Magnetic Resonance Imaging

The purpose of structured education is to provide the opportunity for candidates to develop mastery of discipline-specific knowledge that, when coupled with selected clinical experiences, helps to document qualifications. The *Structured Education Requirements for Magnetic Resonance Imaging* is provided to assist candidates with these requirements.

Candidates for magnetic resonance imaging certification and registration must document at least 16 hours of structured education[1]. The activities must be earned within the 24-month period immediately prior to submission of an application for certification and registration. Structured education activities may be academic courses from an institution accredited by a mechanism recognized by the ARRT[2], CE opportunities approved by a RCEEM or RCEEM+, or a combination of the two.

Structured education documentation must include at least one CE credit or its equivalent in each content category listed below (i.e., Patient Care, Safety, Image Production, and Procedures). The remaining hours may be earned from any one or more of the content areas. Specific topics within each category are addressed in the content outline, which makes up the remaining pages of this document.

Content Category	**Minimum Credit Hours**
Patient Care (includes)	1
Patient Interactions and Management	
Safety (includes)	1
MRI Screening and Safety	
Image Production (includes)	1
Physical Principles of Image Formation	
Sequence Parameters and Options	
Data Acquisition, Processing, and Storage	
Procedures (includes)	1
Neurological	
Body	
Musculoskeletal	
Total	**16**

Acceptable Examples:

Example 1	Example 2	Example 3
Patient Care – 3 hours Safety – 2 hours Image Production – 4 hours Procedures – 7 hours	Patient Care – 1 hour Safety – 1 hour Image Production – 1 hour Procedures – 13 hours	Patient Care – 1 hour Safety – 5 hours Image Production – 5 hours Procedures – 5 hours
TOTAL – 16 hours	TOTAL – 16 hours	TOTAL – 16 hours

1. If there is a structured education requirement document with a newer effective date, you may either use the new document or continue to use this document if you have completed at least one educational activity prior to the effective date of the new version. For more information access the online clinical experience tool, where structured education is also reported.
2. Activities meeting the definition of an approved academic course will be awarded credit at the rate of 12 CE credits for each academic **quarter** credit or 16 CE credits for each academic **semester** credit. See the ARRT *Continuing Education Requirements* document for additional information.

Patient Care

1. Patient Interactions and Management

A. Ethical and Legal Aspects
   1. patients' rights
      a. informed consent (*e.g., written, oral, implied)
      b. confidentiality (HIPAA)
      c. American Hospital Association (AHA) Patient Care Partnership (Patients' Bill of Rights)
         1. privacy
         2. extent of care (e.g., DNR)
         3. access to information
         4. living will, health care proxy, advance directive
         5. research participation
   2. legal issues
      a. verification (e.g., patient identification, compare order to clinical indication)
      b. common terminology (e.g., battery, negligence, malpractice, beneficence)
      c. legal doctrines (e.g., respondeat superior, res ipsa loquitur)
      d. restraints versus immobilization
   3. ARRT Standards of Ethics

B. Interpersonal Communication
   1. modes of communication
      a. verbal/written
      b. nonverbal (e.g., eye contact, touching)
   2. challenges in communication
      a. interactions with others
         1. language barriers
         2. cultural and social factors
         3. physical or sensory impairments
         4. age
         5. emotional status, acceptance of condition
      b. explanation of medical terms
      c. strategies to improve understanding
   3. patient education
      a. explanation of current procedure (e.g., purpose, exam length)
      b. pre- and post-procedure instructions (e.g., preparations, diet, medications, discharge instructions)
      c. respond to inquiries about other imaging modalities
      d. communication with patient during procedure

C. Physical Assistance and Monitoring
   1. patient transfer and movement
      a. body mechanics (e.g., balance, alignment, movement)
      b. patient transfer techniques
   2. assisting patients with medical equipment
      a. infusion catheters and pumps
      b. oxygen delivery systems
      c. other (e.g., nasogastric tubes, urinary catheters, tracheostomy tubes)
   3. routine monitoring
      a. vital signs
      b. physical signs and symptoms
      c. fall prevention
      d. documentation
      e. sedated patients
      f. claustrophobic patients

D. Medical Emergencies
   1. allergic reactions (e.g., contrast media, latex)
   2. cardiac/respiratory arrest (e.g., CPR)
   3. physical injury, trauma, or RF burn
   4. other medical disorders (e.g., seizures, diabetic reactions)

* The abbreviation "e.g.," is used to indicate that examples are listed in parenthesis, but that it is not a complete list of all possibilities.

(Patient Care continues on the following page.)

Patient Care (continued)

E. Infection Control
   1. chain of infection (cycle of infection)
      a. pathogen
      b. reservoir
      c. portal of exit
      d. mode of transmission
         1. direct
            a. droplet
            b. direct contact
         2. indirect
            a. airborne
            b. vehicle-borne (fomite)
            c. vector-borne (mechanical or biological)
      e. portal of entry
      f. susceptible host
   2. asepsis
      a. equipment disinfection
      b. equipment sterilization
      c. medical aseptic technique
      d. sterile technique
   3. CDC Standard Precautions
      a. hand hygiene
      b. use of personal protective equipment (e.g., gloves, gowns, masks)
      c. safe handling of contaminated equipment/surfaces
      d. disposal of contaminated materials
         1. linens
         2. needles
         3. patient supplies
         4. blood and body fluids
      e. safe injection practices
   4. transmission-based precautions
      a. contact
      b. droplet
      c. airborne
   5. additional precautions
      a. neutropenic precautions (reverse isolation)
      b. healthcare associated (nosocomial) infections

F. Handling and Disposal of Toxic or Hazardous Material
   1. types of materials
      a. chemicals
      b. chemotherapy
   2. safety data sheet (e.g., material safety data sheets)

G. Pharmacology
   1. patient history
      a. medication reconciliation (current medications)
      b. premedications
      c. contraindications
      d. scheduling and sequencing examinations
   2. administration
      a. routes (e.g., IV, oral)
      b. supplies (e.g., needles)
      c. procedural technique (e.g., venipuncture)
      d. dose calculation
      e. power injector
         1. fluoro-triggering
         2. timing bolus
         3. automatic bolus tracking
   3. contrast media types and properties (e.g., gadolinium, linear versus macrocyclic, ionic versus non-ionic)
   4. appropriateness of contrast media to examination
      a. patient condition
      b. patient age and weight
      c. laboratory values (e.g., BUN, creatinine, eGFR)
   5. complications/reactions
      a. local effects (e.g., extravasation/infiltration, phlebitis)
      b. systemic effects
         1. mild
         2. moderate
         3. severe
      c. emergency medications
      d. technologist's response and documentation

Safety

1. MRI Screening and Safety

A. Screening and Education (patients, personnel, non-personnel)
   1. biomedical implants
      a. identify and document device, year, make, model
      b. research and verify device labeling (MR safe, MR conditional, MR unsafe)
      c. identify device specific parameters
      d. scanning conditional implants
   2. ferrous foreign bodies
   3. medical conditions (e.g., pregnancy)
   4. prior diagnostic or surgical procedures
   5. topical or externally applied items (e.g., tattoos, medication patches, body piercing jewelry, monitoring devices, clothing)
   6. level 1 and level 2 MR personnel

B. Electromagnetic Fields
   1. static field
      a. translational and rotational forces
      b. magnetohydrodynamic effect
      c. magnetohemodynamic effect
      d. magnetic shielding
      e. spatial gradient of the static magnetic field
      f. FDA guidelines
   2. radiofrequency (RF) field
      a. thermal heating (specific absorption rate [SAR])
      b. conductive loops
      c. proximity burns
      d. RF shielding
      e. FDA guidelines
   3. gradient field
      a. current induction
      b. acoustic noise
      c. peripheral neurostimulation
      d. magnetophosphenes
      e. FDA guidelines

C. Equipment
   1. placement of conductors (e.g., ECG leads, coils, cables)
   2. cryogen safety
   3. ancillary equipment (MR safe, MR conditional, MR unsafe)

D. Environment
   1. climate control (temperature, humidity)
   2. designated MR safety zones
   3. gauss lines
   4. emergency procedures (e.g., quench, fire)

Image Production

1. Physical Principles of Image Formation

A. Instrumentation
   1. electromagnetism (e.g., Faraday's law)
   2. static magnet
      a. types (superconductive, resistive, permanent)
      b. magnetic field strength
      c. shim coils
   3. RF system
      a. coil configuration
      b. surface coils
      c. phased array coils
      d. transmit and receive coils
      e. transmit and receive bandwidth
      f. pulse profile
   4. gradient system
      a. gradient coil configuration
      b. slew rate
      c. rise time
      d. duty cycle

B. Fundamentals
   1. nuclear magnetism
      a. Larmor equation
      b. precession
      c. gyromagnetic ratio
      d. resonance
      e. RF pulse
      f. equilibrium magnetization
      g. energy state transitions
      h. phase coherence
      i. free induction decay (FID)
      j. magnetic susceptibility (e.g., diamagnetism, paramagnetism, superparamagnetism, ferromagnetism)
   2. tissue characteristics
      a. T1 recovery
      b. T2 decay (relaxation)
      c. T2* (susceptibility)
      d. proton (spin) density (PD)
      e. flow
      f. diffusion
      g. perfusion
   3. spatial localization
      a. vectors
      b. X, Y, Z coordinate system
      c. physical gradient
      d. slice select gradient
      e. phase-encoding gradient
      f. frequency (readout) gradient
      g. sampling frequency/rate
      h. k-space (raw data)

C. Artifacts (Cause, Appearance, and Compensation)**
   1. aliasing
   2. Gibbs, truncation
   3. chemical shift
   4. chemical misregistration
   5. magnetic susceptibility
   6. radiofrequency (e.g., zipper)
   7. motion and flow (e.g., patient motion, ghosting)
   8. partial volume averaging
   9. crosstalk
   10. cross excitation
   11. moiré pattern
   12. parallel imaging artifacts
   13. eddy currents
   14. dielectric effect

D. Quality Control
   1. slice thickness
   2. spatial resolution
   3. contrast resolution
   4. signal to noise
   5. center frequency
   6. transmit gain
   7. geometric accuracy
   8. equipment inspection (e.g., coils, cables, door seals)

** The subsequent list of artifacts is not a complete list of all possibilities.

(Image Production continues on the following page.)

Image Production (continued)

2. Sequence Parameters and Options

A. Imaging Parameters
   1. repetition time (TR)
   2. echo time (TE)
   3. inversion time (TI)
   4. number of signal averages (NSA, NEX)
   5. flip angle (e.g., Ernst angle)
   6. field of view (FOV)
   7. matrix
   8. pixel
   9. voxel
   10. number of slices
   11. slice thickness and gap
   12. phase and frequency
   13. echo train length (ETL)
   14. effective TE
   15. bandwidth (transmit, receive)
   16. concatenations (number of acquisitions per TR)
   17. b-value
   18. velocity encoding (VENC)

B. Image Contrast
   1. T1 weighted
   2. T2 weighted
   3. PD weighted
   4. T2* weighted
   5. diffusion weighted imaging (DWI)
   6. susceptibility weighted imaging (SWI)

C. Imaging Options
   1. 2D/3D
   2. slice order (sequential, interleaving)
   3. spatial saturation pulse/band
   4. gradient moment nulling
   5. suppression techniques (e.g., fat, water, Dixon method)
   6. physiologic gating and triggering
   7. in-phase/out-of-phase
   8. rectangular FOV
   9. anti-aliasing
   10. parallel imaging
   11. filtering

FOCUS OF QUESTIONS:

Questions will address the interdependence of the imaging parameters, weightings, and options listed on the left, and how they affect image quality.

Image Quality
- contrast to noise ratio (CNR, C/N)
- signal to noise ratio (SNR, S/N)
- spatial resolution
- acquisition time

(Image Production continues on the following page.)

Image Production (continued)

3. Data Acquisition, Processing, and Storage

A. Pulse Sequences
   1. spin echo (SE)
      a. conventional spin echo
      b. fast spin echo (FSE)
   2. inversion recovery (IR) (e.g., STIR, FLAIR)
   3. gradient echo (GRE)
      a. conventional gradient echo
      b. spoiled gradient echo
      c. coherent gradient echo
      d. steady state free precession (SSFP)
      e. fast gradient echo
      f. MRA/MRV
         1. flow dynamics
         2. time-of-flight (TOF)
         3. phase contrast
         4. contrast enhanced
   4. echo planar imaging (EPI)
   5. diffusion weighted imaging (DWI)
   6. susceptibility weighted imaging (SWI)
   7. perfusion
   8. spectroscopy

B. Data Manipulation
   1. k-space mapping and filling (e.g., centric, spiral, keyhole)
   2. fast Fourier transformation (FFT)
   3. post-processing
      a. maximum intensity projection (MIP) reformation
      b. multiplanar reformation (MPR)
      c. subtraction
      d. apparent diffusion coefficient (ADC) mapping
      e. CINE

C. Informatics
   1. hard/electronic copy (e.g., DICOM file format)
   2. archive
   3. PACS and electronic medical record (EMR)
   4. security and confidentiality
   5. networking

Procedures

1. Neurological

A. Head and Neck
   1. brain
   2. brain for MS
   3. brain for seizure
   4. infant brain (less than one year old)
   5. brain for CSF Flow
   6. IACs
   7. pituitary
   8. orbits
   9. cranial nerves (non IACs)
   10. vascular head (MRA)
   11. vascular head (MRV)
   12. brain perfusion
   13. brain spectroscopy
   14. sinuses
   15. soft tissue neck
       (e.g., parotids, thyroid)
   16. vascular neck

B. Spine
   1. cervical
   2. thoracic
   3. lumbar
   4. sacrum-coccyx
   5. sacroiliac (SI) joints
   6. whole spine
   7. brachial plexus
   8. lumbar plexus

FOCUS OF QUESTIONS

Questions about each of the studies listed on the left may focus on any of the following factors:

Anatomy and Physiology
- imaging planes
- pathological considerations
- protocol considerations
- patient considerations
  (e.g., pediatric, geriatric, bariatric, trauma)

Patient Set-Up
- patient data input
- coil selection and position
- patient orientation
- landmarking
- physiologic gating and triggering

Contrast Media
- effect on images

Additional Procedures
- CINE (e.g., CSF flow study, TMJs)
- surgical planning

(Procedures continue on the following page.)

Procedures (continued)

2. Body

A. Thorax
   1. chest (non cardiac)
   2. breast
   3. vascular thorax

B. Abdomen
   1. liver
   2. pancreas
   3. MRCP
   4. adrenals
   5. kidneys
   6. enterography
   7. vascular abdomen

C. Pelvis
   1. soft tissue pelvis
      (e.g., bladder, rectum)
   2. female soft tissue pelvis
      (e.g., uterus)
   3. male soft tissue pelvis
      (e.g., prostate)
   4. vascular pelvis
      (e.g., femoral, iliac)

3. Musculoskeletal

A. Temporomandibular Joints (TMJs)
B. Sternum
C. Sternoclavicular (SC) Joints
D. Shoulder
E. Long Bones (upper extremity)
F. Elbow
G. Wrist
H. Hand
I. Fingers (non thumb)
J. Thumb
K. Bony Pelvis
L. Hip
M. Long Bones (lower extremity)
N. Knee
O. Ankle
P. Foot
Q. Arthrogram
R. Vascular Extremities

FOCUS OF QUESTIONS

Questions about each of the studies listed on the left may focus on any of the following factors:

Anatomy and Physiology
- imaging planes
- pathological considerations
- protocol considerations
- patient considerations
  (e.g., pediatric, geriatric, bariatric, trauma)

Patient Set-Up
- patient data input
- coil selection and position
- patient orientation
- landmarking
- physiologic gating and triggering

Contrast Media
- effect on images

Additional Procedures
- CINE (e.g., CSF flow study, TMJs)
- surgical planning