in Oncology

Time: 90 minutes

Keywords: Initial diagnosis, Staging, PET/MRI Lung Cancer, PET/MRI Ovarian Cancer

Objectives:

- Explain how the Prostate Cancer is being detected
- List the benefits of PET - MRI in oncological staging
- List the types of cancer most likely to show up on PET scans
- Understand the Benefits and Challenges of PET Oncology
- Explain PET/MRI Liver Disease

Content:

I. Diagnostic Oncology

II. MRI Oncology

1. What it shows
2. Introduction

III. DCE MRI in Oncology

1. DCE-MRI Data Acquisition and Analysis

a. Multiple images (typically 25-100) are acquired as a bolus of contrast agent passes through tissue capillaries

b. The region of interest for a tumor and the feeding vessel arterial input function are defined.

c. Signal intensity values for each voxel are converted into contrast agent concentration using a map of T1 values.

2. What Contrast is

3. What a Contrast Agent is

4. Why we need Contrast Agents

5. MRI contrast agents (CAs)

6. Contrast: Preparation Evolution (MRI)

7. Diffusion-Weighted MRI (DWI)

8. Comparison of TSE-FLAIR and EPI-FLAIR of the Brain a Patient with Subacute Stroke

9. Variations on MRI

a. T1

b. T2

IV. Breast MRI

1. MR Guided Biopsy

2. MR Breast

3. MR Breast Image

4. Brain Metastases on an MRI

5. MRI of the Prostate

6. Melanoma of the liver - MRI scan

7. MRI of SPINAL CORD

8. Functional and whole body MRI

9. Whole body MRI

10. Functional and whole body MRI

11. MRI Ovarian Cancer

V. Limitations of MRI (oncology)

VI. PET Oncology

VII. How PET works in Oncology

1. What PET sees

VIII. Cancer

1. PET scans may be useful in:

a. Detecting cancer

Revealing whether your cancer has spread

b. Checking whether a cancer treatment is working

c. Finding a cancer recurrence

2. PET scan

IX. USE of FDG

1. Over expression of Glucose transporters
2. Higher levels of Hexokinase
3. Down-regulation of Glucose-6-phosphatase
4. Anaerobic glycolysis, less ATP per glucose molecule, more glucose molecules needed for ATP production
5. General increase in metabolism from high growth rates
6. PET Scan Image

X. FDG-PET Scans

1. Clinical Uses of PET in Oncology
    a. Initial diagnosis
    b. Staging
    c. Monitoring response to therapy
2. PET vs. MRI

XI. Benefits of PET Oncology

1. Earlier diagnosis
2. Evaluates Response to Therapy
3. Identifies distant metastases
4. Eliminates invasive procedures
5. Pre-surgical assessment
6. Post-surgical assessment
7. Oncologic Imaging
    a. PET + MR = anatomic + functional + molecular imaging
8. Why it is used

XII. The Role of PET/MRI in Oncology

1. The benefits of PET - MRI in oncological staging
2. With the rapid evaluation of response to treatment
3. Overview of Cancer Imaging
4. Assessment of Local Tumor

XIII. PET/MRI Case Studies

1. PET/MRI Exams

2. PET/MRI Head and Neck
3. PET/MRI Brain Tumor
4. PET/MRI Breast Cancer
5. PET/MRI Bone Marrow
6. PET/MRI Cervical Cancer
7. PET/MRI Colorectal Cancer
8. PET/MRI Esophageal Cancer
9. PET/MRI Liver Disease
10. PET/MRI Lung Cancer
11. PET/MRI Lymphoma
12. PET/MRI Melanoma
13. PET/MRI Neuroendocrine Tumors
14. PET/MRI Ovarian Cancer
15. PET/MRI Prostate Cancer
16. PET/MRI Renal Cancer
17. PET/MRI Head & Neck Cancer
18. PET/MRI Testicular Cancer
19. PET/MRI Spinal canal
20. PET/MRI Sarcoma
21. PET/MRI Thyroid Cancer
22. PET/MRI Oncology Challenges

XIV. PET/MRI Oncology Challenges

1. Ongoing Challenges and Future Directions

Contents

➢ Lecture 55: PET MR Neurology

Time: 120 minutes

Keywords: Diffusion Tensor Imaging, Brownian motion or pedesis, Amyloid Imaging

Objectives:

- Explain what Neurology is
- Define Medical imaging

- List the three basic parts to a Neuron
- Differentiate the central nervous system (CNS) from the peripheral nervous system (PNS)
- Explain the APD-based PET

Content:

I. Diagnostic Imaging

1. Medical imaging

II. What PET/MR is

1. Why PET/MR

III. Why PET/MR Neurology

1. Stand Alone MRI
2. Stand-Alone PET
3. Hybrid PET/MRI

IV. PET/MR Scan Procedure

1. PET/MR Coil Suite
    a. 8-channel High Resolution Brain
    b. Head Neck Unit (HNU)

V. Hybrid PET/MR

1. Hybrid Imaging
2. Key information about the Biograph mMR scanner
3. Dual-Modality Preclinical PET and MRI Imager for Preclinical Studies
4. Digital APD-based PET for artifact-free PET imaging
5. Cryogen-free, self-shielded 3.0T MRI

VI. PET/MRI For Neurological

1. What neurology is
2. Structure and Function

VII. Nervous System

1. Central nervous system (CNS)

a. Brain and spinal cord

b. Cerebrum (or brain)

c. Cerebellum (or “little brain”)

d. Brain stem

e. Frontal lobe

f. Parietal lobe

g. Occipital lobe

h. Temporal lobe

2. Cells of the Nervous System

a. Neurons: Cell body, Axon, Dendrites

b. Neuroglia: astrocytes, oligodendrocytes, microglia, ependymal cells

3. Spinal Cord

4. Peripheral nervous system (PNS)

a. Sympathetic

b. Parasympathetic

VIII. Neurodegeneration

1. Neurological disorders

IX. Diffusion Tensor Imaging (DTI)

1. Brownian motion

2. Diffusion tensor imaging superior at detecting signs of DAI

3. What's Tensor?

4. Diffusion Tensor Imaging of the Brain

5. Biological Diffusion

6. How DTI Works

a. Limitations of MRI and the Importance of Contrast Generation

X. What Is Diffusion and Why Is It Important

1. Water molecules move, even in postmortem brains, unless the sample is frozen;

2. DTI uses this water motion as a probe to infer the neuroanatomy

3. The information DTI carries is dominated by static anatomy and is less influenced by physiology.

XI. How Diffusion is measured by MRI

XII. MRI Measures Water Diffusion along One Predetermined Axis

XIII. Tensor Calculation Is Required to Determine Precise Fiber Orientation

XIV. Three-Dimensional Structures of Axonal Bundles Can Be Reconstructed from DTI Data

XV. Practical Aspects of Data Acquisition

1. DTI imaging of brain

XVI. Why PET/MRI for Neuroimaging

XVII. Systematic Addition of Anatomic Information

XVIII. Correction for Atrophy and Partial-Volume Effects

XIX. Correction of Factors That Influence Regional Tracer Supply

XX. Quantification of PET Tracer Uptake

XXI. Head Motion Correction

XXII. Cross-Validation of Imaging Procedures

XXIII. Diagnostic Improvement

1. Individual Value of Neuroimaging Markers of Neurodegeneration
2. MR Imaging

XXIV. 18F-FDG PET

XXV. Amyloid Imaging

XXVI. Differential Diagnosis

XXVII. PET/MR Neurology

1. History of PET/MR

XXVIII. PET/MRI: Technical Evolution

1. First, the photomultiplier technology must be replaced with magnetic field‐ insensitive photodiodes.
2. Second, compact PET detectors must be constructed so that it shouldn't interfere with the field gradients or MR Radiofrequency.
3. Finally, the MRI scanner must be adapted to accommodate the PET detectors and to allow simultaneous data acquisition without mutual interference.

XXIX. History of PET/MR

XXX. Utilization of Hybrid PET/MR in Neuroimaging

XXXI. Clinical Potential of PET/MRI

1. Neuroimaging

XXXII. PET Neurology

XXXIII. MRI - Head

XXXIV. Advanced PET-MRI Fusion Algorithm

XXXV. PET/MR Scanner Design

XXXVI. MR-based PET Motion Correction

1. MR-based motion correction has the potential to improve PET as a quantitative method

XXXVII. Alzheimer’ s Disease

XXXVIII. Partial Volume Effects Correction

XXXIX. Image-based Radiotracer Arterial Input Function Estimation

XL. Technique Cross-calibration And Validation

1. Cerebral Perfusion
2. Neuronal Activation
3. Brain Baseline State
4. Brain Connectivity Measures

XLI. Advantages of simultaneous PET/MR Brain

1. Brain Tumors

XLII. Dementia / Neurodegeneration

XLIII. Stroke / Cerebrovascular Disorders

XLIV. Neurobiology of Brain Activation

XLV. PET/MR Neurology

Contents

➢ Lecture 56: PET MR Cardiology

Time: 90 minutes

Keywords: Endocardium, Right ventricle, Capillaries, Bright Blood

Objectives:

- Explain gadolinium contrast medium
- Define Arteries
- List things to avoid before PET heart scan
- Differentiate between the Workflow of MRI only and PET/MRI
- Understand Heart's Anatomy

Content:

I. The cardiovascular system

1. What is the cardiovascular system?
2. Functions of the Cardiovascular System
3. Why Does Blood Flow
4. Blood Vessel
    a. Arteries
    b. Capillaries
    c. Veins

II. Heart Anatomy

1. Pulmonary circuit
2. Systemic circuit
    a. Right atrium
    b. Right ventricle
    c. Left atrium
    d. Left ventricle

III. Coverings of the Heart: Anatomy

1. Pericardium: A double-walled sac around the heart composed of:
    a. A superficial fibrous pericardium
    b. A deep two-layer serous pericardium
2. The Function of the Pericardium
3. Heart Wall
    a. Epicardium
    b. Myocardium
    c. Fibrous skeleton
    d. Endocardium
4. Thickness of Cardiac Walls
    a. Myocardium of left ventricle is much thicker than the right
5. Location of the Heart in the Thoracic Cavity
    a. Anterior view of the open chest cavity, showing the position of the heart and major vessels relative to the lungs.
    b. Relationships between the heart and the pericardial cavity. The pericardial cavity surrounds the heart like the balloon surrounds the fist (right).
    c. Diagrammatic view showing the position of the heart and the location of other organs within the mediastinum. In this sectional view, the heart is shown intact so you can see the orientation of the major vessels.
    d. Superior view of a horizontal section through the trunk at the level of vertebra.

IV. MRI Scanner

V. Why A Heart MRI Is Done?

1. What is a Heart MRI?
2. Background of the MRI scanner
3. The Risks of a Heart MRI

2. DO NOT SMOKE ON THE DAY OF THE TEST

3. DO NOT TAKE Medications with caffeine

XIX. How the Test is performed

XX. PET tracer of myocardial blood flow

1. Agent

2. Physical half-life

3. Mean positron range

4. Production

a. N-13 ammonia

b. Rubidium-82

c. O-15 water

5. Imaging Modes

XXI. Multidimensional PET acquisition

XXII. Image reconstruction

XXIII. Algorithm

1. Filtered back projection

XXIV. Attenuation correction

XXV. 2D/3D reconstruction

XXVI. Benefits of a PET scan

XXVII. Risks of a Cardiac PET scan

XXVIII. Pet Scanner

XXIX. Principles of Coincidence Detection

XXX. PET Tracer of Myocardial Blood Flow

XXXI. Imaging Modes

XXXII. PET Image Reconstruction

XXXIII. Image Reconstruction

XXXIV. Limitations of a Cardiac PET scan

XXXV. PET Heart Images

XXXVI. Hybrid PET/MR

XXXVII. Hybrid PET/MR Cardiac

XXXVIII. Why We Need Hybrid PET/MR

XXXIX. Technical Advances of PET/MR System

1. Software Advances

XL. Myocardial Perfusion Imaging and Blood Flow Quantitation with PET/MRI

XLI. What MR Imaging Can Bring To Cardiac Pet Imaging

XLII. What PET Can Bring To Other CMR Applications

XLIII. Workflow Considerations

XLIV. Advance Research on PET/MR

XLV. Future Challenges

Contents

➢ Lecture 57: Pediatric PET MR

Time: 120 minutes

Keywords: Pediatric MR; Pediatric PET/MR;PET/MR Procedures; Imaging technique; Imaging protocols; Table Movement and Coils; Coronal STIR ;T1-weighted;T1-weighted fast spin echo; SSFP; Computed tomography; Lymphoma; Solid Tumors;18 fluorodeoxyglucose (FDG).

Objectives:

- Describe Pediatric MRI
- Explain Table Movement and Coils
- Review Pediatric MRI (Technical Considerations)
- Review Pediatric MRI (Clinical Applications)
- Define Single-shot fast spin echo
- Describe Lymphoma, solid Tumors

Content:

I. Pediatric MRI

II. Pediatric MRI (Technical Considerations)

1. Table Movement and Coils
2. Imaging Sequences and Technique
    a. Coronal STIR
    b. T1-weighted
    c. T1-weighted fast spin echo

d. Contrast material‑enhanced T1-weighted three-dimensional gradient echo

e. Single-shot fast spin echo

f. Steady-state free precession (SSFP)

III. Pediatric MRI (Clinical Applications)

1. Oncologic Applications

a. Lymphoma

b. Solid Tumors

c. Screening of Children with a Cancer Predisposition Syndrome

2. Nononcologic Applications

IV. Oncologic Applications

1. Neurofibromatosis, osteonecrosis after intensive chemotherapy

2. Dermatomyositis

3. Extent of osseous lesions in patients with McCune-Albright syndrome

4. Disseminated cysticercosis

V. Whole-Body Diffusion-weighted Imaging

1. Pediatric MRI (Clinical Applications)

2. Pediatric PET

a. PET Technique

b. Broselow Pediatric Emergency Tape

c. PET Dosimetry

d. 18F-FDG PET CARDIAC IMAGING

e. NORMAL VARIANTS AND DISTRIBUTION

VI. Pediatric PET/MR

VII. PET/MR Procedures

1. What to Wear and Going There

2. Pediatric patient Need an IV

3. The PET/MRI Scan

VIII. Imaging technique

IX. Imaging protocols

1. Head

2. Chest

3. Abdomen

4. Pelvis

5. Sequence parameters of the whole-body MR protocol

X. Preliminary findings

XI. POTENTIAL APPLICATIONS IN PEDIATRIC ONCOLOGY

1. Lymphoma

XII. Lymphomas in children

XIII. Solid child-like tumors even in solid tumours

XIII. Neuroblastoma

XIV. POTENTIAL APPLICATIONS IN NEUROIMAGING

1. Brain Tumors

2. Epilepsy

3. Primary Bone Tumors

4. Soft-Tissue Tumors

XV. POTENTIAL APPLICATIONS IN INFECTIOUS AND INFLAMMATORY DISEASES

XVI. Pediatric Cardiology

XVII. Maternal‑Fetal Medicine

XVIII. Evaluation of treatment response and follow-up

IXX. Limitations and pitfalls in PET/MR

Contents

➢ Lecture 58: PET MR Breast Cancer

Time: 120 minutes

Keywords: Screening tests, Fine Needle Aspiration (FNA) Biopsy, galactogram

Objectives:

- Explain Ductal carcinoma in situ
- Define Staging
- List TNM Stages 0-IV
- Differentiate N1 between pN1mi
- Understand Stereotactic Core Biopsy

Content:

I. What is the Structure of the Breast?

II. How is breast cancer staged?

1. Ductal carcinoma in situ
2. Invasive (or infiltrating) ductal carcinoma
3. Invasive (or infiltrating) lobular carcinoma
4. The T stages (tumor)
5. T1 is further divided into 4 groups
6. T4 is divided into 4 groups
7. The N stages (nodes)
    a. N1
    b. pN1mi
    c. N2 is divided into 2 groups
    d. N3 is divided into 3 groups
    e. The M stages (metastases)
8. Stages of Breast Cancer Using the T, N, M System
    a. Stage I
    b. Stage IIA
    c. Stage IIB
    d. Stage IIIA
    e. Stage IIIB
    f. Stage IIIC
    g. Stage IV

III. Stages of Breast Cancer Using the T, N, M System

IV. How is breast cancer diagnosed?

1. Screening tests
2. Diagnostic tests
3. Biopsy
    a. Ultrasound-guided Core Biopsy
    b. Needle (Wire) Localization Biopsy
    c. Vacuum-assisted core biopsy
4. Monitoring tests

V. Imaging tests used to evaluate breast disease

1. Diagnostic mammogram
2. Breast ultrasound
3. Magnetic resonance imaging
4. Ductogram
5. Chest X-Rays
6. Bone scan
7. CT (CAT) Scans (Computerized Tomography)
8. Positron emission tomography (PET) scan
9. FDG PET, PET/CT, and Breast Cancer
10. Breast Cancer Detection with FDG PET
11. Principles of FDG PET/CT
12. FDG Uptake of Breast Cancer Depends on the Histologic and Biologic Characteristics of the Tumor
13. FDG PET/CT Has Little Role in Differentiating Benign from Malignant Breast Lesions
14. FDG PET/CT

VI. Positron Emission Mammography (PEM)

VII. PET/MR in Breast Cancer

1. Part I. Current Status of Imaging
    a. Technical Recommendations
    b. Clinical Use
    c. Preoperative Breast MRI
    d. Assessment of the Response to Neoadjuvant Chemotherapy
    e. Breast MRI for Occult Primary Breast Cancer
    f. Breast MRI for Diagnosis of Local Recurrence
    g. PET Tracers for Breast Cancer
    h. 18F-FDG Metabolic Tracer
    i. Steroid Receptor PET Tracers
    j. HER2 Receptor PET Tracers
    k. Tumoral Gastrin-Releasing Peptide Receptors Radiolabeled Analogs
    l. Membrane Lipid Synthesis PET Tracers
    m. Amino Acid PET Tracers
    n. PET Imaging of Hypoxia

o. Neovascularization Biomarkers

p. PET Tracers for Bone Metastases

q. For Screening or to Confirm Diagnosis Locally?

r. For Initial Staging?

s. For the detection of distant metastases

t. For inflammatory breast cancers

u. For the Evaluation of Response to Therapy in Breast Cancer?

v. For Patient Follow-up, Recurrence Detection, and Restaging of Patients With Breast Cancer?

w. Current Role of PET/CT in the Planning of Radiation Therapy PET/CT-guided radiotherapy planning is widely used

2. Part II. Current Status of Hybrid PET/MR in Breast Cancer Imaging

a. Local Assessment of Breast Cancer

b. A 16-channel MR coil for simultaneous PET/MR imaging in breast cancer

c. Regional and Distant Staging

d. Regional Lymph Nodes Assessment

e. Distant Metastasis

f. Liver Metastases

g. Bone Metastatic Invasion

h. Lung Metastases

i. Brain Metastases

j. Evaluation of Response to Therapy

k. Follow-up, Recurrence Detection, and Restaging Patients with Breast Cancer

3. Part III. Potential Improvements and Future Role

l. New MRI Sequence and Use of Functional MRI, Including Spectro-MRI in Routine

m. Improvements in PET Technology and New PET Tracers

n. Radiation Therapy Planning With PET/MR

VIII. Problems with Supine PET

IX. Prone MRI and PET

X. Management of Breast Lesions

XI. Limitations

XII. Breast MRI for Screening

XIII. Current Status of PET in Breast Cancer Imaging

XIV. 18F-FDG-PET Applications in Management of Breast Cancer

XV. Potential Improvements and Future Role

XVI. Tracer for Breast cancer imaging BEYOND FDG

1. Imaging Apoptosis with Annexin V Derivatives

XVII. Protocol Considerations: whole-body FDG-MR_PET with integrated FDG-MR-PET Mammography

XVIII. MR-PET Mammography

XIX. Restating

XX. Follow-up

Contents

➢ Lecture 59: PET/MR Contrast Agents Reaction and Treatment

Time: 90 minutes

Keywords: Regulatory Authority, Imaging Agents or Tracers, Types of Medical Imaging Agents, Contrast Agents, MRI Contrast Agents, Gastrointestinal MRI contrast agents, Intravenous MRI contrast agents, Intravascular (blood pool) MRI contrast agents, Tumor specific MRI contrast agents, Hepatobiliary MRI contrast agents, Reticuloendothelial MRI contrast agents, Gadolinium Contrast Medium (MRI Contrast agents), Contrast Agent Nanoparticle, Risk of Contrast Agent, Treatment Of Contrast Reactions

Objectives:

- Discuss the Contrast agent for MRI and PET Scan
- Explain Various forms of contrast media have been used to improve medical imaging
- Describe Contrast agent reaction and Treatment
- Recognizing and managing the small but real risks inherent in the use of contrast media

Content:

I. Introduction

II. Regulatory Authority

1. The European Medicines Agency (EMA)
2. The Food and Drug Administration (FDA or USFDA)
3. Food and Drug Administration (Guidelines)
    a. Conducting Safety Assessments
    b. Clinical Indication

c. Design, Analysis, and Interpretation of Clinical Studies

III. Imaging Agents or Tracers
    1. Other common names
        a. Contrast Agent
        b. Radioactive Agent
        c. Radioactive Dye
        d. Radiopharmaceutical
    2. PET and Nuclear Medicine Imaging Agents
        a. 64Cu-ATSM
        b. FDG (18F-fluorodeoxyglucose)
        c. 18F-fluoride
        d. FLT
        e. FMISO
        f. Gallium
        g. Technetium-99m
        h. Thallium
IV. Types of Medical Imaging Agents
    1. Diagnostic Radiopharmaceuticals
    2. Contrast Agents
V. Contrast Agents
VI. MRI Contrast Agents
    1. Definition of Contrast in MRI
    2. History
    3. Why we need Contrast Agents
    4. Paramagnetic
    5. Diamagnetism
    6. Superparamagnetic
    7. Ferromagnetic
VII. Gastrointestinal MRI contrast agents
    1. Positive Contrast Agents
        a. Paramagnetic Agents
        b. Short T1-relaxation Agents

c. Combination Contrast Agents

2. Negative Contrast Agents
    a. Diamagnetic Agents
    b. Superparamagnetic Agents
    c. Perfluorochemicals Agents

VIII. Intravenous MRI contrast agents
    1. Ionics
    2. Nonionics
        a. Gadodiamide
        b. Gadoteridol

IX. Intravascular (blood pool) MRI contrast agents
    1. Advantages of Intravascular Agents
    2. Types of Intravascular Contrast Agents
        a. Gd-DTPA labeled albumin
        b. Gd-DTPA labeled dextran
        c. Chromium-labeled red blood cells

X. Tumor specific MRI contrast agents
    1. Monoclonal antibodies
    2. Metalloporphyrins
    3. Nitroxides
    4. Ferrioxamine methanesulfonate

XI. Hepatobiliary MRI contrast agents
    1. Manganese chloride
    2. Hepatobiliary chelates

XII. Reticuloendothelial MRI contrast agents
    1. Liver and spleen imaging
    2. Lymph node imaging

XIII. Gadolinium Contrast Medium (MRI Contrast agents)
    1. Gadolinium contrast medium
    2. Why do I need to have gadolinium contrast medium?
    3. The risks of gadolinium contrast medium injections

XIV. MRI Contrast Agent Nanoparticle

1. Nanoparticles(NPs)
2. Effects of SPIONs on MRI contrast

XV. Risk of Contrast Agent

1. Gadolinium-Based Contrast Agents Linked to Brain Hypersensitivity
2. Categories of Reactions
    a. Mild
    b. Moderate
    c. Severe
3. Types of reactions
    a. Anaphylactoid
    b. Nonanaphylactoid (chemotoxic, vasovagal, idiopathic reactions)
    c. Combined (1 and 2)
4. Incidence of Adverse Effects
5. Patient Selection and Preparation Strategies
6. Administration of contrast medium to breast feeding mothers
7. Injection of Contrast Media
8. Injection Discomfort / Pain
9. Extravasation Risk Factors
10. Extravasations of IV contrast
11. Contrast Reactions In Children
12. Adverse Reactions to Gadolinium-based Contrast Media
13. Treatment
14. Other Risk Factors
15. Administration of IV Contrast Media
    a. Policy
    b. Procedure

XVI. Treatment Of Contrast Reactions

1. Five important immediate assessments
2. Administration Of Contrast Media To Pregnant Or Potentially Pregnant Patients
3. Gadolinium-Based Contrast Agents (GBCAs)
    a. Mutagenic effect of GBCAs
    b. Risk of nephrogenic systemic fibrosis

c. Recommendations for the use of GBCA-enhanced MRI examinations in pregnant patients

4. Administration Of Contrast Media To Women Who Are Breast- Feeding
    a. Recommendation
5. Organ and System-Specific Adverse Effects from the Administration of Iodine-Based or Gadolinium-Based Contrast Agents
6. Treatment of Acute Reactions to Contrast Media in Children
7. Management of Acute Reactions to Contrast Media in Adults
8. Equipment for Contrast Reaction Kits in Radiology
9. Warming of Gadolinium-Based Contrast Media—Suggestions
    a. Recommendation

Contents

➢ Lecture 60: PET/MR Fusion/Case Studies

Time: 120 minutes

Keywords: MRI Case Study, PET/MR Case Study, PET/MR in Children Case Study, cross sectional anatomy, MRI Cervical Spine, Magnetic Resonance (MR) Defecography, Myeloma, Neuroendocrine tumor (NET), Lung cancer, Examination for Ca Breast, Brain imaging, Head and neck oncology, Lung cancer with metastatic disease, Cardiac imaging, Cervical and vulvar cancers, Lymphomas in children

Objectives:

- Discuss MRI and PET/MR Case Studies
- Explain "Normal and Abnormal" case studies
- Describe of three-dimensional organization of anatomy and physiological patterns
- Define of structural organization of the human body
- Illustrate cross sectional CT, MRI, PET/MR anatomical detail
- Review cross sectional anatomy in representation of anatomical positions, sizes, shapes, and relationships of structures

Content:

I. MRI Case Study
    1. MRI Cervical Spine
        a. Background

b. Methods
c. Diagnostic Results

2. Magnetic Resonance (MR) Defecography
    a. Patient history
    b. Physical examination
    c. Provisional diagnosis
    d. MRI technique and Findings
3. Case Studys: findings, diagnosis, discussion
    a. Contrast-enhanced MR angiography of the neck
    b. T1 weighted MR image of the knee
    c. MRI was performed due to right hip pain
    d. MRI of a 47 year old patient who presented to ED with epilepsy
    e. A 58-year-old male with chest pain and clammy sweat
    f. A 66-year-old male patient with chest pain

II. PET/MR Case Study
1. 18 F-FDG PET/MR: Its Incremental Value in Assessing the Multiple Myeloma Patient
    a. A 68-year-old female with pain of back, rib, and right hip, which appeared related to exercise (imaging findings, diagnosis, discussion and conclusion)
    b. A patient in their early 60s with a newly diagnosed, well-differentiated neuroendocrine tumor with hepatic metastasis (imaging findings, diagnosis, discussion)
2. Evaluation of metastatic spread in case of a neuroendocrine tumor (NET)
3. Evaluation of lung cancer
4. Simultaneous PET MRI: Single Stop Examination for Ca Breast
5. Other clinical cases
    a. Brain imaging
    b. Head and neck oncology
    c. Lung cancer with metastatic disease
    d. Cardiac imaging
    e. Cervical and vulvar cancers

III. PET/MR in Children Case Study
1. Lymphomas in children

a. An 11-year-old boy with T-cell lymphoma with involvement of the neck, mediastinum, kidneys and bone marrow
b. A 13-year-old boy with Hodgkin disease stage II
c. A 2.5-year-old boy with bilateral cervical Burkitt lymphoma

2. Solid child-like tumours
    a. A 15-year-old boy with left testicular tumour with left retroperitoneal, supraclavicular and hepatic metastases
    b. A 2-year-old boy with a large abdominal neuroblastoma that emanates from the sympathetic chain
3. Evaluation of treatment response and follow-up

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