Magnetic Resonance Curriculum

A Multiorganizational Curriculum Project Group produced this MR Curriculum.

Acknowledgements

Just as the modality and applications of Magnetic Resonance are complex and dynamic (and sometimes long), so too was the development of this multiorganizational MR curriculum. In 2006, the American Society of Radiologic Technologists (ASRT), the Association of Educators in Imaging and Radiologic Sciences (AEIRS) and the Section for Magnetic Resonance Technologists of the International Society for Magnetic Resonance in Medicine (SMRT) came together at a Summit with a unified mission:

To develop a nationally recognized entry-level MRI Curriculum that includes didactic and clinical competencies.

Also at the Summit were the American Registry of Radiologic Technologists (ARRT) and the Joint Review Committee on Education in Radiologic Technology (JRCERT), both in support of this multiorganizational approach.

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As MR continues to evolve, so too will this MR curriculum guideline. Please forward any comments to the ASRT, AEIRS or SMRT. All three organizations will continue to work collaboratively to support this effort.

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Luann J. Culbreth

Magnetic Resonance Curriculum

Introduction

This curriculum identifies the cognitive base of entry-level education in the practice of magnetic resonance (MR) technology. This document represents a collaborative effort involving representatives from the American Society of Radiologic Technologists (ASRT), Association of Educators in Imaging and Radiologic Sciences (AEIRS) and the Section for Magnetic Resonance Technologists (SMRT) of the International Society for Magnetic Resonance in Medicine (ISMRM).

This curriculum document establishes national, standardized educational guidelines for MR, including clinical and didactic components. The curriculum is suitable for all programs in this discipline, including limited fellowships, certificate programs, as well as collegiate-based education programs. The curriculum recognizes that the educational components are not static, but represent current practice and trends in the field. Educators are responsible for incorporating new concepts and trends in the curriculum as they occur.

This document contains education appropriate to body areas defined through examinations of the ARRT. The content is designed to assure quality patient care and production of quality diagnostic images.

This curriculum is divided into specific content areas that represent the essential components of an MR program. The content and objectives should be adapted to meet the mission, goals and needs of each MR program. Faculty members are encouraged to expand and broaden these fundamental objectives as they incorporate them into their curricula. The curriculum committee intentionally omitted specific instructional methods to encourage programmatic prerogative and creativity in instructional delivery.

Advances in diagnostic imaging and employer expectations demand independent judgment by MR technologists. Consequently, the educational process must foster, develop and assess critical-thinking skills. Critical thinking is incorporated in multiple content areas and faculty is expected to develop and implement critical thinking throughout the curriculum. In summary, the MR curriculum is based on data relevant to today's health care environment. The curriculum offers a foundation for lifelong learning that will serve MR technologists throughout their careers. It offers faculty the flexibility to develop curriculum designed to meet the needs of individuals performing diagnostic magnetic resonance procedures.

Magnetic Resonance Curriculum

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Clinical Practice and Patient Management

Description
Content is presented as a progression in competency levels through clinical performance objectives and competency exams. Students can access the facilities, personnel, examinations and educational materials necessary to competently achieve content objectives. Activities include demonstration and observation, after which the student assists in performing the activity. When a satisfactory degree of proficiency is apparent, the student can perform the activity under direct supervision. When both the student and instructor are satisfied with the student's proficiency, the student performs studies under indirect supervision to gain experience and expertise in MR imaging.

Rationale
Technologists performing magnetic resonance imaging must competently apply basic protocols, recognize when and how to appropriately alter the standard protocol and recognize equipment and patient considerations that affect image quality. The technologist is responsible for maintaining a safe MRI environment. This course provides the necessary supervised clinical education to become proficient in these skills.

Prerequisites
1. Introduction to MRI — coursework that provides the basic terminology of imaging parameters, patient screening and safety for the patient and personnel within the MRI department.
2. Didactic coursework proceeds or is offered in conjunction with the clinical education.

Objectives
Upon completion of the clinical education, the student will:
1. Maintain a safe work environment for patients, visitors and health care workers.
2. Properly schedule and prescreen patients.
3. Communicate professionally with patients and staff members.
4. Use standard protocols to perform routine MR examinations.
5. Use DICOM to archive and send images.
6. Identify when to modify a protocol and successfully perform the modification.
7. Identify the probable cause of image quality problems and recommend an appropriate solution.
8. Perform and monitor quality assurance tests.
9. Power up and shut down the system.
10. Correlate the requested exam with clinical history and reported physical exam findings.
11. Ensure patient safety by correlating surgical, accident and occupational history.
12. Properly screen patients for contraindications to MR.
13. Monitor the patient to ensure proper attire and that no unauthorized metals enter the exam room.
14. Maintain a clean, comfortable and safe environment.

15. Employ proper precautions to prevent disease transmission.
16. Monitor linens and supplies and restock when necessary.
17. Demonstrate how to properly prepare a patient for the requested exam.
18. Demonstrate the actions required if a patient requires sedation.
19. Demonstrate the actions required if a patient requires contrast media.
20. Demonstrate the actions required for allergic reactions.
21. Demonstrate the actions required if a patient is claustrophobic.
22. Demonstrate how to use earplugs or headphones to reduce possible acoustic damage.
23. Ensure proper setup of MR coils, equipment, table accessories and cushioning.
24. Demonstrate an understanding of a patient's cultural, ethnic or value system differences.
25. Speak with patients in a professional and empathetic manner to alleviate any concerns they express.
26. Demonstrate professional ethics by preserving the patient's modesty.
27. Demonstrate how to give proper instructions to optimize patient comfort and cooperation.
28. Respond appropriately in emergency situations.
29. Recognize patient adverse reactions during MR procedures to contrast administration and act appropriately.
30. Identify and report equipment problems.
31. Adhere to national, organizational and departmental standards, protocols, policies and procedures regarding MR exams and patient care.
32. Ensure that professional performance and competence is reflected throughout an exam.
33. Critique images for appropriate clinical information, image quality and patient information.
34. Demonstrate the appropriate corrective actions to improve inadequate image information.
35. Consistently maintain patient confidentiality standards.
36. Perform safe, ethical and legal practices.

Content

I. Clinical Practice

A. Code of ethics/professional behavior
   1. Scope of practice
   2. Incident reporting mechanisms
   3. Standards for supervision
      a. Direct
      b. Indirect

B. Professional communication
   1. Patient
   2. Patient's family and friends
   3. Health care team

C. Role of health care team members
   1. Technical
   2. Professional
   3. Patient's Bill of Rights

D. Scheduling and sequencing exams

II. Procedural Performance

A. Order/requisition evaluation and measures

B. Facilities setup

C. Patient assessment, education and care
   1. Patient monitoring – emergent and non-emergent
      a. Vital signs – ranges and values
   2. Temperature
      a. Fahrenheit
      b. Celsius
   3. Pulse
   4. Respiration
   5. Blood pressure
   6. Normal values
   7. Interfering factors
   8. Terminology
   9. Adult vs. pediatric
   10. Documentation
   11. Pain assessment
   12. Body type

D. Acquiring and recording vital signs
   1. Procedures
   2. Demonstration

E. Review of laboratory data
   1. Normal ranges for:
      a. Blood urea nitrogen (BUN)
      b. Creatinine
      c. Hemoglobin
      d. Red blood cells (RBCs)
      e. Platelets
      f. Oxygen (O_2) saturation
      g. Prothrombin
      h. Part thromboplastin time
      i. Glomerular filtration rate calculation (GFR)

F. Patient chart
   1. Aspects of patient chart
   2. Retrieving specific information
   3. Proper documentation in the chart

III. Infection Control

A. Terminology
   1. Nosocomial
   2. Communicable
   3. Infectious pathogens
   4. Human immunodeficiency virus (HIV)
   5. Hepatitis
      a. Hepatitis A Virus (HAV)
      b. Hepatitis B Virus (HBV)
      c. Hepatitis C Virus (HCV)
      d. Hepatitis D Virus (HDV)
      e. Hepatitis E Virus (HEV)
      f. Others

B. Centers for Disease Control and Prevention (CDC)
   1. Purpose
   2. Publications and bulletins

C. Cycle of infection
   1. Infectious pathogens – blood-borne and airborne
   2. Reservoir of infection
      a. Direct
      b. Indirect

D. Preventing disease transmission
   1. Transmission-based precautions
   2. Health care worker
      a. Immunization
      b. Booster
      c. Post-exposure protocols

E. Asepsis
   1. Medical
      a. Definition
      b. Procedures
         1) Hand washing
         2) Chemical disinfectants
   2. Surgical
      a. Definition
      b. Growth conditions for microorganisms
      c. Methods used to control microorganisms
         1) Moist heat
            a) Boiling
            b) Steam under pressure
         2) Dry heat

a) Incineration
b) Dry heat sterilized
3) Gas
4) Chemicals

d. Procedures – demonstrate
1) Opening packs
2) Gowning/gloving
3) Skin preparation
4) Draping
5) Dressing changes

e. Packing
f. Storage
g. Rules for surgical asepsis

F. Environmental asepsis
1. Handling linens
2. Wound care
a. Cleansing
b. Dressing
3. Techniques
a. Dress
b. Hair
c. Handwashing
d. Gloves
e. Eye protection
f. Cleaning and proper disposal of contaminated waste
4. Practice

G. Isolation techniques and communicable diseases
1. Category-specific
2. Disease-specific
3. Standard precautions
4. Examples
a. HIV virus (AIDS)
b. Hepatitis
1) Type A
2) Type B
3) Type C (non-A or -B)
4) Type D
5) Type E
c. Tuberculosis (TB)
d. Respiratory syncytial virus (RSV)
e. Other

H. Isolation patient in the imaging department

1. Procedure
    a. Gowning
    b. Gloving
    c. Masking
2. Patient transfer
3. Cleaning and proper disposal of contaminated waste
4. Cleaning of imaging equipment

I. Precautions for compromised patient (reverse isolation)
1. Purpose
2. Procedure

J. Psychological considerations

IV. Medical Emergencies

A. Terminology

B. Emergency equipment

C. Latex reactions

D. Shock
1. Signs and symptoms
2. Types
    a. Hypovolemic
        1) Hemorrhage
        2) Plasma loss
        3) Drugs
    b. Disruptive
        1) Anaphylactic
        2) Neurogenic
        3) Septic
3. Medical intervention

E. Diabetic emergencies – signs, symptoms and interventions
1. Hypoglycemia
2. Ketoacidosis
3. Hyperosmolar coma

F. Respiratory and cardiac failure – signs, symptoms and interventions
1. Adult vs. pediatric
2. Equipment

G. Airway obstruction – signs, symptoms and interventions

H. Cerebral vascular accident (stroke) – signs, symptoms and interventions

I. Fainting and convulsive seizures, signs, symptoms and interventions
   1. Types
      a. Nonconvulsive (petit mal)
      b. Convulsive (grand mal)
   2. Reasons for fainting

J. Other medical conditions
   1. Epistaxis
   2. Nausea
   3. Postural hypotension
   4. Vertigo
   5. Asthma
   6. Psychiatric

K. Unique Situations and Trauma
   1. Head injuries
   2. Four levels of consciousness
   3. Symptoms
   4. Medical intervention
   5. Adult vs. pediatric

L. Spinal injuries
   1. Assessment
   2. Symptoms
   3. Medical intervention
   4. Transportation

M. Extremity fractures
   1. Types
   2. Symptoms
   3. Splints
   4. Casts
   5. Positioning
   6. Adult vs. pediatric

N. Wounds
   1. Symptoms
   2. Medical intervention

O. Burns
   1. Burn classifications
   2. Medical intervention

P. Reactions to contrast agents
    1. Signs and symptoms of mild, moderate and severe contrast reactions
    2. Medical interventions for each type of reaction
    3. Vasovagal reactions

V. Contrast Studies

A. Patient education
    1. Technologist's responsibility
    2. Standard procedure

B. Preparation for examination
    1. Diet
    2. Bowel preparation
        a. Laxatives
        b. Enemas
    3. Care during the procedure
    4. Follow-up care

C. Procedure
    1. Monitoring and care during invasive procedures
        a. Preparation for MR-compatible cardiac monitoring
        b. Electrocardiogram (ECG) rhythms
            1) Normal
            2) Abnormal
        c. Patient care considerations
            1) Adverse reactions
                a) Reactions to contrast media
            2) Other medical conditions
                a) Nephrogenic systemic fibrosis (NSF)

VI. Tubes, Catheters, Lines and Collection Devices

A. Terminology

B. Function of devices

C. Nasogastric/nasointestinal

D. IVs, butterflies, angiocatheters and power injectors

E. Suction
    1. Adult vs. pediatric
    2. Special precautions

F. Tracheostomy
    1. Suction techniques

2. CPR with tracheostomy

G. Chest (thoracostomy) tube
   1. Purpose
   2. Location

H. Central venous lines
   1. Purpose
   2. Types

I. Tissue drains

J. Oxygen administration using MR-conditional equipment
   1. Values
   2. Oxygen therapy
   3. Oxygen delivery systems
      a. Low-flow systems
      b. High-flow systems
   4. Documentation
   5. Special precautions

K. Urinary collection
   1. Procedure
      a. Male
      b. Female
   2. Alternative methods of urinary drainage
   3. Documentation

L. Other
   1. Ileostomy
   2. Ureteroileostomy

VII. Imaging

A. Positioning
   1. Body mechanics
   2. Exam coils
   3. Positioning accessories

B. Technical Considerations
   1. Protocols
      a. Scan menus
      b. Scan sequences
   2. Variations

C. Image processing

1. Display functions
2. Archival
    a. Legal requirements for image documentation and retention

D. Image analysis
1. Image quality
    a. window levels and widths
    b. formats
2. Image quality
    a. Parameters
    b. Artifacts
    c. Region of interest

E. Patient/personnel protection
1. Screening
    a. Metallic objects
    b. Implants/pacemakers
    c. Sickle cell disease
    d. Renal disease
    e. Asthma
    f. Pregnancy
    g. Breast feeding
    h. Dialysis
    i. Claustrophobia
2. Equipment/accessories
    a. Coils
    b. Call button
    c. Earplugs/ headphones
    d. MR-conditional:
        1) ECG leads
        2) Oxygen/tanks
        3) IV pumps
        4) Anesthesia equipment
        5) Pulse oximeters
        6) Blood pressure cuffs
        7) Suction
        8) Monitors
3. Medical/artifact error reduction
    a. Environment
        1) Gauss lines
        2) RF shielding/magnetic shielding
        3) Warning alarms/signs
    b. Biological Considerations
        1) RF field
            a) SAR

b) Biological effects
c) FDA guidelines

2) Static and gradient fields

VIII. Competency (Mandatory, Elective)* from *ARRT Clinical Experience Requirements (http://arrt.org/education/mr)*

A. Head and neck

B. Spine

C. Thorax

D. Abdomen and pelvis

E. Musculoskeletal

F. Special imaging procedures

G. Quality control

*Refer to ARRT Competency Requirements for mandatory and elective requirements.

Computers in Imaging and Medical Informatics

Description
Content introduces knowledge in computing and information processing. It presents computer applications in the radiologic sciences related to image capture, display, storage and distribution. Additional content is designed to provide the basic concepts of patient information management. Medical records management, including privacy and regulatory issues, are examined. The role of the technologist is identified and discussed. In addition, this content imparts an understanding of the components, principles and operation of digital imaging systems found in MR, image data management, storage and data manipulation (post-processing). Factors that impact image acquisition, display, archiving and retrieval are discussed.

Rationale
This course is required to develop an understanding of computers in the imaging environment. The subjects are formatted in individual outlines and can be sequenced according to the desired level of knowledge. Topics include: computers, computer components and characteristics, digital imaging (image acquisition, data management, storage, data manipulation (post-processing), display, archiving and retrieval), patient information systems, picture archiving and communication system (PACS), Health Insurance Portability and Accountability Act (HIPAA), hospital information systems (HIS) and radiology information systems (RIS).

Prerequisites
1. Medical terminology – a course in terminology used in the medical profession.
2. Basic computer skills.

Objectives
Upon completing the course, the student will be able to:
1. Apply knowledge base to use computerized systems.
2. Identify various types of computers.
3. Explain the way a computer operates.
4. Identify various terms related to computer fundamentals and components.
5. Describe how to apply various types of software.
6. Describe the various types of hardware applications.
7. Distinguish between analog and digital signals.
8. Define analog-to-digital conversion and digital signal processor.
9. Describe the major functions of the central processing unit (CPU).
10. Differentiate among the various input and output devices.
11. Give examples of various types of memory.
12. Use technology to retrieve, evaluate and apply information.
13. Describe computer care and preventive maintenance.
14. Distinguish among the Internet, intranet and other online services.
15. Apply The Joint Commission/HIPAA standards regarding accountability and protection of patient information.

16. Explain RIS, HIS and PACS applications as they relate to radiology.
17. Describe how the Internet affects distribution of health information.
18. Define digital imaging and communications in medicine (DICOM).
19. List the requirements of a patient consent document.
20. Identify the challenges in protecting patient information.
21. Distinguish between various types of patient records.
22. Explain the contents of a medical record.
23. Apply protocols to properly chart patient information.
24. Explain the procedures for document administration.
25. Discuss privacy and regulatory issues related to patient information.
26. Assess how HIPAA is applied to patient information systems.
27. Define medical informatics and describe examples of informatics systems found in today's patient care setting.
28. Identify potential abuses related to using confidential patient information.
29. Describe methods of complying with HIPAA.

Content

I. Computer Fundamentals

A. Terminology
   1. Analog
   2. Digital
   3. Binary

B. Types of computers
   1. Supercomputer/mainframe
   2. Minicomputer
   3. Microcomputer

C. Digital fundamentals
   1. Binary coding
      a. Bits
         1) Bit depth
      b. Bytes
         1) Information content
         2) Megabytes/image
   2. Digital signal processor (DSP)
      a. A-D conversion
      b. D-A conversion

D. Considerations
   1. Environmental conditions
      a. Temperature
      b. Humidity
   2. Computer catastrophes
   3. Ethical/legal concerns

4. Preventive maintenance
5. Security
    a. Passwords
    b. Limited access
    c. Firewalls

II. Computer Components

A. Hardware
1. Computer
    a. Mainframe
    b. Hard drive
2. Monitor
3. Keyboard
4. Mouse

B. Software
1. Word processing
2. Database
3. Spreadsheet
4. Desktop publishing
5. Graphics
6. Integrated application programs
7. Image manipulations
    a. DICOM
    b. Joint photographic experts group (JPEG)

C. Central processing unit (CPU)
1. Arithmetic logic unit (ALU)
2. Control unit (CU)

D. Input and output (I/O) devices (peripherals)
1. Input
    a. Keyboards
    b. Non-keyboard devices
    c. Touch screen
    d. Voice activation
2. Output
    a. Printers
    b. Video monitors
    c. Graphic displays
    d. Voice output
3. Storage/memory
    a. Primary memory
        1) Random access memory (RAM)
        2) Read-only memory (ROM)

b. Secondary storage
    1) Magnetic tape
    2) Magnetic disk
    3) CD-ROM
    4) DVD
    5) Off-site storage

III. Computer Operations

A. Programming
    1. Definition
    2. Purpose
    3. Languages
    4. Software

B. Computer Functions (for Imaging)
    1. Image acquisition
    2. Image processing
    3. Image display
    4. Image storage

C. Implementation
    1. Definition
    2. Purpose

IV. Radiology Applications

A. Patient information and image manipulation
    1. Seamless patient/image information
        a. Scheduling
        b. Image/patient evaluation
        c. Billing/coding
    2. Documentation
        a. Completeness
        b. Quality control
        c. Quality assurance

B. Patient information systems
    1. Patient information
        a. Personal information
        b. Clinical information
        c. Other
    2. HIS
    3. RIS
    4. DICOM

C. Image information systems

1. PACS
    a. Terminology
    b. System components and functions
    c. Image manipulation
    d. Access to report information
    e. Access from multiple locations
    f. Image retrieval
    g. PACS issues – contingency plans
    h. DICOM
2. Image display and manipulation
    a. Viewing
    b. Post-processing
    c. Measurements
3. Teleradiology

D. Technologist's responsibilities
1. Access order (worklist)
2. Image acquisition
3. Post-processing – image manipulation
4. Annotation issues
5. Transmitting an image(s) to PACS
6. HIPAA and patient confidentiality

V. Digital Imaging

A. Digital image characteristics
1. Picture elements – pixels
2. Pixel size
    a. Field of view (FOV)
    b. Matrix
3. Voxel size
    a. FOV
    b. Thickness
    c. Matrix
4. Matrix size
5. Image quality characteristics
    a. Spatial resolution
    b. Temporal resolution
    c. Image contrast
    d. Data size

B. Digital image acquisition
1. MR image acquisition
    a. Protocol/parameter selection
        1) Resolution (FOV, thickness, matrix)

2) Contrast – repetition time (TR), echo time (TE), inversion time (TI), and flip angle (FA)
3) Other parameters

b. System requirements
1) Hardware requirements
2) Software requirements

c. Anatomical considerations
1) Anatomy of interest
2) Plane/baseline reference
3) Anatomical variations
4) Body habitus
5) Pathology

d. Positioning aids

e. Special concerns
1) Age
2) Patient condition
3) Positioning

2. MR image formation
a. K-space
b. Analog to digital converter
c. Fourier transformation

C. Imaging standards
1. Protocol selections
2. Parameter selections
3. Problem-solving process
4. Role of the MR technologist

D. Artifacts
1. Determining the cause(s) of artifacts
2. Optimizing acquisition parameters to reduce artifacts

VI. Quality Assurance and Post-processing

A. Image display
1. Window/level
2. Brightness/contrast
3. Reconstruction algorithms

B. Image evaluation
1. Image quality (SNR)
2. Image quality (image contrast)

C. Post-processing
1. 3-D
2. Maximum intensity projection (MIP)

3. Region of interest (ROI)
    a. Measurements
    b. Signal intensity
4. Image display
    a. Brightness
    b. Contrast

VII. Display

A. Monitor
1. Liquid crystal display (LCD)
2. Cathode ray tube (CRT)

B. Film
1. Dynamic range
2. Degraded thermal film
3. Film storage

C. Image display
1. Image quality display
    a. Contrast
    b. Recorded detail/spatial resolution
    c. Distortion
2. PACS
    a. Terminology
    b. System components and function
    c. PACS operation
        1) Image manipulation
        2) Access to report information
        3) Access from multiple locations
        4) Image retrieval
        5) Contingency plans
    d. DICOM

D. Procedural factors display
1. Image identification
    a. Patient information
    b. Date of examination
    c. Parameters and options
    d. Institutional data
2. Documenting an ordered exam
    a. Prescription
    b. Patient chart
    c. Telephone orders
    d. Faxed orders
    e. Electronic orders – Computerized Physician Order Entry (CPOE)

f. Contrast agent
g. Pre-examination preparation

3. Artifacts
   a. Image acquisition errors
   b. Corrective action
4. Equipment
   a. Spatial resolution
   b. More contrast resolution

E. Image evaluation
1. Contrast
   a. Appropriate for exam
   b. Evidence of processing error
2. Spatial resolution
3. Distortion
4. Artifacts

VIII. Computer Advancements for Imaging

A. The Internet
1. History
2. Internet vs. intranet

B. Intranets
1. Access to information
2. Security of patient information

C. Enhancer to customer service
1. Referring physician
2. Patient

Ethics and Law in the Imaging Sciences

Description
Content provides a fundamental background in ethics. The historical and philosophical bases of ethics and the elements of ethical behavior are discussed. The student examines a variety of ethical issues and dilemmas found in clinical practice.

An introduction to legal terminology, concepts and principles also are presented. Topics include misconduct, malpractice, legal and professional standards. The importance of proper documentation and informed consent is emphasized.

Content

I. Ethics and Ethical Behavior

A. Origins of history of medical ethics

B. Moral reasoning

C. Personal behavior standards

D. Competence

E. Professional attributes

F. Standards of practice

G. Self-assessment and self-governance

H. Code of professional ethics

I. Ethical concepts
   1. Ethics principles
   2. Violation process

J. Systematic analysis of ethical problems

K. Ethical patient care data research/data discovery

II. Ethical Issues in Health Care

A. Individual and societal rights

B. Cultural considerations

C. Economical considerations

D. Technology and scarce resources

E. Access to quality health care

F. Human experimentation and research

G. Medical/health care research

H. End-of-life decisions

III. Legal Issues

A. Parameters of legal responsibility

B. Patient personal information
   1. Health Insurance Portability and Accountability Act (HIPAA)
   2. Confidentiality of patient information

C. Intentional misconduct

D. Negligence/malpractice
   1. Definitions
   2. Components of malpractice
   3. Legal doctrines
   4. Legal and professional standards
   5. Medical liability
   6. Sources of Law
   7. Civil and Criminal Liability

E. Legal risk reduction

IV. Patient Consent

A. Definition

B. Types

C. Condition for valid consent

D. Documentation of consent

Fundamentals of Imaging Science and Health Care

Description
Content provides an overview of the foundations in radiologic science and the practitioner's role in the health care delivery system. The principles, practices and policies of the health care organization(s) are examined and discussed in addition to the professional responsibilities of the MR technologist.

Content

I. The Health Science Professions

A. Radiologic technology
   1. Radiography specialties
      a. Diagnostic radiography
      b. Computed tomography
      c. Mammography
      d. Cardiac-interventional radiography
      e. Vascular-interventional radiography
      f. Bone densitometry
      g. Quality management
      h. Radiologist assistant
      i. Multiskilled
   2. Radiation therapy
   3. Nuclear medicine technology
   4. Diagnostic medical sonography
   5. Magnetic resonance imaging
   6. PACS administration
   7. Education
   8. Management

B. Health care professions
   1. Health information technology
   2. Medical laboratory sciences
   3. Occupational therapy
   4. Pharmacy
   5. Physical therapy
   6. Respiratory therapy
   7. Social services
   8. Nursing
   9. Other

II. The Health Care Environment

A. Health care systems
   1. Hospitals

a. Veterans Administration/military
b. Not-for-profit
c. For-profit
d. System/network
2. Clinics
3. Independent facilities
4. Mental health facilities
5. Long-term/residential facilities
6. Hospice

B. Health care delivery settings
1. Outpatient/ambulatory care
2. Inpatient
3. Long-term care
4. Preventive care
5. Home health care
6. Telehealth/telemedicine

C. Payment/reimbursement systems
1. Self pay
2. Indemnity insurance
3. Entitlement/governmental programs
a. Medicare
b. Medicaid
4. Managed care

III. Hospital Organization

A. Philosophy

B. Mission
1. Role within the community
2. Commitment to education within the profession and community health

C. Administrative services
1. Governing board
2. Hospital administration
3. Admissions
4. Information systems
5. Procurement
6. Accounting
7. Support services
a. Facilities management
b. Environmental services (housekeeping)
c. Security
8. Personnel

D. Medical services
    1. Personnel
        a. Medical director
        b. Medical staff
        c. House staff
            1) Medical residents
            2) Interns
            3) Medical students
    2. Nursing services
    3. Clinical services
        a. Internal medicine
        b. Surgery
        c. Mental health
        d. Geriatrics
        e. Pediatrics
    4. Clinical support services
        a. Dietary
        b. Medical laboratories
        c. Oncology
        d. Pastoral care
        e. Rehabilitation
        f. Social services
        g. Risk management
        h. Pharmacy

IV. Radiology Organization

A. Professional personnel
    1. Radiology director/chair
    2. Radiologists
        a. Attending
        b. Fellow
        c. Resident
        d. Intern
    3. Radiation physicist
    4. Technologists
        a. Administrative director
        b. Chief/senior technologist
        c. Staff technologist
        d. Quality control/assurance officer/technologist
    5. Radiologist assistant
    6. Radiology nurses

B. Support services
    1. Clerical staff

a. Administrative assistant
b. Receptionist
c. Medical secretary

2. Financing/accounting
3. Patient transportation services
4. File room/image management
5. Information systems manager
   a. RIS
   b. PACS

C. Patient services

D. Educational personnel
1. Educational/program director
2. Clinical coordinator
3. Didactic instructor
4. Clinical instructor
5. Clinical staff
6. Students

V. Accreditation

A. Definition

B. Programmatic accreditation
1. Joint Review Committee on Education in Radiologic Technology (JRCERT)

C. Institutional accreditation
1. Degree granting regional (college/proprietary)
2. Health care organization(s)
   a. The Joint Commission
   b. American Osteopathic Association
   c. American College of Radiology (ACR)
   d. Intersocietal Accreditation Commission (IAC)
   e. American Medical Association (AMA)

D. Regional Continuing Education Evaluation Mechanism (RCEEM)
1. American College of Radiology (ACR)
2. American Healthcare Radiology Administrators (AHRA)
3. American Institute of Ultrasound in Medicine (AIUM)
4. American Society of Nuclear Cardiology (ASNC)
5. American Society of Radiologic Technologists (ASRT)
6. Canadian Association of Medical Radiation Technologists (CAMRT)
7. Radiological Society of North America (RSNA)
8. Society of Diagnostic Medical Sonography (SDMS)
9. Section for Magnetic Resonance Technologists (SMRT)

10. Society of Nuclear Medicine Technologist Section (SNMTS)
11. Society for Vascular Ultrasound (SVU)

VI. Regulatory Agencies

A. Federal

B. Reimbursement

C. State

VII. Professional Credentialing

A. Definition
   1. Certification
   2. Registration
   3. Licensure

B. Agencies
   1. National
      a. American Registry of Radiologic Technologists (ARRT)
      b. Nuclear Medicine Technology Certification Board (NMTCB)
      c. American Registry of Diagnostic Medical Sonographers (ARDMS)
      d. American Healthcare Radiology Administrators (AHRA)/Radiology Administration Certification Commission (RACC)
      e. State – licensure

VIII. Professional Organizations

A. Purpose, function, activities

B. Local organizations

C. State organizations

D. National organizations
   1. American Society of Radiologic Technologists (ASRT)
   2. American Healthcare Radiology Administrators (AHRA)
   3. Association of Collegiate Educators in Radiologic Technology (ACERT)
   4. Association of Educators in Imaging and Radiologic Sciences Inc. (AEIRS)
   5. Section for Magnetic Resonance Technologists (SMRT)
   6. American Registry for Diagnostic Medical Sonographers (ARDMS)
   7. Nuclear Medicine Technology Certification Board NMTCB)
   8. Magnetic Resonance Managers Society (MRMS)
   9. American College of Healthcare Executives (ACHE)

E. International
   1. International Society of Radiographers and Radiological Technologists (ISRRT)

2. International Society for Magnetic Resonance in Medicine (ISMRM)

F. Related associations and organizations
   1. American Board of Radiology (ABR)
   2. ACR
   3. RSNA
   4. AMA

IX. Professional Development and Advancement

A. Continuing education and competency programs
   1. Definition
   2. Rationale/benefits
   3. Requirements
      a. ARRT
      b. State
      c. Institutional

B. Continuing education opportunities
   1. Postprimary certification
   2. Collegiate/educational programs
   3. Self-learning activities
   4. Professional conferences

C. Employment considerations
   1. Geographic mobility
   2. Economic factors
   3. Manpower issues

D. Advancement opportunities
   1. Education
      1. Administration
      2. Faculty
         a. Didactic
         b. Clinical
   2. Administration
   3. Physics
   4. Research
   5. Industrial
   6. Medical informatics
   7. Sales/applications

General Education

General education is an integral part of MR technologist development. The content assists in developing the communication, human diversity, scientific inquiry, critical-thinking and judgment skills required to perform the responsibilities of an entry-level MR technologist. Knowledge gained from general education serves to enhance the content and application of the MR curriculum.

General education provides personal enrichment and exploration outside the confines of the technical curriculum. The general education content objectives in this curriculum purposely are labeled "global content objectives" to give program officials flexibility in determining specific college-level credit-bearing course work that will satisfy these objectives. A program must offer a minimum of 15 credit hours of general education course work. The minimum 15 credit hours must include Communications and Mathematics/Analytical Studies. For the remaining general education credits, institutions are encouraged to require courses from different categories, such as the Social/Behavioral Sciences, Natural Sciences, Computing or Humanities/Fine Arts, to insure a diversified educational experience.

Required post-secondary general education gained through college credit bearing course work must meet the global content objectives listed below:

Required Post-secondary General Education:

- Communications
  - Write, read, speak and listen critically
  - Develop the ability to perceive, gather, organize and present information
  - Locate, evaluate and synthesize material from diverse sources and points of view

- Mathematical/Logical Reasoning
  - Develop skills in analysis, quantification and synthesis
  - Apply problem-solving or modeling strategies

- Arts and Humanities
  - Develop knowledge and understanding of the human condition
  - Demonstrate respect for diverse populations
  - Develop an understanding of ethics and the role they play in personal and professional lives
  - Recognize and critically examine attitudes and values

- Information Systems
  - Develop knowledge base for using computerized systems
  - Use technology to retrieve, evaluate and apply information

- Social/Behavioral Sciences
  - Adapt interactions to meet cultural/psychological needs of people

- Develop an understanding of individual and collective behavior
- Promote the development of leadership skills
- Develop capacity to exercise responsible and productive citizenship
- Function as a public-minded individual

- Natural Sciences
  - Understand and apply scientific method
  - Make informed judgments about science-related topics
  - Develop a scientific vocabulary

MR Imaging Procedures

Description
This content provides the student with imaging techniques related to the central nervous system (CNS), neck, thorax, musculoskeletal system and abdominopelvic regions. The content covers specific clinical application, coils that are available and their use, considerations in the scan sequences, specific choices in the protocols (e.g., slice thickness, phase direction and flow compensation), and positioning criteria. Anatomical structures and the plane that best demonstrates anatomy are discussed as well as signal characteristics of normal and abnormal structures.

Rationale
This content outlines the critical criteria relevant to acquiring high-quality images of various anatomical regions. Due to different considerations for the various regions in the body, imaging protocols vary. The student studies the variations in imaging parameters for specific body regions and the resultant effect on signal characteristics and the anatomy represented. Evaluation criteria for determining the quality of images provides MR technologists with a better understanding of what constitutes a high-quality image. In a competency-based educational system, this content is completed prior to competency examinations.

Prerequisites
1. MR physical principles. Overview of imaging parameters and terminology, safety and patient care procedures.
2. Sectional anatomy. Human anatomy in axial, sagittal and coronal planes. Other planes are discussed when appropriate to particular anatomy. Correlating anatomy to MR images. (May take place simultaneously with Imaging Procedures.)
3. Pulse sequences and image formation. Physical principles of magnetic resonance, relaxation characteristics, signal production, pulse sequences, signal-to-noise and parameter influences, fluid flow compensation and demonstration, and image formation.
4. MR instrumentation. Equipment used to produce the MR signal and image, specific coil designs, quality assurance measures and equipment safety

Objectives
Upon completing the clinical education, students will be able to:

1. State the coils available for MR and their specific application.
2. Describe considerations in designing an imaging protocol and state the application of protocols in specific situations.
3. Demonstrate proper patient screening.
4. Demonstrate knowledge of scanning menus, archival procedures and display functions.
5. Demonstrate proper windowing levels and widths.
6. Demonstrate proper use of MR-safe monitoring devices.
7. Demonstrate how to prepare contrast materials and use MR injectors.

8. State positioning criteria for different areas of the body.
9. State advantages and disadvantages of axial, sagittal, coronal and oblique images (i.e., what structures are best demonstrated).
10. Describe common pulse sequences used to evaluate the different areas of the body.
11. State tissue signal characteristics of anatomical structures with and without contrast.
12. Explain the use of contrast media in evaluating pathology.
13. Describe common artifacts that occur during imaging.
14. Describe the differences between adult and pediatric pulse sequences in MR.
15. Describe the differences in tissue signal characteristics between adult and pediatric examinations.
16. Describe the criteria for imaging windows for different areas of the body.
17. Describe the MR characteristics of blood as seen on arterial and venous magnetic resonance angiography (MRA).
18. Identify how field strength affects the ability to visualize select pathology.
19. Describe the MR tissue characteristics of select pathological processes.
20. Discuss saturation pulses, which help to identify arteries and veins.
21. Evaluate images for appropriate positioning, anatomy, pulse sequences and overall quality.
22. Identify the common indications and common pathology for the central nervous system, soft tissue structures of the head and face, orbit, nasopharynx, oropharynx, neck, and spine, the abdomen, the musculoskeletal system, the soft tissue pelvis that includes the male and female reproductive systems, the chest, the heart, mediastinum, the brachial plexus and breast exams.
23. Demonstrate effective communication skills with patients, their family members and staff.
24. Demonstrate MR safety and protective practices associated with MR examinations.
25. Cite the components of the central nervous system, including the brain and spinal cord.
26. Identify the normal anatomic location of the components of the central nervous system, including the brain and spinal cord, on diagrams and scan images.
27. Describe the normal MR tissue characteristics of the components of the brain and spine.
28. Explain the principles of MR spectroscopy.
29. Discuss the current and future development of in vivo spectroscopic diagnosis of disease processes.
30. Discuss the hardware requirements for MR spectroscopy.
31. Describe and discuss the various imaging planes and pulse sequence parameters that maximize the diagnostic value of an MR scan of the central nervous system including the brain and spine.
32. Describe the normal MR tissue characteristics of the soft tissue structures of the head and face, orbit, nasopharynx, oropharynx, neck and spine.
33. Describe the effects of blood flow characteristics on image quality, including laminar turbulent, vortex and stationary or stagnant flow.
34. Identify common pathology of the soft tissue structures of the head and face, orbit, nasopharynx, oropharynx, neck and spine on MR images.
35. Identify common vascular lesions on MRA images.
36. Identify the normal anatomic location of the soft tissue structures of the head and face, orbit, nasopharynx, oropharynx, neck, spine and vasculature of the neck on scan images.
37. Review the components of the abdomen.

38. Identify the normal anatomic location of the abdomen components on diagrams and scan images.
39. Describe the normal MR tissue characteristics of the components of the abdomen.
40. Describe and discuss imaging planes and pulse sequence parameters that maximize the diagnostic value of an MR scan of the abdomen.
41. Discuss the different types of MRA procedures, when they are used and the characteristics of the resultant images.
42. Identify common pathology of the abdomen on MR images.
43. Review the anatomy of the musculoskeletal system.
44. Identify the normal anatomic location of musculoskeletal system components on diagrams and scan images.
45. Describe and discuss the imaging planes and pulse sequencing parameters that maximize the diagnostic value of an MR scan of the upper extremity, lower extremity, shoulder girdle and pelvic girdle.
46. Identify common pathological conditions seen in the musculoskeletal system on MR images.
47. Review the components of the soft tissue pelvis including the male and female reproductive systems.
48. Identify the normal anatomic location of the components of the male and female pelvis on diagrams and scan images.
49. Describe the normal MR tissue characteristics of the components of the male and female pelvis.
50. Describe and discuss imaging planes and pulse sequence parameters that maximize the diagnostic value of an MR scan of the pelvis including the male and female reproductive systems.
51. Identify common pathology of the pelvis, including the male and female reproductive systems and their tissue characteristics on MR images.
52. Review the components of the chest, heart, mediastinum, brachial plexus and breast.
53. Identify the normal anatomic location of the components of the chest, heart, mediastinum, brachial plexus and breast on diagrams and scan images.
54. Describe the normal MR tissue characteristics of the components of the chest, heart, mediastinum, brachial plexus and breast.
55. Describe and discuss imaging planes and pulse sequence parameters that maximize the diagnostic value of an MR scan of the chest, heart, mediastinum, brachial plexus and breast.
56. Discuss the various saturation techniques used in breast imaging.
57. Identify common pathology of the chest, heart, mediastinum, brachial plexus and breast on MR images.

Content

I. Imaging Considerations

A. Coil types

B. Pulse sequences

C. Parameters (phase/frequency direction)

D. Flow and motion effects

E. Motion reduction techniques

F. Contrast agents

G. Artifacts

H. Windowing

II. Imaging Planes

A. Positioning criteria

B. Axial, sagittal, coronal
   1. Movement and direction
      a. Inferior – Superior
      b. Left – Right
      c. Posterior – Anterior
      d. Oblique

C. Anatomy best demonstrated

D. Slice thickness

III. Signal Characteristics

A. Proton density vs. T1-weighted vs. T2-weighted of normal anatomy

B. Spin-echo vs. gradient-echo

C. With and without contrast agents

IV. General Considerations

A. Evaluation of MR orders
   1. Patient identification
   2. Verification of procedure(s) ordered
   3. Establishes Patient rapport
      a. Explains procedure
      b. Proper screening of patient
         1) Screening for metal on patient
         2) Screening for metal inside of patient
         3) Screening for physical indications that may contraindicate exam and/or hinder exam results
         4) Determines any contrast contraindications

4. Patient Preparation
    a. Appropriate disrobing and gowning
    b. Removing items that are contraindicated in the MRI suite and/or may cause artifacts
5. Room preparation
    a. Clean and organized exam environment maintained
    b. Necessary supplies and accessory equipment available
6. Patient assistance
7. Patient monitoring
8. Exam evaluation
9. Patient dismissal

V. Considerations for Routine MR Procedures

A. Patient instructions

B. Patient positioning

C. Part placement

D. Earplugs or earphones

E. Coil selection

F. Localization

G. Special considerations
1. Atypical conditions
2. Anesthesia considerations
3. Ancillary staff considerations
4. Special needs patients
5. Trauma

VI. Positioning and Procedural Considerations for Specific Studies

A. MR/MRA of the central nervous system
1. Clinical indications
    a. Vascular disease
    b. Trauma
    c. Neoplasia
    d. Inflammation
    e. Anomalies
2. Anatomic locations
    a. Brain
    b. Spine and spinal cord

B. MR of the musculoskeletal system

1. Clinical indications
    a. Degenerative disease
    b. Infection/inflammation
    c. Vascular
    d. Trauma
    e. Neoplasia
2. Anatomic locations
    a. Hip
    b. Femur
    c. Knee
    d. Lower leg
    e. Ankle and foot
    f. Shoulder
    g. Elbow
    h. Wrist and hand
    i. Temporomandibular joint dysfunction (TMJ)

C. MR/MRA of the abdomen and pelvis
1. Clinical indications
    a. Infection/inflammation
    b. Vascular
    c. Trauma
    d. Neoplasia
2. Anatomic locations
    a. Abdomen
    b. Retroperitoneum
    c. Pelvis, male and female

D. MR/MRA of the thorax
1. Clinical indications
    a. Infection/inflammation
    b. Vascular disease
    c. Trauma
    d. Neoplasia
    e. Anomalies
2. Anatomic locations
    a. Mediastinum
    b. Chest
    c. Brachial plexus
    d. Neck
    e. Breast
3. Pediatric MRI/MRA
    a. Clinical Indications
4. Tumor/infections
5. Developmental anomalies, congenital malformations

6. Myelination patterns
7. Age related
8. General anesthesia

VII. Procedural Considerations for Contrast Studies

A. Equipment and materials needed

B. Contrast media
   1. Purpose
   2. Types

VIII. Procedural Considerations for Special Studies

IX. Patient Education

A. Communication
   1. Types
   2. Barriers
      a. Methods for overcoming barriers
   3. Clinical situations
   4. Common MR safety issues and concerns

MR Parameters, Imaging Options, and Quality Assurance

Description
This course provides the student with knowledge of the parameters and imaging options used to create MR images. In addition, the content introduces quality assurance measures used in maintaining image quality.

Rationale
This course is necessary to educate the student on how to create high-quality diagnostic images that will be reviewed by the interpreting physician. A thorough knowledge base in the application of parameters, imaging options and quality assurance allows technologists to obtain the highest quality images possible, ensuring accurate diagnosis of the patient's condition.

Objectives
Upon completion of this course, the student will be able to:
1. Describe the imaging parameters that determine image contrast.
2. Describe the imaging parameters that determine spatial resolution on MR images.
3. Describe the imaging parameters involved in MR image formation.
4. Apply MR imaging parameters in the clinical setting.
5. Describe many typical imaging options used to optimize image quality.
6. Understand parameters and imaging options to obtain diagnostic MR images with minimal image artifacts.
7. Maintain high-quality MR images via routine quality assurance practices

Content

I. MR Imaging Parameter and Sequence Selections
- A. Pulse sequence selections
  - 1. Spin echo
    - a. Types
      - 1) Single echo
      - 2) Multiecho
      - 3) Rapid acquisition recalled echo (RARE)
        - a) Fast Spin Echo (FSE) / Turbo Spin Echo (TSE)
      - 4) Single Shot – Fast Spin Echo (SS-FSE)/Half Acquisition Single Shot Turbo Echo (HASTE)
    - b. Image contrast
      - 1) T1
      - 2) T2
      - 3) Proton Density (PD)
  - 2. Inversion recovery
    - a. Types
      - 1) Spin-echo inversion recovery (SE IR)
      - 2) Fast spin-echo inversion recovery (FSE-IR)

3) Gradient-echo inversion recovery (GRE-IR)
b. Image contrast
1) Short tau inversion recovery (STIR)
a) Spectrally selected inversion recovery (SPIR)
b) Spectral selected attenuation inversion recovery (SPAIR)
2) Fluid-attenuated inversion recovery (FLAIR)
3) T1 FLAIR
3. Gradient echo
a. Types
1) GrE
2) EPI
b. Image Contrast
1) T1
2) T2*
3) PD

B. Image contrast parameters
1. Extrinsic contrast parameters (user selectable parameters)
a. TR – repetition time
1) Image influenes
a) T1 contrast
b) Scan time
c) Signal-to-noise ratio (SNR)
d) Number of slice locations
b. TE – echo time
1) Image influenes
a) T2 contrast
b) Number of slices
c) SNR
d) Susceptibility artifact
2) TE settings for FSE
a) Effective TE
b) Target TE
c. TI – Inversion time
1) STIR
a) Short TI (varies with field strength)
b) Suppresses fat
c) Suppresses gadolinium
2) FLAIR
a) Long TI (varies with field strength)
b) Suppresses water
3) T1 FLAIR
d. Flip angle
1) T1 contrast
2) Ernst angle

e. "B" value
    1) Diffusion weighting
    2) Gradient amplitude and duration
f. Velocity encoding (VENC)
    1) Gradient amplitude and duration

2. Intrinsic contrast parameters (determined by tissue characteristics)
    a. T1 recovery time
    b. T2 decay time
    c. Proton/spin density
    d. Physiologic motion
        1) Periodic motion
            a) Pulsatile flow
            b) Respiration
            c) Flow velocity/direction
        2) Aperiodic motion
            a) Peristalsis
            b) Molecular diffusion

3. Extrinsic contrast influences (contrast media)
    a. T1 agents
        1) Gadolinium
            a) IV agent
                (1) Dynamic imaging
                (2) Delayed imaging
            b) Dose
                (1) Single dose (0.1 mmol/kg)
                (2) Double dose
                (3) Triple dose
            c) Affects on images
                (1) Relaxivity
                (2) Shortens T1 relaxation time
                (3) Bright on T1WI
        2) Manganese
            a) IV agent
                (1) Delayed imaging
                (2) Liver imaging
            b) Dose
            c) Effects on images
                (1) Shortens T1 relaxation time
                (2) Bright on T1WI
    b. T2 agents
        1) Gadolinium
            a) IV agent
                (1) Delayed liver imaging
                (2) Affects on images
                    (a) Shortens T2 relaxation time

(b) Dark on T2*WI

b) Oral agent

(1) MRCP or bowel imaging

(2) Affects on images

(a) Shortens T2 relaxation time

(b) Dark on T2WI and T2*WI

C. Resolution parameters

1. Voxel size

a. Voxel size parameters

1) FOV

2) Thickness

3) Matrix

b. Affect on Quality

1) SNR

2) Affect on resolution

3) Affect on scan time

2. Sampling parameters

a. Sampling parameters

1) Number of signals averaged (NSA)

a) Number of excitations (NEX)

b) Number of acquisition (NAQ)

2) Receiver bandwidth

a) Sampling time

b) FOV

c) TE

3) Number phase encodings (matrix)

a) Resolution

b) Scan time

4) Echo Train Length ("ETL")/turbo factor

a) Echo spacing

b) Effective TE

c) Number of shots

5) Slices in a 3-D (volume) acquisition

a) SNR

b) Scan time

b. Effect on quality

1) SNR

2) Effect on resolution

3) Effect on scan time

3. Dimensionality

a. 2-D

b. 3-D

c. Thickness / gap

d. Slice order

II. Imaging Options

A. Saturation pulses
   1. Spatial preset
   2. Spectral saturation, chemical saturation (fat saturation)

B. Gradient moment nulling (flow comp)

C. Physiologic gating and triggering
   1. Respiratory gating
   2. Cardiac gating

D. Magnetization transfer

E. Phase/frequency orientation

F. Bandwidth (receive)
   1. Narrow
   2. Wide

G. Signal suppression techniques
   1. Fat suppression
      a. Fat saturation (chemical sat)
         1) SPIR
         2) SPAIR
         3) SPECIAL
      b. STIR
   2. Water suppression
   3. Silicone suppression

H. In/out of phase

I. Antialiasing

III. Quality Assurance

A. Artifacts, cause, appearance and compensation
   1. Physics artifacts
      a. Chemical shift
         1) Types
            a) First kind (frequency direction on SE images)
            b) Second kind (out of phase imaging)
         2) Cause
         3) Compensation
      b. Susceptibility
         1) Metal

2) Tissues with dissimilar chemical compensation

2. Sampling artifacts
   a. Aliasing
   b. Cross-talk
3. Motion artifacts
4. Technical errors
   a. Improper centering
   b. Coil selection
5. Hardware artifacts
   a. Corduroy
   b. RF leak
      1) Zipper
      2) Buzz

B. Cause and appearance

C. Compensation

D. Operator-adjustable parameters

E. Quality assurance
   1. Electronic measurements
   2. NMR measurement
   3. Archival QA
   4. QA of display and multiformat cameras
   5. Record keeping

MR Pathology

Description
This course familiarizes the student with the common pathologies found in magnetic resonance imaging and the appearance of these pathologies in various imaging protocols. The course content is inclusive of all commonly-imaged body systems and areas.

Rationale
The technologist should recognize the need for additional sequences and changes in protocols based upon recognizing pathological changes. In addition, a technologist must be aware of indications that show a contrast agent is required. The knowledge of disease processes and their signal characteristics on various imaging sequences is essential to ensure the best practices in patient care and quality imaging.

Prerequisites
Some course work may take place simultaneously.
1. Introduction to MR imaging.
2. MR physics and instrumentation.
3. Sectional anatomy
4. Imaging procedures

Objectives
Upon completing the course, the student will be able to:
1. State pathologies that commonly require an MR study.
2. Display understanding of the signal characteristics displayed by abnormal tissues during various pulse sequences and imaging modes in illustrating pathological processes.
3. Recognize changes in anatomical sizes and shapes of structures that can indicate pathology.
4. Describe basic pathological processes demonstrated by MR.
5. Identify the nature and courses of the pathologies listed in the course outline.
6. Describe the effect of contrast agents on visualizing pathology.

Content

I. Central Nervous System
- A. Brain
  - 1. Neoplastic disorders
    - a. Intra-axial
      - 1) Astrocytoma
      - 2) Glioblastoma
      - 3) Ependymoma
      - 4) Ganglioma
      - 5) Neuroblastoma
      - 6) Metastases
      - 7) Lymphoma

8) Medulloblastoma
9) Hemangioblastoma

b. Extra-axial
1) Meningioma
2) Epidermoid
3) Dermoid
4) Lipoma
5) Pituitary adenoma
6) Pineal gland tumors

2. Infections and inflammatory disorders
a. Meningitis
b. Cerebral abscess
c. Encephalitis
d. HIV and associated infections
e. Sarcoidosis
f. Multiple sclerosis

3. Vascular disorders
a. Stroke
1) Acute
2) Subacute
3) Brain hypoxia

b. Venous sinus occlusion
c. Arterial origin
1) Aneurysm
2) Vascular malformation
3) Nontraumatic hemorrhage

4. Congenital and hereditary disorders
a. Aquaductal stenosis
b. Chiari malformations
c. Dandy-Walker

5. White matter disorders
6. Trauma
a. Skull fracture
b. Hematomas
c. Shearing injury
d. Contusion
e. Hemorrhage
f. Child abuse
g. Arterial dissection

7. Other (i.e., aging, metabolic, idiopathic, iatrogenic, phakomatoses, etc.)

B. Spine and spinal cord
1. Tumor and tumor-like disorders
a. Metastases (vertebral body and spinal cord)
b. Spinal cord astrocytoma

c. Spinal cord ependymoma
d. Spinal meningioma
e. Hemangioma
f. Bone and/or spinal cord cyst
g. Chordoma
h. Paget disease

2. Inflammatory disorders
   a. Spondylitis
   b. Discitis
   c. Abscesses
3. Vascular disorders
   a. Arteriovenous malformation
   b. Cavernous angioma
   c. Infarctions
4. Trauma
   a. Fractures
   b. Hematomas
5. Degenerative spine
   a. Herniated disc
   b. Free herniated disc fragment
   c. Postsurgical fibrosis and arachnoiditis
   d. Spondylolysis and spondylolisthesis
   e. Ossified ligaments
6. Other (e.g., congenital anomalies, demyelinating disorders, etc.)

II. Head and Neck

A. Eye and orbital contents
1. Persistent hyperplastic primary vitreous
2. Retinopathy
3. Retinoblastoma
4. Hemangioma
5. Melanoma
6. Tumors
7. Optic neuritis
8. Grave ophthalmopathy
9. Sarcoidosis
10. Abscess
11. Orbital trauma

B. Sinuses, pharynx (nasal and oral), and larynx
1. Ostiomeatal unit obstruction
2. Cysts and polyps
3. Sinusitis
4. Malignancy
5. Mucocele

6. Papilloma

C. Temporal bone and TMJ
   1. Tumor and tumor-like disorders
      a. Schwannoma
      b. Cholesteatoma
      c. Cholesterol granuloma
   2. Bell palsy
   3. Vascular middle ear anomalies
   4. Fractures
   5. Dislocated TMJ

D. Neck
   1. Masses
      a. Nasopharyngeal space
      b. Parapharyngeal space
      c. Parotid space
      d. Retropharyngeal space
      e. Oropharyngeal space
      f. Masticator space
      g. Buccinator space
      h. Carotid space
      i. Laryngeal
      j. Angiofibroma
      k. Hemangioma
      l. Hygroma
      m. Thyroid
      n. Glomus jugulare
   2. Metastases
   3. Cysts
   4. Sialolithiasis

E. Brachial Plexus
   1. Masses
   2. Malignancy
   3. Response to therapy
   4. Trauma

III. Thorax

A. Mediastinum
   1. Thyroid masses
   2. Thymoma
   3. Duplication cysts
   4. Lymph node enlargement
   5. Lymphoma

6. Teratoma
7. Neurogenic
8. Pancoast tumors
9. Aneurysms
10. Esophageal tumors

B. Chest wall
1. Malignant processes
2. Inflammatory lesions

C. Respiratory system

D. Cardiac and aorta
1. Aneurysm
2. Dissection
3. Coarctation
4. Thrombus
5. Infarction
6. Hypertrophic cardiomyopathy
7. Pericardial disease
8. Intracardiac masses
9. Valvular heart disease
10. Congenital heart conditions
    a. Ventricular septal defect (VSD)
    b. Atrial septal defect (ASD)
    c. Tetralogy of Fallot (TOF)

E. Breast
1. Dysplasia
2. Cysts
3. Benign tumors
4. Inflammatory conditions
5. Carcinomas
6. Post surgery or radiation
7. Implant rupture

IV. Abdomen

A. Liver
1. Hemangioma
2. Cysts
3. Abscesses
4. Hepatocellular carcinoma
5. Hepatic metastases
6. Venous thrombosis
7. Hemochromatosis

8. Transplant
9. Gall bladder and ductal anomalies

B. Pancreas
   1. Pseudocyst
   2. Cystic fibrosis
   3. Pancreatitis
   4. Transplants
   5. Adenocarcinoma
   6. Islet cell tumors
   7. Lymphoma
   8. Metastases
   9. Ductal anomalies

C. Kidneys
   1. Polycystic kidney disease
   2. Renal cell carcinoma
   3. Transitional cell carcinoma
   4. Metastatic disease
   5. Wilm's tumor
   6. Nephroblastoma
   7. Infarction
   8. Infection
   9. Transplant

D. Adrenals
   1. Adenoma
   2. Metastasis
   3. Pheochromocytoma
   4. Neuroblastoma
   5. Hemorrhage

E. Spleen and lymphatics
   1. Infections
   2. Benign focal lesions
   3. Hodgkin and non-Hodgkin lymphoma

F. Gastrointestinal (GI) tract
   1. Colon polyps
   2. Tumors
   3. Congenital anomalies

G. Vascular disorders
   1. Renal artery stenosis

V. Pelvis

A. Female reproductive organs (uterus, ovaries, vagina and associated structures)
   1. Neoplastic disorders
      a. Leiomyoma
      b. Endometrial polyps
      c. Endometrial carcinoma
      d. Cervical carcinoma
      e. Adenocarcinoma
      f. Vaginal carcinoma
      g. Ovarian carcinoma
      h. Dermoid/teratoma
      i. Fibroma
   2. Inflammatory disorders
      a. Pelvic inflammatory disease
      b. Salpingitis and oophoritis
   3. Endometriosis
   4. Ovarian cysts
   5. Other
      a. Congenital anomalies and hereditary disorders
      b. Traumatic disorders

B. Male reproductive organs (prostate, seminal vesicles and associated structures)
   1. Neoplastic disorders
      a. Benign prostatic hyperplasia
      b. Prostatic carcinoma
   2. Inflammatory disorders
      a. Prostatitis
      b. Orchitis and epididymitis
   3. Other
      a. Congenital anomalies and hereditary disorders
      b. Traumatic disorders

C. Bladder
   1. Neoplastic disorders
   2. Inflammatory disorders
   3. Other
      a. Congenital anomalies and hereditary disorders
      b. Traumatic disorders

VI. Musculoskeletal

A. Skeletal system
   1. Traumatic injury
   2. Bone fracture union
   3. Bone neoplasms and tumor like lesions
      a. Cartilage lesions

b. Fibrous lesions
c. Osteoid osteoma
d. Tumor-like lesions
e. Malignant tumors
f. Metastases

4. Inflammatory disorders
   a. Osteomyelitis
   b. Periprosthetic infections
5. Other
   a. Congenital abnormalities
   b. Osteonecrosis and bone infarcts
   c. Avascular necrosis
   d. Contusion

B. Soft tissues
1. Neoplastic disorders
   a. Lipomatous tumors
   b. Vascular lesions
   c. Synovial lesions and sarcoma
   d. Fibrous tumors
   e. Peripheral nerve sheath tumors
   f. Benign vs. malignant lesions
2. Inflammatory disorders
   a. Infections and abscesses
   b. Myositis
   c. Bursitis
   d. Tenosynovitis
   e. Osteomyelitis

C. Joints
1. Fibrocartilage disorders
   a. Articular cartilage injuries
   b. Cartilage status
   c. Degenerative joint disease
2. Ligament and tendon tears
   a. Rotator cuff tear
   b. Anterior/posterior cruciate tear
   c. Patellar tendon tear
   d. Collateral ligament
   e. Achilles tendon
   f. Labral tears
3. Inflammatory disorders
   a. Infections and abscesses
   b. Myositis
   c. Bursitis

d. Tenosynovitis
e. Osteomyelitis
f. Overuse synovitis
g. Ganglion and bursal cysts
h. Rheumatoid and seronegative arthritides

4. Meniscal Disorders
   a. Meniscal tears
      1) Bucket handle
      2) Anterior horn
      3) Posterior horn
   b. Meniscal cysts
   c. Discoid lateral meniscus
5. Other
   a. Trauma
   b. Congenital anomalies and hereditary disorders
   c. Bone marrow abnormalities

VII. General Vascular Disorders

A. Atherosclerosis

B. Post radiation injury

C. Dissections

D. Aneurysms

E. Graft patency

F. Venous mapping

G. Vena caval tumor invasion

MR Instrumentation and Imaging

Description
This unit provides a comprehensive overview of the instrumentation associated with MR imaging. The subjects are formatted in individual outlines and can be sequenced according to level of knowledge desired. Topics include: magnetism, properties of magnetism, MR system components, MR magnets (permanent, resistive, superconducting, hybrid), radiofrequency (RF) systems, gradient systems, shim systems and system shielding.

Rationale
This course is required in order to understand the system components necessary for MR image acquisition. The course provides information on the fundamentals of MR instrumentation/hardware. This information enables the student to maximize MR image quality by understanding MRI components.

Prerequisites
1. Medical Terminology – a course in terminology used in the medical profession.
2. Patient Care – methods, equipment, psychology, communication and a rationale of patient care techniques.
3. An overview of imaging parameters and terminology, safety and patient care procedures.
4. A course in the fundamentals of digital imaging systems.

Objectives
Upon completion of the course, students will be able to:
1. Understand magnetism and magnetic properties.
2. Define gauss (g), Tesla (T) and the electromagnetic spectrum.
3. Describe the three basic types of magnets and give the advantages and disadvantages of each.
4. Discuss the differences in low-, mid-, high- and ultra-high field systems.
5. Describe field strength in relation to image quality (image contrast, SNR and artifacts).
6. Explain the functionality of the radiofrequency system in MR imaging.
7. Explain the functionality of the gradient system in MR imaging.
8. Explain the functionality of the shim system in MR imaging.
9. Explain the functionality of the ancillary equipment in MR imaging.
10. Compare MR instrumentation to other imaging modalities.

Content

I. Magnetism
- A. Magnetic properties
  - 1. Diamagnetism
    - a. Principles
      - 1) Electron configurations
      - 2) Effects of externally applied magnetic fields

b. Materials
1) Examples of materials (wood, glass, gold, etc.)
2) Nonmagnetic

2. Paramagnetism
a. Principles: slightly magnetic
1) Electron configurations
2) Effects of externally applied magnetic fields
b. Materials
1) Contrast agents
a) Gadolinium
b) Manganese
c) Others

3. Superparamagnetism
a. Principles: slightly higher than paramagnetic
b. Materials
1) T2* contrast agents
a) Iron oxide
(1) Oral agents (liver)
(2) Others

4. Ferromagnetism
a. Principles: highly magnetic
b. Materials
1) Iron
2) Steel
c. Permanent magnets/bipolar

B. Magnetic field strength (units of measure)
1. Gauss (g)
2. Tesla (T)

II. Magnets

A. Types of magnets/magnet configurations
1. Permanent
a. Characteristics
1) Field strength (low field)
2) Configuration
b. Temperature dependence
1) 70° +/- 2° F
2) Maintain homogeneity
c. Ferromagnetic materials
1) Iron
2) Other materials

2. Resistive
a. Characteristics
1) Field strength (low field)

2) Configuration
b. Temperature dependence
1) Water cooled
3. Superconductive
a. Characteristics
1) Field strength (high field)
2) Configuration
b. Temperature dependence
1) Cryogens
a) Liquid helium
b) Liquid nitrogen
c) 4 Kelvin
2) Quench
a) Reduce magnetic field
b) Safety considerations
(1) Frostbite/hypothermia
(2) Asphyxia/hypoxia
4. Hybrid
a. Characteristics
1) Field strength
2) Configuration

B. Field direction
1. Horizontal field
2. Vertical field

C. Field configuration
1. B_0
2. Static field
3. Safety considerations for static magnetic fields

D. Field strengths and imaging systems
1. Ultra-low field (for example: 0.01T)
2. Low field (for example: 0.3 T)
3. Mid field (for example: 0.5 T)
4. High field (for example: 1.0 T to 2.0 T)
5. Ultra-high field (for example: 3.0 T and greater)

E. Field strengths and imaging considerations
1. SNR and field strength
2. Image contrast and field strength
a. T1 relaxation and field strength
1) TR and field strength
2) Flip angle and field strength
3) T1 and field strength

b. T2 relaxation and field strength
    1) TE and field strength
    2) TE artifacts and field strength
c. T2* and field strength
    1) TE and field strength
    2) TE artifacts and field strength

3. Artifacts and field strength
    a. Susceptibility
    b. Chemical shift
    c. Dielectric effect
    d. Other artifacts and field strength

F. Field strengths and safety considerations
1. FDA regulations
2. Forces
    a. Translational force
        1) Projectiles
        2) Missile effect
    b. Rotational force
        1) Torque
    c. Bioeffects
        1) Magnet – hemo-dynamic effect
        2) Magnet – hydro-dynamic effect
        3) Elevated T-wave
    d. Implanted devices
        1) Cardiac pacemaker
        2) Intracranial vascular clips
        3) Intraocular ferrous foreign bodies
    e. Ancillary equipment
        1) MR safe
        2) MR conditional
        3) MR unsafe
    f. Safety screening
        1) Patients
        2) Others
    g. Other safety considerations

G. Magnetic field shielding
1. Regulations
    a. 5 gauss
    b. Shielding
2. Mechanisms for magnetic field shielding
    a. Passive shielding
    b. Active shielding
3. "Zoning" (ACR white paper)

a. Zone 1 (accessible to all)
b. Zone 2 (connects Zone 1 to Zone 3 – examples: reception area)
c. Zone 3 (near Zone 4 – restricted access)
d. Zone 4 (magnet room)

4. "Levels of training" (ACR white paper)
   a. Level 1
   b. Level 2
   c. Non-MR personnel

H. Magnetic field function
   1. Align nuclei in a magnetic field
      a. Magnetic moments
      b. Vectors
         1) Magnitude
         2) Direction
      c. Alignment
         1) Low energy state (aligned with the magnetic field)
         2) High energy state (aligned opposed to the magnetic field)
         3) Net magnetization

I. Magnetic field production
   1. Power supply (for resistive)
   2. No power for superconducting
      a. Power to ramp up
   3. No power for permanent magnets

III. Shim Systems

A. Types of shim systems
   1. Passive shimming
      a. Shim plates
      b. Metal
   2. Active shimming
      a. Shim coils
      b. Shim power supply

B. Shim function
   1. Maintain homogeneity
      a. Units of measure
      b. Parts per million (PPM)
   2. Performed by
      a. Technologists
      b. Service engineers

C. Shim field production
   1. Power supply

IV. Radiofrequency Systems

A. Types of RF coils/RF configurations
   1. Transmit coils
      a. Linear
      b. Quadrature
         1) Birdcage coil
         2) Saddle coil
         3) Other configurations
      c. Multichannel
   2. Receive-only coils
      a. Linear
         1) Single coil
            a) 3" to 5" round coil
            b) Saddle coils
         2) Helmholtz pair
         3) Maxwell pair
      b. Quadrature
         1) Birdcage coil
         2) Saddle coil
      c. Multichannel
         1) 8-channel coil
         2) 32-channel coil
         3) Other configurations
      d. Phased array
         1) Linear array (example: spinal coil)
         2) Volume array (example: torso coil)
   3. Transmit/receive
      a. Linear
      b. Quadrature
      c. Multichannel

B. RF field configuration
   1. B1
   2. Oscillating field
   3. Safety considerations for RF fields

C. RF field production
   1. Power supply
   2. Amplifiers and preamplifiers
   3. Receivers

D. Resonance and RF frequencies
   1. Precession
      a. Spin alignment (angled to the magnetic field)

b. Precessional frequency
2. Larmor equation
   a. ωo = Boγ □□Frequency in megahertz
   b. ωo = Boγ (2Π) Frequency in radians
3. Larmor frequency
   a. Related to field strength (B0)
   b. Related to chemicals
      1) Gyro-magnetic ratio (magneto-gyric ratio)
         a) Hydrogen (1H)
         b) Phosphorus (31P)
         c) Other chemicals
      2) Spin angular momentum
      3) Magnetic moment
4. Units of measure
   a. MHz (megahertz)
   b. Hz (hertz)
5. Energy Level (radiation)
   a. Electromagnetic spectrum
   b. Nonionizing radiation vs. ionizing radiation
   c. Low energy
6. RF excitation pulses
   a. 90° RF pulse
   b. 180° RF pulse
   c. Flip angle

E. Signal induction
1. Faraday's law of induction
   a. The equations
      1) dB/dT = dV
      2) ΔB/ΔT = ΔV
   b. MR signal induction
      1) Free induction decay (FID)
      2) Echo
2. Safety considerations (related to gradient coils but due to Faraday's law)
   a. Peripheral nerve stimulation
      1) Magneto-phosphenes ("stars in your eyes")

F. RF and field strengths
1. Ultra-low field (for example: 0.01 T)
   a. Ultra-low frequency
   b. Coil configurations
2. Low field (for example: 0.2 T)
   a. Low frequency
   b. Coil configurations (for vertical fields vs. horizontal)
3. Mid field (for example: 0.5 T)

a. Medium frequency
b. Coil configurations (for vertical fields vs. horizontal)

4. High field (for example: 1.0 T to 2.0 T)
    a. High frequency
    b. Coil configurations (for vertical fields vs. horizontal)
5. Ultra-high field (3.0 T and greater)
    a. Ultra-high frequency
    b. Coil configurations (for vertical fields vs. horizontal)

G. RF fields and safety considerations
1. FDA guidelines
    a. SAR
    b. Over time
2. SAR
    a. Watts/kg
    b. Patient weight
3. Bioeffects
    a. Nonionizing radiation
    b. Heating tissues
4. Other safety considerations
    a. RF heat deposition
    b. Burns

H. RF field shielding
1. Regulations and recommendations
2. Mechanisms for RF field shielding
    a. Copper
        1) In walls
        2) Around door
        3) In window
    b. Faraday cage

I. RF coil function
1. Transmit coils
    a. Excite proton spins
    b. Resonance
    c. Larmor frequency
    d. Transmit gain
2. Receive coils
    a. Receive MR signal
    b. Faraday's Law of Induction
    c. Tuning
    d. Receiver gain (attenuation)
3. Transmit/receive coils
    a. Decoupling

V. Gradient Systems

A. Types of gradients/gradient configurations
   1. Wire configurations determine gradient slope
      a. Characteristics
      b. Gradient slope (amplitude or strength)
      c. Polarity (direction)

B. Gradient characteristics
   1. Strength/amplitude
      a. Millitesla/meter (mT/m)
      b. Gauss/meter (g/cm)
      c. Inter-relationship (10 (mT/m) = 1 g/cm)
   2. Rise time
      a. Microseconds
   3. Amplitude and rise time
      a. Slew rate
      b. T/m/sec (Tesla per meter per second)
   4. Duty cycle
      a. Percent of time that the gradient can work
      b. Gradient heating

C. Gradient fields and safety considerations
   1. FDA guidelines
      a. Faraday's Law ($\Delta B/\Delta T = \Delta V$)
      b. Until a patient feels discomfort
   2. Bioeffects
      a. Peripheral nerve stimulation
      b. Acoustic noise
   3. Other safety considerations
      a. No skin-to-skin contact
      b. Burns

D. Gradient function
   1. Spatial encoding
      a. Slice selection
      b. Phase encoding
      c. Frequency encoding
   2. Gradient refocusing
      a. Gradient echoes
      b. Gradient moment nulling

E. Gradients
   1. Physical gradients
      a. Z (superior to inferior)
      b. Y (anterior to posterior)

c. X (right to left)

2. Logical gradients
   a. Z (slice selection)
   b. Y (phase encoding)
   c. X (frequency encoding or readout)
      1) Signal detection
      2) Nyquist Theorem
      3) K-space filling
         a) Normal k-space filling
         b) centric
         c) Partial Fourier

VI. Ancillary Equipment

A. Additional instrumentation for scanning
   1. ECG leads for gating
   2. Respiratory bellows for respiratory triggering

B. Power injectors
   1. Contrast media
   2. Syringes
   3. Tubing
   4. Safety considerations

C. MR-conditional supplies
   1. Patient monitoring
      a. ECG
      b. Pulse oximetry
      c. Fiber optic
   2. Oxygen tanks
   3. Patient transportation
      a. Wheelchairs
      b. Stretchers
      c. Patient tables (detachable)
   4. Intravenous supplies
      a. IV poles
      b. Medical pumps
   5. Step-stools
   6. Other MR-safe supplies

D. Remote workstations (imaging manipulation)
   1. Archiving and data storage
      a. Magnetic tape storage
      b. CD-ROM storage
      c. DVD
      d. PACS

2. Windows and levels
3. Region of interest (ROI)
4. Annotations
5. Post-processing
    a. Maximum intensity projection (MIP)
    b. Simple sum of squared difference (SSD)
    c. Vascular segmentation
    d. 3-D surface (volume) rendering
    e. Multiplanar reconstruction
6. Other functions

VII. Computer Systems

A. Characteristics
1. Memory
2. Speed
3. Capabilities

B. Components
1. Technologist interface
2. Keyboard/mouse
3. Monitor

C. Capabilities
1. Protocols
2. Parameters
3. Data manipulation

D. Array processor
1. Fourier transform
2. Half and partial Fourier
3. 2-D/3-D imaging

VIII. Operational Flow

A. Image/system selection
1. High-field vs. low-field vs. ultra-high
2. Mobile vs. fixed
3. Traditional bore vs. open systems
4. Permanent, resistive, superconducting

B. Site selection
1. Environmental considerations
2. Magnetic field impact
3. Radio frequency (RF field impact)
4. Safety considerations

C. Facility design

1. New construction
2. Integration into existing structure
3. Shielding
    a. Magnetic active and passive
    b. RF shielding
4. Zoning

D. Government regulations, certificate of need

E. Ancillary equipment

F. Staffing and staff training (when required/where applicable)
1. Physician
2. Radiologic technologist
3. Clerical/support
4. Nurse
5. Anesthesiologist/anesthetist
6. Physicist

IX. Imager Maintenance

A. Maintenance contracts

B. Preventive maintenance

C. Repairs

D. Quality assurance (testing)

X. Facility Operational Equipment

A. Patient scheduling
1. Scanning schedule/registration (scheduling system)
2. Request forms
3. Patient history/screening forms
    a. Screening for contraindications
    b. Screening for history
4. Patient instructions
5. Medications and sedation

B. Patient/visitor comfort at scan facility
1. Patient waiting area
2. Patient changing area
3. Accommodating for delays in schedule
    a. Claustrophobia
    b. Sedation
        1) Pharmacology

2) Emergency response (code cart)
4. Monitoring
5. Post-sedation instructions

C. Patient/physician/health professional education
1. Patient brochure
2. Physician education
3. In-service education of ancillary personnel
4. FDA guidelines

D. General safety precautions, policies and procedures
1. Written policies and procedures
2. Posting of magnetic field warnings; safety zone/warning zones
3. In-service education of staff/ancillary personnel
4. Pregnancy
   a. Technologist
   b. Patient
5. FDA guidelines
6. Restrictive barriers, shielding
7. Screening of individuals entering the magnetic field
   a. Identification of risk factors
      1) Magnetic field, biomedical implanted devices, other
      2) RF field, biomedical implanted devices, other
      3) Gradient field, biomedical implanted devices, other
   b. Restrictions of potential hazardous objects
   c. Restriction of instruments, etc., that may be damaged or dangerous
   d. Removal of artifact-creating objects
   e. Consent and screening forms — acknowledgment of contraindications
   f. Procedure for magnet quench
   g. SAR requirements
   h. Sedation issues and use of monitoring devices
   i. Hearing protection devices and techniques

E. Emergencies while patient is in the scanner
1. Patient related
   a. Breathing or cardiac
   b. Equipment failure/magnetic quench
   c. Projectiles
   d. Emergency evacuation procedure

F. Biological effects/hazards
1. Static magnetic field
2. RF energy
3. Gradient magnetic fields

MR Pulse Sequences, Image Formation and Image Contrast

Description
This unit is designed to provide the student with a comprehensive overview of MR pulse sequences, image formation and image contrast. Pulse sequences include spin echo, fast spin echo, gradient echo, inversion recovery, echo planar, parallel imaging and spectroscopy. In addition, tissue characteristics, contrast agents and post-processing techniques are covered.

Rationale
This course is required to understand MR pulse sequences, image formation and image contrast. The course provides information on selecting pulse sequences. This information enables the student to maximize MR image quality by understanding the basis of MR imaging.

Objectives
Upon completing the course, the student will be able to:

1. Explain intrinsic parameters that affect image quality such as: MR tissue characteristics that include spin density, T1 and T2 relaxation.
2. Explain extrinsic parameters that affect image quality such as: TR, TE, TI, flip angle and lesser used parameters such as venc and "b" value.
3. Apply the principles of pulse sequences and timing diagrams in MR.
4. Define the use of gradient and RF pulses in acquiring MR images.
5. Understand the concepts of image formation in MR.
6. Describe scan time and the associated parameters.
7. Select the appropriate pulse sequence for clinical application.
8. Describe image contrast appearance according to image weighting.

Content

I. Intrinsic Contrast Characteristics (Tissue Characteristics)

A. Longitudinal regrowth (T1 recovery)
   1. T1 relaxation
   2. Spin-lattice interaction
   3. Exponential recovery

B. Transverse decay (T2 Decay)
   1. T2 relaxation
   2. Spin-spin interaction
   3. T2*
   4. Exponential decay

C. Spin density
   1. Actual proton density (total number of mobile water protons)
   2. Relative proton density (spin excess during thermal equilibrium)

D. Flow and motion
    1. Orders of motion
        a. First order (constant velocity)
        b. Second order (acceleration)
        c. Third order (jerk)
    2. Flow characteristics
        a. Laminar flow
        b. Vortex flow
        c. Turbulent flow

E. Diffusion
    1. Restricted diffusion
    2. Unrestricted diffusion

F. Magnetization transfer

II. Extrinsic Contrast Characteristics (User-selection Parameters for Image Contrast)

A. TR – repetition time
    1. Time constant (time to repetition)
        a. SE, FSE sequences – Time to repetition (90° to 90°)
        b. GrE, EPI sequence – time between initializing RF pulses (flip-flip)
        c. IR sequences – time between initializing (180° to 180°)
    2. Effects on image quality
        a. T1 information on MR images
        b. Scan time
        c. SNR
        d. Number of slice locations

B. Echo Time (TE)
    1. Time constant (time to echo)
        a. For spin echo (SE)
            1) Time from FID to echo
            2) (90° to 180° x 2)
        b. For gradient echo (GrE)
            1) Time from FID to echo
            2) Flip – gradient refocusing x 2
    2. Effects on image quality
        a. T2 information on MR images
        b. SNR
        c. Number of slice locations
        d. Susceptibility artifact

C. Inversion time (TI)
    1. Time constant (time to inversion)
        a. For IR

1) Time from inversion pulse to excitation pulse
2) (180° to 90°)

b. STIR
1) Fat suppression

c. Fluid attenuated inversion recovery (FLAIR)
1) Fat suppression

d. SPIR
1) Chemical suppression
2) 180° at the frequency of fat

2. Effects on image quality
a. Fat suppression
b. Water suppression
c. Silicone suppression

D. Flip angle – degree of angulation of the net magnetization
1. RF pulse
a. Duration of RF pulse
b. Power deposition
1) 90° to 180° increase in power x 4
2) Quadratic increase in power
a) Double flip angle
b) 4 x power deposition

2. Effects on image quality
a. SNR (Ernst angle)
b. Image contrast (T1 information)

E. Imaging options for MR image contrast
1. PC-MRA
a. Velocity encoding (VENC) – certain flow velocities bright
b. Flow direction (certain flow directions bright)

2. Diffusion imaging
a. Shots (reduces/increases blurring)
b. "b" value (certain diffusion characteristics bright)

3. Flow imaging
a. Saturation pulses (flowing vessels black)
1) Spatial presaturation (flowing vessels black)
2) Spectral saturation (certain tissues black)
a) Chemical shift selective suppression
b) Fat suppression
c) Water suppression
d) Silicone suppression

b. Gradient moment nulling (flowing vessels bright)

III. Pulse Sequences

A. Timing diagrams

1. RF pulse timing (image contrast manipulation)
    a. TR
    b. TE
    c. TI
2. Gradient pulse timing (for spatial encoding and MR image formation)
    a. Logical gradients (associated with timing diagrams)
        1) Z – Slice selection
        2) Y – Phase encoding
        3) X – Frequency encoding
    b. Physical gradients (associated with imaging planes)
        1) Z – superior to inferior
            a) Slice selection for axial slices
            b) Phase encoding short axis of the anatomy
                (1) Most sagittal and some coronal images
                (2) Sometimes swap phase and frequency
            c) Frequency for long axis of anatomy
                (1) Most sagittal and some coronal images
                (2) Sometimes swap phase and frequency
        2) Y – posterior to anterior
            a) Slice selection for coronal slices
            b) Phase encoding (short anatomy)
            c) Frequency encoding (long anatomy)
        3) X – right to left
            a) Slice selection for sagittal slices
            b) Phase encoding (short anatomy)
            c) Frequency encoding (long anatomy)

B. Pulse sequence configurations
    1. Partial saturation
        a. Early MR sequencing
        b. 90° and gradient pulses
    2. Spin echo
        a. Single echo (90° to 180°)
        b. Multiecho (90° to 180° to 180°)
        c. Quality characteristics
            1) Reduced susceptibility artifact
            2) Increased SNR
    3. Inversion recovery
        a. Types of IR sequences
            1) Spin echo IR
            2) FSE – IR
            3) Double IR (driven equilibrium)
            4) Gradient echo – IR
        b. IR sequence image contrast
            1) STIR

a) Short TI
b) Suppress fat

2) FLAIR
a) Long T1
b) Suppress water/fluid

3) SPAIR
a) Spectral IR
b) Chemical shift suppression IR

4. Rapid acquisition recalled echo (RARE)
a. Vendor names
1) Fast spin-echo (FSE)
a) Parameters
(1) ETL
(2) Effective TE
(3) Echo spacing
b) FSE types
(1) Conventional FSE
(2) FSE-IR
(3) Single shot FSE

2) Turbo spin-echo
a) Parameters
(1) Turbo factor
(2) TE
(3) Echo spacing
b) FSE types
(1) Conventional TSE
(2) HASTE (Half Acquisition TSE)

5. Gradient echo
a. Steady state – coherent gradient echo
1) Susceptibility sequences (T2*)
2) Flow sequences
a) PC MRA
b) Cine PC
c) Cine'

b. Spoiled – incoherent gradient echo
1) T1 sequences (rapid/dynamic imaging)
2) Flow sequences
a) TOF MRA
b) Contrast-enhanced MRA

c. Rapid gradient echo – echo planar sequences (EPI)
1) Susceptibility sequences (T2*)
2) Diffusion
3) Perfusion
a) Contrast-enhanced (dynamic susceptibility weighted sequences)
b) Spin-tagged suppression

4) Blood oxygenation-level dependent (BOLD)

6. Spectroscopy sequences
   a. Single voxel
   b. Multivoxel

IV. Image Contrast Characteristics

A. T1-weighted image
   1. For spin echo
      a. Parameter selection (short TR/TE)
      b. Image contrast characteristics (fat bright/water dark)
      c. Generally acquired for anatomy
   2. For gradient echo
      a. Parameter selection (short TR/TE)
      b. Image contrast characteristics (fat bright/water dark)
      c. Generally acquired for rapid/dynamic imaging
      d. In/out-of-phase imaging
   3. Gradient echo (spoiled sequences for flow)
      a. TOF-MRA
      b. Dynamic contrast-enhanced MRA

B. T2-weighted image
   1. For spin echo
      a. Parameter selection (long TR/TE)
      b. Image contrast characteristics (fat dark/water bright)
      c. Generally acquired for pathology
   2. For gradient echo
      a. Parameter selection (short TR/TE)
      b. Image contrast characteristics (fat bright/water dark)
      c. Generally acquired for T2*
   3. Gradient echo (steady state sequences for flow)
      a. PC MRA – flow velocity and flow direction
      b. Cine PC – dynamic cardiac and vascular imaging
   4. Gradient echo (EPI sequences)
      a. Diffusion – for stroke
      b. Perfusion – for stroke and for tumors
      c. BOLD – for brain function

C. PD-weighted image
   1. For spin echo
      a. Parameter selection (long TR/short TE)
      b. Image contrast characteristics (fat bright/water bright)
      c. Generally acquired for anatomy and pathology
   2. For gradient echo
      a. Parameter selection (short TR/TE)
      b. Image contrast characteristics (fat bright/water bright)

V. MR Contrast Media

A. Types
   1. Gadolinium
      a. T1 (IV) agent (enhanced T1WI and MRA)
      b. T2 (IV) agent (perfusion imaging)
   2. Manganese
      a. T1 (IV) agent
      b. Liver agent
   3. Iron oxide
      a. IV agent for liver
      b. Oral agent for bowel imaging

B. Dosing for gadolinium
   1. 0.1 mmol/kg
   2. 0.2 cc/kg

C. Mechanism of action (gadolinium)
   1. T1 shortening
   2. T2 shortening

D. Effects on images
   1. Bright on T1WI
   2. Dark on T2WI

E. Safety characteristics
   1. Few contraindications
   2. Precautions
   3. Nephrogenic systemic fibrosis (NSF)

VI. MR Image Formation

A. Gradients
   1. Z
   2. Y
   3. X

B. Spatial localization
   1. Slice selection
      a. Imaging planes
         1) Sagittal
         2) Axial
         3) Coronal
         4) Oblique
      b. Slice thickness
         1) Gradient amplitude (strength)

2) Transmit bandwidth

2. Phase encoding
   a. FOV (gradient amplitude)
   b. Matrix (phase encoding steps)
      1) Sampling
      2) K-space filling
         a) Normal filling
         b) Centric filling
         c) Spiral
         d) Zero fill
         e) One-half Fourier
         f) Rectangular FOV
            (1) Parallel imaging
            (2) SENSE
            (3) SMASH
   c. Scan time (phase matrix)
   d. Resolution (pixel size)
3. Frequency encoding
   a. FOV
   b. Matrix
   c. Readout gradient
      1) Sampling
      2) Receiver bandwidth
         a) SNR
         b) Sampling time
      3) Nyquist theorem

C. Gradient refocusing
   1. Gradient echoes
   2. Gradient moment nulling

VII. Post-processing

A. Measurements
   1. ROI – region of interest
   2. Distance

B. Reconstruction/reformatting
   1. Multiplanar reconstruction (MPR)
   2. 3-D reformats
   3. Volume reconstruction (VR)

C. MRA reformats/reconstructions
   1. Maximum intensity pixel (MIP)
   2. Shaded surface display (SSD)

MR Safety

Description
This content introduces the basic principles of MR safety and covers the basic concepts of patient management. Educating patients and ancillary staff on magnet safety also is presented. Patient and magnet-related emergencies represent a unique situation to an MR technologist; recommended procedures and responsibilities of the technologist will be discussed for these situations. This content also covers MR contrast agents.

Rationale
This introduction provides basic knowledge of MR safety, patient preparation and monitoring of patients in the MR suite. This information enables the student to better communicate with the health care team to ensure the patients' safety.

Prerequisites
Methods of patient care – equipment, psychology, communication and rationale of patient care techniques.

Objectives
Upon completing the education, the student will be able to:
1. Discuss the elements of safety management that ensure an MR facility operates safely.
2. Demonstrate proper screening and preparation of patients for MR.
3. Monitor patients during procedures.
4. Describe when and how to quench the magnet and handle other emergencies in the MR environment.
5. Demonstrate an understanding of MR contrast agents.

Content

I. Introduction

A. Magnetic fields in MR
   1. Main static field aligns spins
   2. Radio frequency field flips spins
   3. Gradient field is used for spatial encoding of the image

B. MR safety concerns
   1. Force and torque on magnetic materials from the static magnetic field
   2. Heating caused by the RF magnetic field used to flip spins
   3. Nerve stimulation caused by gradient magnetic fields used for spatial encoding
   4. Implanted medical devices affected by the static magnetic field, RF magnetic field and gradient magnetic fields

C. MR safety organizations
   1. International Electrotechnical Commission (IEC)

2. U.S. Food and Drug Administration (FDA)
3. National Electrical Manufacturers Association (NEMA)
4. American Society for Testing and Materials (ASTM)
5. American College of Radiology (ACR)
6. International Society for Magnetic Resonance in Medicine (ISMRM) Safety Group
7. Institute for Magnetic Resonance Safety Education and Research (IMRSER)

II. Static Magnetic Field

A. Force and torque on magnetic materials caused by the static magnetic field can cause projectile hazards
   1. Potential dangers in a hospital setting with examples of projectiles
   2. Force vs. distance from magnet: The force increases very rapidly as distance to magnet decreases

B. Magnetic shielding: active and passive

C. Designing MR guidelines for safety
   1. Provide written safety policies and procedures
   2. Enforce vigilance in controlling access to the MR suite to trained MR personnel
   3. ACR guidelines regarding MR suite safety zones I through IV
   4. Lock MR suite door when trained MR personnel are absent
   5. Provide safety education to all staff that could potentially work near the magnet, including the local fire department
   6. Post warning signs citing examples of potentially dangerous projectiles

D. Field strength relevance to safety

E. Status of high-field MR safety studies

III. Radio Frequency (RF) Magnetic Field

A. Theory of RF heating in MR
   1. Faraday's Law
   2. Factors that affect the amount of heat produced
   3. Most heat is deposited on perimeter of body where it can be more easily dissipated

B. Regions with high resistance can cause focal heating

C. RF heating in clinical MR
   1. Use SAR to estimate temperature increase
   2. SAR = absorbed power/mass (e.g., watts/kg)
   3. Concerns are for core (whole body) and localized heating

D. Responsibilities of technologist concerning patient safety in avoiding RF heating
   1. Position patients properly
   2. Position monitoring equipment properly

3. Screen patients for electronically conducting jewelry, tattoos, cosmetics, medication patches, etc.
4. Monitor patients with physiological conditions that are unable to dissipate heat
5. Monitor patients who are unable to respond due to sedation or mental status
6. Limit pregnant individuals from being present in the RF field

E. How a scanner estimates SAR
1. Scanner calibration routine
2. Determines energy needed to get a 90° flip and 180° flip
3. Adds energy of all RF pulses in a sequence and divides by pulse repetition time (TR) to calculate power
4. Divides by patient weight to calculate whole body SAR

F. IEC/FDA limits for whole-body heating
1. Normal mode limit (suitable for all patients)
2. First level controlled mode (medical supervision)

IV. Gradient Magnetic Fields

A. Gradient coils and current waveforms
1. Linear magnetic fields for spatial encoding
2. Echo planar imaging pulse train

B. Effects on patients
1. Nerve stimulation
a. Orientation of field gradient with respect to the body
b. Location in the body
c. Duration of the gradient pulse

C. Hearing damage caused by dangerously loud sound pressure levels

D. Hyperbolic relationship between pulse duration and stimulation threshold
1. Nerve stimulation
2. Variations in patient response to nerve stimulation

V. Patient and Personnel Safety Screening in MR (Technologist Responsibilities)

A. Obtain documentation and consent in the form of an MR safety screening questionnaire completed by the patient or guardian

B. Obtain any necessary special consent documentation for non-FDA approved MR scanning for the following instances:
1. Pregnancy
2. Injection of contrast to a pregnant patient
3. Implanted device
4. Cardiac stress agent

C. Patient and personnel safety — contraindications for entering the MR suite
    1. Implanted electronic devices
    2. Implanted metallic objects at risk of deflection
    3. Indications for plain film radiography for safety screening include intra-ocular foreign bodies, shrapnel and bullets in the body
        a. The physician in charge should be consulted in each instance and approve of the patient entering the MR environment

VI. Equipment Safety Screening in MR Environment (Technologist Responsibilities)

A. Screen all equipment before allowing entrance to the MR suite

B. Properly label MR-safe equipment

C. Keep all MR conditional and MR unsafe equipment clear of the MR suite and anteroom

D. Recognize table stop and emergency shut-down switches that control electricity to the scanner, and quench or magnet run-down switch

E. Monitor, record and report cryogen levels

F. Monitor the cryogen exhaust vent line for blockages

G. Monitor the cryogen fill line for ice blockages

H. Maintain awareness and marking of gauss lines in MR area

I. Display warning signs prominently
    1. Strong magnetic field
    2. This magnet is always on
    3. Radio frequency field
    4. Hearing protection necessary
    5. Hazardous material including phantom liquids and helium dewars
    6. Laser light in use

J. Display signage that prohibits items and implants
    1. Implants susceptible to electromagnetic fields
    2. Open flame
    3. Electronic media
    4. Ferrous objects
    5. Credit cards

VII. Monitoring of Ancillary Equipment

A. Perform quality measurement of the RF coils

B. Perform quality measurement of software

C. Perform and report cryogen levels

D. Perform checks on pulse receptor, ECG cables and disposable electrodes

E. Measures to take if phantom fluid spills
   1. First aid in case of contact with phantom fluid
   2. Mandatory reporting to local fire department of phantom fluid contents in case of fire
   3. Disposal as special waste
   4. Gauss lines and their relationship to electronic equipment

VIII. Emergencies in the MR Environment Requiring Technologist Action

A. Code blue: Remove patient from the MR suite

B. Fire emergency
   1. Evacuate patients and others
   2. Suspend all electricity to the MR scanner
   3. Follow institution's fire emergency procedure
   4. Employ MR safe fire equipment
   5. Local fire department should be trained by MR personnel
   6. Follow procedures when the fire cannot be contained

C. Metallic items pinned to the magnet
   1. If a person is in immediate danger
   2. If equipment only is pinned to the magnet

D. Quench
   1. Causes
   2. Procedure for evacuation
   3. Remove patient and staff from MR suite
   4. Establish a procedure for gaining entry to the MR suite in case positive pressure is pinning the door to the MR suite (if the door opens inward)
   5. Maintain the room
   6. Notify in-house maintenance personnel
   7. Notify vendor service of quench
   8. Risks of cryogen boil-off during quench
      a. Asphyxiation from displacement of oxygen
      b. Frostbite
      c. Fire due to condensation of oxygen

IX. Safety in MR Contrast Administration

A. Patient history
   1. Sickle cell (in crisis)
   2. Severe asthma

3. Drug allergy
4. Adverse reaction to contrast media
5. Kidney function

B. Preparation
   1. Proper dose
   2. Check for expiration date on contrast vial before administering
   3. Keep the vial until patient has been released
   4. Use sterile technique in preparing lines, tubing and needles
   5. Obtain venous access

C. Contrast administration
   1. Administration by hand
      a. Check for integrity of venous access
      b. Visualize access site during administration, watch for extravasation
   2. Administration by power injector
      a. Check for integrity of venous access site
      b. Understand the relationship between the gauge of the angiocatheter vs. the rate of contrast media flow and follow the guidelines of angiocatheter manufacturer
      c. Follow guidelines for contrast administration through alternative sites such as venous access ports, central lines, etc.

D. Adverse reactions
   1. Local events
      a. Stop contrast administration
   2. Treatment/follow-up guidelines
      a. Compress (hot or cold)
      b. Written instructions for patient to follow after discharge
      c. Notify the physician in charge that the patient needs to be examined
      d. Document/report the extravasation
   3. Systemic events
      a. Stop contrast administration immediately if dose is not complete
      b. Remove patient from MR suite if treatment is required
      c. Assess patient for breathing difficulty
      d. Notify the physician in charge to examine the patient before he/she is released
      e. Treatment/follow-up guidelines:
         1) Appropriate health care provider to administer medications if necessary
         2) Give patient written instructions to follow after discharge
         3) Document/report the contrast reaction
      f. Keep epinephrine and asthma-related drugs in MR suite for emergencies
      g. Have the respiratory therapy immediate response number available
      h. Have code blue button available in the MR area

E. Gadolinium-based MR contrast and NSF
   1. ACR guidelines regarding renal function and dialysis.

Pharmacology and Drug Administration

Description
Content provides basic concepts of pharmacology. This section covers the theory and practice of basic techniques of venipuncture and administering diagnostic contrast agents and/or intravenous medications. The appropriate delivery of patient care during these procedures is emphasized.

Considerations
Prior to introducing this educational content, students should have successfully completed patient care objectives (including CPR/BLS certification), as well as objectives related to anatomy and physiology of the circulatory and excretory systems.

Although regulations regarding administration of contrast media and intravenous medications vary in different states and institutions, the skill should be included in the didactic and clinical curriculum with demonstrated competencies of all appropriate disciplines regardless of the state or institution where the curriculum is taught.

In states or institutions where students are permitted to perform intravenous injections, the program has specific ethical and legal responsibilities to the patient and the student. The student shall be assured that:

- Legal statutes allow student MR technologists to perform this procedure.
- Professional liability coverage is adequate.
- Adequate supervision is provided.
- Appropriate, structured, laboratory objectives are identified.
- Competency is demonstrated and evaluated before the student performs this task unsupervised.

Content

I. Drug Nomenclature

A. Chemical name

B. Generic name

C. Trade name

II. Methods of Drug Classification

A. Chemical group

B. Mechanism/site of action

C. Primary effect

III. General Pharmacologic Principles

A. Pharmacokinetics

B. Pharmacodynamics

IV. Five Rights of Drug Safety

A. The right medication

B. The right dose

C. The right patient

D. The right time

E. The right location

V. Drug Categories of Relevance to MRI (Side Effects, Uses and Impacts on Medical Imaging)

A. Analgesics

B. Antiemetic drugs

C. Antianxiety drugs

D. Antidepressants

E. Anti-inflammatory drugs

F. Antiarrhythmic drugs

G. Vasodilators and vasoconstrictors

H. Diuretics

I. Antihypertensive drugs

J. Anticoagulant and coagulant drugs

K. Antiallergic and antihistamine drugs

L. Bronchodilators

M. Antibacterial drugs

N. Antiseptic and disinfectant agents

O. Sedative and hypotonic drugs

P. Anesthetic agents

Q. Cathartic and antidiarrheal drugs

R. Diagnostic contrast agents

VI. Classification of Contrast Agents

A. Types of compound
   1. Metallic salts
   2. Organic iodides
      a. Ionic contrast agents
      b. Nonionic contrast agents
   3. Iodized oils
   4. Gaseous

B. Pharmacologic profile of contrast agents
   1. Chemical composition
   2. Absorption characteristics
   3. Distribution characteristics
   4. Metabolic characteristics
   5. Elimination characteristics
   6. Indications, actions and effects
   7. Interactions and contraindications
   8. Patient reactions

C. Dosage

D. Preparation

VII. Routes of Drug Administration

A. Systemic
   1. Oral
   2. Rectal
   3. Tube/catheter
   4. Inhalation

B. Parenteral
   1. Intravenous
   2. Intra-arterial
   3. Intrathecal

VIII. Intravenous Drug Therapy

A. Purpose

B. Advantages

C. Methods
   1. Continuous infusion
   2. Intermittent infusion
   3. Direct injection

D. Sites of administration
   1. Peripheral
   2. Central

E. Complications
   1. Infiltration
   2. Extravasation
   3. Phlebitis
   4. Air embolism
   5. Drug incompatibility
   6. Low fluid level in container

F. Initiation of intravenous therapy
   1. Intravenous infusion/venipuncture equipment
   2. Patient identification, assessment and instructions
   3. Dosage, dose calculations and dose-response
      a. Adults
      b. Pediatrics
   4. Patient preparation
   5. Application of standard precautions
   6. Procedure for intravenous infusion/direct puncture
   7. Site observation
   8. Emergency medical treatment procedure
      a. Appropriate codes
      b. Emergency cart (crash cart)
      c. Emergency medications
      d. Accessory equipment
         1) Oxygen
         2) Suction
      e. Emergency medical treatment follow-up tasks
   9. Discontinuation of intravenous therapy
      a. Equipment/supplies for withdrawal
      b. Patient preparation
      c. Application of standard precautions
      d. Withdrawal procedure
      e. Site observation

f. Patient observation
g. Post-procedural tasks

10. Documenting administration
11. Documenting a complication/reaction

IX. Current Practice Status

A. Professional standards
1. Scope of Practice
2. Practice Standards
3. Professional liability and negligence

B. State statutes

C. Employer prerogative

X. Informed Consent

Physical Principles of Magnetic Resonance Imaging

Description
This unit provides the student with a comprehensive overview of MR imaging principles. The subjects are formatted in individual outlines and can be sequenced according to the level of knowledge desired. Topics include the history of MR, nuclear MR signal production, tissue characteristics, pulse sequencing, imaging parameters/options and image formation.

Rationale
This course is required in order to understand the basic principles of MR image acquisition. The course provides information on the fundamentals of MR image acquisition. This information is useful to enable the student to maximize MR image quality by understanding the fundamentals of MR imaging.

Prerequisites
1. Medical Terminology – a course in terminology used in the medical profession.
2. Patient Care – methods, equipment, psychology, communication and rationale behind patient care techniques.
3. Overview of imaging parameters and terminology, safety and patient care procedures.
4. A course in the fundamentals of digital imaging systems.

Objectives
Upon completing this course, the student will be able to:
1. Know the researchers who provided the means for MR imaging.
2. Describe various nuclei in a magnetic field.
3. Explain how an image is acquired in MR (nuclei in a magnetic field, excitation, relaxation).
4. Explain how an MR signal is produced and detected.
5. Explain MR tissue characteristics, such as spin density and T1 and T2 relaxation.
6. Understand the behavior of various nuclei in the magnetic field and/or during the application of the radiofrequency pulse.
7. Understand the concept of resonance and excitation in MR.
8. Understand the concept of relaxation in MR.
9. Apply the principle of pulse sequences and image formation to appropriate clinical applications.
10. Describe and apply the imaging parameters and options available to the user for optimal MR imaging.

Content

I. History of MR
- A. Scientific discovery of the principles of nuclear magnetic resonance (NMR)
  1. Felix Bloch (Bloch equations)
  2. Edward Purcell
  3. Sir Peter Mansfield

B. Scientists associated with MR
    1. Nikola Tesla
    2. Jean Baptiste Fourier (Fourier transformation)
    3. Richard R. Ernst (Ernst angle)
    4. Joseph Larmor (Larmor equation)
    5. Michael Faraday (Faraday's Law of Induction)
    6. Charles Dumoulin (MRA)

C. Early MR images
    1. Raymond Damadian
    2. Paul Lauterbur

II. Matter

A. Periodic table of elements
    1. MR active nuclei
        a. Hydrogen (1H)
            1) Water(H_20)
            2) Fat (CH3)
            3) Soft tissue structures of the body
        b. Phosphorous (31P)
        c. Other MR active chemicals (uneven mass number)
    2. Chemicals that are not MR active (even mass number)

B. Atom
    1. Nucleus
        a. Proton
        b. Neutron
    2. Electron

III. Nuclear Magnetism

A. Definitions
    1. Approach/methodology
        a. Quantum
        b. Classical
    2. Frames of reference
        a. Laboratory frame of reference
        b. Rotating frame of reference

B. Nuclei in a magnetic field
    1. Nuclear alignment
        a. Magnetic moment
        b. Vectors
            1) Magnitude
            2) Direction
    2. Energy states

a. Low energy state
    1) Spin up
    2) Parallel
b. High energy state
    1) Spin down
    2) Antiparallel

IV. MR Signal Production

A. Thermal equilibrium
1. Magnetization
    a. Longitudinal magnetization ("z" axis)
    b. Transverse magnetization ("x" "y" plane)
    c. Net magnetization
2. Spin excess

B. Precession
1. Precessional frequency
2. Larmor frequency (ωo)
    a. Hertz (Hz)
    b. Megahertz (MHz)
3. Larmor equation ($\omega o = Bo\ \gamma$)
    a. Field strength (Bo)
    b. Gyro-magnetic ratio (γ) – (spin angular momentum and the magnetic moment)
        1) (γ) for 1H = 42.6 MHz/T
        2) (γ) for 31P = 17.2 MHz/T
        3) (γ) for other MR active chemicals

C. Resonance
1. Excitation
    a. RF pulse (B1)
        1) 90° RF pulse – when the RF pulse tips the magnetization into the transverse plane it is known as a "90° RF pulse"
        2) 180° RF pulse – when the RF pulse tips the magnetization into the 180° it is known as a "180° RF pulse"
        3) Flip angle – the degree that the magnetization is "tipped" is known as the flip angle
    b. Bioeffects for RF pulses
        1) Heating tissues
        2) Measured by SAR
        3) Limited by the FDA
    c. NMR Signals
        1) FID
        2) Echoes
            a) Spin echo signal

b) GRE

2. Relaxation characteristics that relate to MR image contrast
   a. T1 relaxation
      1) Longitudinal recovery
      2) Spin-lattice
      3) T1 recovery (exponential relaxation/recovery)
         a) In one T1 time, 63% of longitudinal magnetization recovers
         b) In one T1 time, 37% of longitudinal magnetization remains
   b. T2 relaxation
      1) Transverse decay
      2) Spin-spin
      3) T2 decay (exponential relaxation/decay)
         a) In one T2 time, 63% of transverse magnetization decays
         b) In one T2 time, 37% of transverse magnetization remains
   c. Relaxation and contrast media in MR
      1) Enhanced T1 relaxation with contrast agents
         a) Gadolinium
         b) Manganese
      2) Enhanced T2* relaxation with contrast agents
         a) Gadolinium
         b) Iron oxide
3. Tissue characteristics that relate to MR image contrast
   a. Proton density
      1) Number of mobile water protons
      2) Varies with tissue type
   b. Relative proton density
      1) Number of mobile water protons in the spin excess
      2) Varies with tissue type and field strength

V. MR Signal Induction/Sampling/Conversion

A. MR signal induction
   1. FID
      a. Free of the RF pulse
      b. Induced in the receiver coil
      c. Decays over time
   2. Echo/readout
      a. Sampled at the TE time
      b. Sampling points related to the frequency matrix
      c. Sampling points stored as lines in k-space
   3. Nyquist theorem
      a. Must be sampled at discrete time intervals
      b. Sampled twice at its highest frequency

B. MR signal conversion
   1. Fourier transformation

a. Frequency domain (spectrum)
b. Time domain (FID)

2. Array processor
   a. Performs multiple Fourier transformation equations

C. Spectroscopy
1. Spectrum (1H)
   a. Chemical shift
      1) Spectral resolution
      2) Parts per million (PPM)
   b. Field strength
2. Spectrum of other MR active chemicals

VI. MR Image Contrast Characteristics

A. Weighting in MR imaging
1. T1 weighted images
   a. Parameter values
      1) Short TR
      2) Short TE
   b. Image contrast characteristics
      1) Tissues with short T1 times bright
      2) Tissues with long T1 times dark
2. T2 weighted images
   a. Parameter values
      1) Long TR
      2) Long TE
   b. Image contrast characteristics
      1) Tissues with short T2 times dark
      2) Tissues with long T1 times bright
3. T2* weighted images (GRE sequences)
   a. Parameter values
      1) Short TR
      2) Short TE
      3) Short flip angle
   b. Image contrast characteristics
      1) Tissues with short T2 times dark
      2) Tissues with long T1 times bright
   c. Susceptibility artifacts are increased with gradient echo sequences
4. Proton density (PD) weighted images
   a. Parameter values
      1) Long TR
      2) Short TE
   b. Image contrast characteristics
      1) Tissues with high proton density times bright
      2) Tissues with high proton density times bright

5. Image contrast characteristics/comparison
    a. T1-weighted image
    b. T2-weighted image
    c. T2*-weighted image
    d. PD-weighted image
    e. Flow imaging
    f. Diffusion imaging
    g. Magnetization transfer
6. Introduction to pulse sequences and image contrast
    a. Partial saturation
    b. Spin echo
        1) Conventional spin echo
        2) FSE (turbo spin echo, rapid acquisition recalled echo)
    c. GRE
        1) Steady state (T2)
            a) PC MRA
            b) Steady-state dynamic cine
        2) Spoiled (T1)
            a) Dynamic imaging
            b) In/out of phase imaging
            c) MRA
                (1) TOF MRA
                (2) Enhanced dynamic MRA
        3) Echo planar imaging
            a) Rapid imaging
            b) Perfusion
            c) Diffusion
            d) Functional (BOLD) imaging
    d. Inversion recovery
        1) Standard IR
            a) STIR
            b) FLAIR
        2) FSE – IR
            a) STIR (FSE)
            b) FLAIR (FSE)

B. Image quality comparison of spin echo vs. gradient echo
    1. T1 weighted images
        a. T1 spin echo – generally higher quality and lower susceptibility artifacts
            1) 90° and 180° RF pulses
            2) Short TR/short TE
        b. T1 gradient echo – generally lower quality and higher susceptibility artifacts
            1) Flip angle RF pulses with gradient echo
            2) Short TR/short TE with smaller flip angle and RF and/or spoiling
    2. T2 weighted images

a. T2 spin echo – generally higher quality and lower susceptibility artifacts
    1) 90° and 180° RF pulses
    2) Short TR/short TE
b. T2 gradient echo – generally lower quality and a higher number of susceptibility artifacts
    1) Flip angle RF pulses with gradient echo
    2) Short TR/short TE with smaller flip angle and RF and/or spoiling

VII. Introduction to MR Image Formation

A. Magnetic field gradients
    1. Physical gradients
        a. "Z" (superior to inferior)
        b. "Y" (anterior to posterior)
        c. "X" (right to left)
    2. Logical gradients
        a. "Z" (slice selection – timing diagram)
        b. "Y" (phase encoding – timing diagram)
        c. "X" (frequency encoding – timing diagram)

B. Gradient functions
    1. Image formation
        a. Slice selection
            1) Gradient amplitude
            2) Transmitter bandwidth
        b. Phase encoding
            1) Imaging matrix
            2) FOV
            3) Scan time
        c. Frequency encoding
            1) Imaging matrix
            2) FOV
            3) Receiver bandwidth
            4) TE
    2. Gradient signal refocusing
        a. Gradient echo
        b. Gradient moment nulling
        c. "b" value
        d. "VENC" settings

VIII. Imaging Planes

A. Sagittal

B. Axial

C. Coronal

D. Oblique

IX. K-Space and Image Formation

A. Normal filling

B. Centric filling

C. Zero fill

D. Rectangular FOV

E. Parallel imaging

Sectional Anatomy

Description
This is a study of human anatomy as seen in multiple orthogonal planes. Bone, muscle, vascular structures, organs and soft tissues of the following anatomical regions are studied: central nervous system (brain and spine), other structures in the head, soft tissue neck, musculoskeletal, cardiovascular, thorax, abdomen and pelvis.

Rationale
The student should be able to recognize normal anatomy to ensure that the region of interest is adequately imaged. A study of normal anatomy and normal variations, as well as its appearance in multiple planes, enables the student to better recognize abnormal conditions and make the associated imaging changes required to adequately demonstrate the patient's anatomy and pathology.

Prerequisites
Human Anatomy and Physiology I and II – anatomy of all body regions.

Objectives
Upon completing the course, the student will be able to:
1. Identify anatomical structures as seen in multiple orthogonal planes on MR images.
2. Describe gross anatomic relationships in the body.
3. Describe anterior-posterior, proximal-distal and lateral-medial relationships of anatomy.
4. Distinguish normal anatomy from abnormal anatomy.

Content

I. The Head

A. Bones of the skull and cranium
   1. Cranial cavity
   2. Facial skeleton
   3. Paranasal sinuses
   4. Foramina of the skull

B. The Brain
   1. Nervous tissue and organization
      a. White matter structures
      b. Gray matter structures
   2. Regions of the brain
      a. Cerebrum to include hemispheres, lobes, fissures, sulci, etc.
      b. Diencephalon to include epithalamus, thalamus, hypothalamus, etc.
      c. Brainstem
         1) Midbrain
         2) Pons

3) Medulla oblongata
4) Cranial nerves

d. Cerebellum to include hemispheres and peduncles

3. The Ventricular System
   a. Cerebrospinal fluid
   b. Choroid plexus
   c. Lateral ventricles
   d. Third ventricle
   e. Fourth ventricle
4. Meninges
   a. Dura mater and major extensions
   b. Arachnoid
      1) Subarachnoid cisterns
   c. Pia mater
5. Arterial blood supply
   a. Anterior supply (major branches)
   b. Posterior supply (major branches)
   c. Circle of Willis
6. Venous drainage
   a. Superficial drainage system
   b. Dural sinuses
   c. Internal jugular vein
7. Cranial nerves
8. The orbital cavity
   a. Skeletal formation of the orbital cavity
   b. Bulbus oculi (eyeball)
      1) Fibrous tunic
      2) Vascular tunic
   c. Orbital muscles
   d. Vascular supply
   e. Optic nerve
9. Auditory canal
   a. Temporal bone and bony structures
   b. Vestibulocochlear nerve and course
10. Endocrine system - pituitary gland
    a. Sphenoid bone
    b. Infundibulum
    c. Hypophysis (pituitary gland)

II. The Spine

A. Vertebral column
   1. Sections
   2. Curvatures

B. Typical vertebrae components

1. Cervical vertebrae components
2. Thoracic vertebrae components
3. Lumbar vertebrae components

C. Sacrum

D. Coccyx

E. Intervertebral discs
   1. Nucleus pulposus
   2. Annulus fibrosus

F. Spinal cord
   1. Composition
      a. White matter
      b. Gray matter
   2. Components

G. Spinal plexus
   1. Cervical
   2. Brachial
   3. Lumbar
   4. Sacral

III. The Soft Tissue Neck (Skeletal Components – see Spine)

A. Tissue organization
   1. Suprahyoid
   2. Infrahyoid

B. Viscera of the neck
   1. Pharynx
      a. Nasopharynx
      b. Oropharynx
      c. Palatine tonsils
      d. Hypopharynx
   2. Rectopharyngeal space
   3. Larynx (distinguishing between true and false cords)
   4. Esophagus
   5. Trachea
   6. Thyroid gland
   7. Salivary glands

C. Vascular supply (major branches)

D. Musculature of the neck

1. Muscles of mastication
2. Anterior triangle
3. Posterior triangle

IV. The Thorax

A. Skeletal anatomy of the thorax
   1. Sternum
   2. Thoracic vertebrae
   3. Ribs

B. Thoracic cavity
   1. Lungs
   2. Mediastinum

C. Heart
   1. Superficial features of the heart
   2. Chambers and valves
   3. Vascular supply and drainage
      a. Coronary arteries
      b. Cardiac veins
   4. The great vessels of the heart
      a. Aorta
         1) Ascending aorta
         2) Arch
         3) Descending aorta
      b. Pulmonary trunk
      c. Superior vena cava
      d. Inferior vena cava

D. Associated thoracic structures
   1. Thymus
   2. Trachea and bronchi
   3. Esophagus
   4. Azygos veins

E. Breast
   1. General structure
   2. Hormonal participation

F. Lymphatic system

V. The Abdomen

A. Abdominal regions

B. Diaphragm

1. Structure
2. Openings

C. Abdominal musculature
   1. Anterolateral muscles
   2. Posterior muscles

D. Abdominal peritoneum
   1. Mesentery
   2. Peritoneal elements

E. Peritoneal cul-de-sacs

F. Abdominal vasculature
   1. Abdominal aorta
   2. Branches

G. Venous drainage of the abdomen
   1. Inferior vena cava
   2. Major veins connecting to inferior vena cava (IVC)

H. Hepatic portal system
   1. Portal vein
   2. Veins connecting to portal system

I. Abdominal viscera
   1. Liver
      a. Lobes
      b. Vasculature
   2. Gallbladder
   3. Esophagus
   4. Stomach
      a. Vasculature
      b. Divisions
   5. Small intestine
   6. Large intestine
   7. Spleen
   8. Pancreas
      a. Vascular landmarks
      b. Divisions
      c. Blood supply
   9. Kidneys
      a. Blood supply
      b. Structure
   10. Suprarenal gland

a. Blood supply
b. Composition

VI. The Pelvis

A. Pelvic cavity

B. Bony pelvis
1. Sacrum
2. Coccyx
3. Os Coxae
4. Pubis
5. Ischium
6. Ilium
7. Acetabulum

C. Pelvic musculature
1. Wall of the false pelvis
2. Pelvic floor
3. Wall of the true pelvis

D. Vasculature
1. Common iliac arteries
2. Common iliac veins

E. Innervation

F. Pelvic viscera
1. Gastrointestinal organs
2. Urinary organs

G. Viscera of female pelvis
1. Peritoneal folds
2. Ligaments
3. Ovaries
4. Uterus
   a. Body
   b. Fundus
   c. Uterine wall
   d. Perimetrium
   e. Ligamentous attachments
5. Uterine tubes
6. Cervix
7. Vagina
8. Maternal and fetal

H. Viscera of the male pelvis
    1. Scrotum
    2. Ductus deferens
    3. Spermatic cord
    4. Cremaster muscle
    5. Seminal vesicles
    6. Prostate
    7. Bulbourethral glands
    8. Penis

I. External genitalia and related perineum
    1. Regions
    2. Female external genitalia
    3. Male external genitalia

VII. The Upper Extremity

A. Shoulder joint
    1. Bony components
    2. Ligaments
    3. Musculature
    4. Bursae

B. Upper arm (brachium)
    1. Bony components
    2. Muscular components (anterior and posterior)
    3. Vasculature
    4. Innervation

C. Elbow joint
    1. Bony components
    2. Articulations
    3. Ligaments
    4. Musculature
    5. Vasculature
    6. Innervation

D. Cubital fossa
    1. Musculature
    2. Fascia
    3. Contents (identify nerves, arteries, veins and tendons that emphasize a medial to lateral [ulnar to radial] relationship)

E. Forearm
    1. Bony components
    2. Muscular components (anterior and posterior)

3. Vasculature
4. Innervation

F. Wrist
1. Bony compartments
2. Ligamentous components
3. Tendinous components
4. Vasculature
5. Innervation

G. Hand
1. Bony components
2. Muscular components
3. Vasculature
4. Innervation

VIII. Lower Extremity

A. Hip joint
1. Bony components
2. Ligamentous components
3. Muscular components (anterior, posterior and medial groups)
4. Vascular components
5. Innervation

B. The thigh
1. Bony components
2. Muscular components (anterior, medial and posterior compartments)
3. Vasculature
4. Innervation

C. The knee
1. Bony components
2. Ligamentous components
   a. Menisci
   b. Extracapsular ligaments
   c. Intracapsular ligaments
3. Muscular components
4. Neurovascular components

D. The leg
1. Bony components
2. Muscular components
   a. Anterior compartment
   b. Posterior compartment
      1) Superficial

        2) Deep
    c. Lateral compartment
3. Vasculature
4. Innervation

E. The ankle
1. Bony components
2. Ligamentous components
3. Musculotendinous components (medial, lateral, anterior and posterior groups)
4. Neurovascular components

F. The foot
1. Bony components
2. Muscular components
    a. Dorsal
    b. Plantar
3. Innervation
    a. Dorsal
    b. Plantar
4. Vasculature

References

This list of magnetic resonance resources can assist educators in sampling the pool of references and study materials that pertain to medical imaging. The resources list should be viewed as a snapshot of available materials. Omission of any title is not intentional. Because the creation of literature and media related to the field is dynamic, educators are encouraged to search additional sources for recent updates, revisions and additions to this title collection.

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