

# 3-D Image Postprocessing Educational Framework

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## Introduction

Today there are multiple imaging modalities capable of capturing volumetric patient image data. Once captured, the capabilities of advanced hardware stations and software packages can be applied to image data sets to provide unique anatomical renderings. These renderings enhance data interpretation and improve communications between the interpreting radiologist and referring physician and between the referring physician and patients.

The tasks involved in retrieving the data set for a given patient exam and applying postprocessing techniques, such as volume rendering and multiplanar reformations, allow real-time viewing of exam data in any plane with the ability to screen-capture the images for permanent digital archive. A variety of measurements also may be extracted from the volume data. The consistency and accuracy of 3-D multiplanar reformations depend on the quality of the captured volumetric data set combined with the skillful use of 3-D workstations to apply postprocessing techniques for data manipulation. Education and the development of skills for these highly specialized tasks are not often included in entry-level radiologic science programs.

The purpose of this educational framework is to provide program planners with a detailed listing of the knowledge and skill items required of individuals tasked with performing 3-D and other postprocessing reformations of diagnostic patient image data. Computed tomography (CT) and magnetic resonance (MR) postprocessing are the main focus of this framework, although other modalities that acquire volumetric data are advancing and potentially may include 3-D reformation.

This document is divided into specific content areas that represent the essential components of an educational framework designed to prepare technologists to perform the tasks associated with 3-D image postprocessing. Every attempt has been made to be manufacturer-neutral in the construction of this framework. The content and objectives should be organized to meet the mission, goals and needs of each 3-D image postprocessing program. Faculty are encouraged to expand and broaden these fundamental objectives as they incorporate them into their curricula. Specific instructional methods were omitted intentionally to allow for programmatic prerogative as well as creativity in instructional delivery.

# 3-D Image Postprocessing Educational Framework

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# Foundations

This foundations section represents an inventory of pre-existing knowledge and skills gained through an entry-level radiography educational experience and reinforced through professional practice. The content in this section is intended to aid technologists in career planning and program managers in the development of preassessment tools for candidate selection.

## **Basic Principles of Computed Tomography**

Content is designed to provide entry-level radiography students with principles related to computed tomography (CT) image acquisition, display and detection of image artifacts.

## **Basic Principles of Magnetic Resonance Imaging**

Content is designed to provide entry-level radiography students with principles related to magnetic resonance (MR) image acquisition, display and detection of image artifacts.

## **Clinical Practice**

Content and clinical practice experiences should be designed to sequentially develop, apply, critically analyze, integrate, synthesize and evaluate concepts and theories in the performance of radiologic procedures. Through structured, sequential, competency-based clinical assignments, concepts of team practice, patient-centered clinical practice and professional development are discussed, examined and evaluated.

Clinical practice experiences should be designed to provide patient care and assessment, competent performance of radiologic imaging and total quality management. Levels of competency and outcomes measurement ensure the well-being of the patient preparatory to, during and following the radiologic procedure.

## **Digital Image Acquisition and Display**

Content is designed to impart an understanding of the components, principles and operation of digital imaging systems found in diagnostic radiology. Factors that impact image acquisition, display, archiving and retrieval are discussed. Guidelines for selecting exposure factors and evaluating images within a digital system assist students to bridge between film-based and digital imaging systems. Principles of digital system quality assurance and maintenance are presented.

## **Ethics and Law in the Radiologic Sciences**

Content is designed to provide a fundamental background in ethics. The historical and philosophical bases of ethics, as well as the elements of ethical behavior, are discussed. The student will examine a variety of ethical issues and dilemmas found in clinical practice.

An introduction to legal terminology, concepts and principles also will be presented. Topics include misconduct, malpractice, legal and professional standards and the ASRT scope of practice. The importance of proper documentation and informed consent is emphasized.

**Human Structure and Function**

Content is designed to establish a knowledge base in cross-sectional anatomy, physiology and medical terminology. Components of the cells, tissues, organs and systems will be described and discussed.

**Patient Care in Radiologic Science**

Content is designed to provide the basic concepts of patient care, including consideration for the physical and psychological needs of the patient and family. Routine and emergency patient care procedures are described, as well as infection control procedures using standard precautions. The role of the radiographer in patient education is identified.

**Pharmacology and Drug Administration**

Content is designed to provide basic concepts of pharmacology. The theory and practice of basic techniques of venipuncture and administration of diagnostic contrast agents and/or intravenous medications is included. The appropriate delivery of patient care during these procedures is emphasized.

**Radiation Protection**

Content is designed to present an overview of the principles of radiation protection including the responsibilities of the radiographer for patients, personnel and the public. Radiation health and safety requirements of federal and state regulatory agencies, accreditation agencies and health care organizations are incorporated.

## **2-D (Planar) and 3-D (Volumetric) Anatomy**

### **Description**

Content is intended to develop a strong understanding of multiplanar images (axial, sagittal, coronal and orthogonal) of human anatomy created by modalities such as CT and MR that will aid in performing critical assessment of volumetric image renderings from these data sets.

### **Objectives**

1. For each body section listed below, locate anatomical structures on CT and MR images in the transverse, coronal, sagittal and orthogonal imaging planes.
  - a. Head
  - b. Neck
  - c. Thorax
  - d. Abdomen
  - e. Pelvis
  - f. Upper extremity
  - g. Lower extremity
2. Translate anatomical structures from their 2-D planar image appearance into their appearance within multiplanar, curved planar and 3-D volumetric reformations.
3. Manipulate 3-D volumetric data sets to enhance the appearance of select anatomical structures.

## Content

### I. Head and Brain

#### A. Cranial bones

1. Frontal
2. Ethmoid
  - a. Nasal conchae (turbinates)
  - b. Nasal septum
3. Parietal
4. Sphenoid
  - a. Lesser wings
    - 1) Tuberculum sellae
    - 2) Sella turcica
    - 3) Dorsum sellae
    - 4) Anterior and posterior clinoid process
    - 5) Optic canals
  - b. Greater wings
    - 1) Foramen rotundum
    - 2) Foramen ovale
      - a) Foramen spinosum
5. Occipital
  - a. Foramen magnum
  - b. Internal and external occipital protuberance
  - c. Jugular foramen
6. Temporal
  - a. Zygomatic process
  - b. External auditory meatus (EAM)
  - c. Internal auditory canal
    - 1) Bones/structures of inner ear
  - d. Mastoid process
  - e. Petrous portion or ridge

#### B. Facial bones

1. Mandible
2. Maxillae
3. Zygomas
4. Nasal bones

#### C. Sinuses

1. Frontal
2. Maxillary
3. Ethmoidal
4. Sphenoidal

#### D. Facial muscles

1. Masseter

2. Frontalis
  3. Temporalis
- E. Surface anatomy of the brain
1. Fissures (sulci)
    - a. Longitudinal cerebral
    - b. Lateral (Sylvian)
    - c. Central (of Rolando)
  2. Convolutions (gyri)
    - a. Precentral
    - b. Postcentral
- F. Lobes of the brain and midline cerebral hemisphere structures
1. Frontal
  2. Parietal
  3. Occipital
  4. Temporal
  5. Insula (island of Reil)
  6. Cerebellum
  7. Corpus callosum (genu, rostrum, body and splenium)
  8. Septum pellucidum
  9. Sella turcica
  10. Pineal gland
  11. Falx cerebri
  12. Septum pellucidum
- G. Cranial nerves
1. Olfactory
  2. Optic
  3. Oculomotor
  4. Trochlear
  5. Trigeminal nerve
    - a. Mandibular nerve
    - b. Inferior alveolar nerve
  6. Abducens
  7. Facial
  8. Vestibulocochlear
  9. Glossopharyngeal
  10. Vagus
  11. Accessory
  12. Hypoglossal
- H. Brainstem and adjoining structures
1. Diencephalon
    - a. Thalamus
    - b. Hypothalamus



- c. Optic chiasm
- d. Optic tracts
- e. Infundibulum (pituitary stalk)
- f. Pituitary gland
- g. Mammillary bodies
- h. Pineal gland
- 2. Midbrain
- 3. Pons
- 4. Medulla oblongata
  - a. Spinal cord
- I. Arteries (circle of Willis)
  - 1. Vertebral
  - 2. Basilar
  - 3. Internal carotid
  - 4. Anterior and posterior communicating
  - 5. Anterior and posterior cerebral
  - 6. Posterior inferior cerebellar artery
  - 7. Middle cerebral
- J. Venous structures
  - 1. Venous sinuses
    - a. Superior sagittal sinus
    - b. Vein of Galen
    - c. Straight sinus
    - d. Confluence of sinuses (torcular herophili)
    - e. Transverse sinus
    - f. Sigmoid sinus
  - 2. Internal jugular
- K. Ventricular system
  - 1. Lateral ventricles (anterior, body, posterior, inferior or temporal and trigone or atrium)
  - 2. Interventricular foramen (of Monro)
  - 3. Third ventricle
  - 4. Cerebral aqueduct (of Sylvius)
  - 5. Fourth ventricle
  - 6. Foramen of Luschka
  - 7. Foramen of Magendie
  - 8. Choroid plexus
  - 9. Cerebrospinal fluid
- L. Meninges
  - 1. Dura mater
    - a. Extensions of the dura mater
      - 1) Falx cerebri

- 2) Falx cerebelli
  - 3) Tentorium cerebelli
  - 4) Diaphragma sellae
2. Arachnoid
  3. Pia mater
- M. Basal ganglia
1. Caudate nucleus
  2. Putamen
  3. Globus pallidus
  4. Claustrum
  5. Internal capsule
  6. External capsule
  7. Extreme capsule
- N. Orbit
1. Globe
  2. Lens
  3. Optic nerve
  4. Lacrimal gland
  5. Lateral rectus muscle
  6. Medial rectus muscle
  7. Superior rectus muscle
  8. Inferior rectus muscle
  9. Superior oblique muscle
  10. Inferior oblique muscle
  11. Orbital fat
  12. Ophthalmic artery
  13. Retinal vein
- O. Anatomical structures of calvarium and brain
1. Diploe
  2. Subcutaneous soft tissue
  3. Superior sagittal sinus (anterior and posterior)
  4. Central sulcus
  5. Interhemispheric fissure
  6. Falx cerebri
  7. Centrum semiovale
  8. Corpus callosum (genu, rostrum, body and splenium)
  9. Septum pellucidum
  10. Fornix
  11. Sylvian fissure
  12. Insula
  13. Lentiform nucleus (putamen and globus pallidus)
  14. Caudate nucleus (head)
  15. Internal capsule (anterior, body and posterior sections)

16. External capsule
17. Claustrum
18. Hippocampus
19. Cerebral peduncles
20. Mammillary bodies
21. Tentorium cerebelli
22. Petrous portion or ridge
23. Cerebellar tonsil
24. Internal auditory canal (IAC)
25. Nasal septum
26. External auditory canal (EAC)
27. Clivus
28. Mastoid air cells

P. Lines of angulation (imaging baselines)

1. Supraorbitomeatal line
2. Orbitomeatal line
3. Infraorbitomeatal line

Q. Anatomical landmarks

1. Glabella
2. Nasion
3. Acanthion
4. Mental point
5. External auditory meatus (EAM)

## II. Neck

A. Bones

1. Cervical vertebrae
  - a. Parts of vertebrae
  - b. Arteries in cervical spine

B. Organs

1. Pharynx
2. Larynx
3. Esophagus
4. Trachea
5. Salivary glands
6. Thyroid gland
7. Parathyroid glands
8. Lymph nodes

C. Vasculature and neurovasculature

1. Carotid arteries
2. Vertebral arteries
3. Jugular veins

4. Carotid sheath

D. Musculature

1. Anterior triangle
2. Posterior triangle
3. Sternocleidomastoid
4. Sternohyoid
5. Scalene
6. Trapezius

**III. Chest and Mediastinum**

A. Situs

1. Solitus
2. Inversus
3. Ambiguus
  - a. Asplenia (right sidedness)
  - b. Polysplenia (left sidedness)

B. Bony thorax

1. Thoracic vertebrae
  - a. Arterial supply to spine
  - b. Parts of vertebrae
2. Sternum
3. Ribs
4. Costal cartilages
5. Scapulae
6. Clavicles

C. Pulmonary

1. Apices (lung)
2. Diaphragm
3. Angles
4. Hilum
5. Lobes (lungs)
6. Trachea
7. Carina
8. Primary (mainstem) bronchi
9. Secondary bronchi

D. Mediastinum

1. Thymus gland
2. Heart
  - a. Coronary vessels
    - 1) Arteries
    - 2) Veins
  - a) Coronary sinus

- 3) Variant coronary artery anatomy
  - b. Chambers
    - 1) Atria
      - a) Atrial appendages
      - b) Left lateral ridge left atrium
    - 2) Ventricles
    - 3) Interatrial and ventricular septum
    - 4) Papillary muscles
  - c. Valves
- 3. Cardiovascular blood flow – pulmonary vessels
    - a. Pulmonary arteries
    - b. Pulmonary veins
      - 1) Anatomical variations
      - 2) Drainage patterns lung lobes
  - 4. Aorta and branches
    - a. Ascending aorta
    - b. Aortic arch
    - c. Branches of the aortic arch
      - 1) Anatomical variations
    - d. Subclavian arteries
      - 1) Internal thoracic/mammary arteries
    - e. Descending (thoracic) aorta
      - 1) Bronchial arteries
      - 2) Intercostal arteries
        - a) Artery of Adamkiewicz
  - 5. Veins
    - a. Superior vena cava (SVC)
    - b. Inferior vena cava (IVC)
    - c. Azygos vein
    - d. Hemiazygos vein
    - e. Innominate veins
    - f. Subclavian veins
  - 6. Esophagus
- E. Breasts
  - F. Lymphatic structures
    - 1. Thoracic duct
    - 2. Lymph nodes
    - 3. Lymph node stations
  - G. Musculature
    - 1. Pectoralis major/minor
    - 2. Serratus anterior
    - 3. Latissimus dorsi
    - 4. Rhomboideus

#### **IV. Abdomen**

- A. Diaphragm and openings
  - 1. Aortic hiatus
  - 2. Caval hiatus
  - 3. Esophageal hiatus
  
- B. Surface landmarks and regions
  - 1. Quadrants
    - a. Upper left
    - b. Upper right
    - c. Lower left
    - d. Lower right
  
- C. Addison's planes (regions)
  - 1. Left hypochondriac
  - 2. Epigastric
  - 3. Right hypochondriac
  - 4. Left lumbar
  - 5. Umbilical
  - 6. Right lumbar
  - 7. Left iliac
  - 8. Hypogastric
  - 9. Right iliac
  
- D. Abdominal organs and structures
  - 1. Bony structures
    - a. Lumbar vertebrae
  - 2. Abdominal cavity
    - a. Peritoneum
    - b. Peritoneal space
    - c. Retroperitoneum
    - d. Retroperitoneal space
  - 3. Liver
    - a. Hepatic arteries
    - b. Portal venous system
    - c. Liver segments
      - 1) Liver lobes
      - 2) Couinaud classification
    - d. Variant vascular anatomy of living related liver donors
  - 4. Gallbladder and biliary system
  - 5. Pancreas
    - a. Pancreatic ducts
    - b. Parts of pancreas
  - 6. Spleen
  - 7. Adrenal glands

8. Urinary system and tract
    - a. Kidneys
      - 1) Cortex
      - 2) Medulla
      - 3) Renal pelvis
    - b. Ureters
    - c. Variant vascular anatomy of living related kidney donors
  9. Stomach
  10. Small intestine
  11. Colon
  12. Musculature
    - a. Rectus abdominis
    - b. Internal/external obliques
    - c. Transversus abdominis
    - d. Psoas
    - e. Gluteus
  13. Lymph nodes
- E. Branches of the abdominal aorta
1. Anterior visceral branches
    - a. Celiac axis
      - 1) Left gastric
      - 2) Splenic
      - 3) Hepatic
        - a) Gastroduodenal artery
    - b. Superior mesenteric
      - 1) Jejunal and ileal
      - 2) Inferior pancreaticoduodenal
      - 3) Middle colic
      - 4) Right colic
      - 5) Ileocolic
      - 6) Replaced right hepatic
    - c. Inferior mesenteric
      - 1) Left colic
      - 2) Sigmoid
      - 3) Superior rectal
  2. Lateral visceral branches
    - 1) Suprarenal
    - 2) Renal
      - a) Accessory renal
    - 3) Testicular or ovarian
  3. Parietal branches
    - a. Inferior phrenics
    - b. Lumbar
    - c. Middle sacral
  4. Terminal branches

- a. Common iliacs
- F. Tributaries of the inferior vena cava
  - 1. Anterior visceral
    - a. Hepatic veins
  - 2. Lateral visceral
    - a. Right suprarenal
    - b. Renal veins
      - 1) Left gonadal vein
      - 2) Left suprarenal vein
    - c. Right testicular or ovarian
  - 3. Tributaries of origin
    - a. Common iliacs
      - 1) Median sacral
- G. Tributaries of the portal vein
  - 1. Splenic
    - a. Inferior mesenteric
  - 2. Superior mesenteric
  - 3. Right gastric
  - 4. Cystic
  - 5. Left gastric
- V. **Pelvis**
  - A. Bony structures
    - 1. Proximal femur
    - 2. Ilium
    - 3. Ischium
    - 4. Pubis
    - 5. Sacrum
    - 6. Coccyx
    - 7. Acetabulum
  - B. Pelvic vasculature
    - 1. Arterial
      - a. Common iliacs
      - b. Internal iliacs
      - c. External iliacs
      - d. Ovarian/testicular
    - 2. Venous
      - a. External iliacs
      - b. Internal iliacs
      - c. Common iliacs
  - C. Pelvic organs
    - 1. Urinary bladder



- a. Ureter
- b. Urethra
- 2. Small intestine
  - a. Terminal ilium and ileocecal valve
- 3. Colon
  - a. Ascending
  - b. Descending
  - c. Sigmoid
  - d. Rectum
  - e. Vermiform appendix
- 4. Female reproductive organs
  - a. Vagina
  - b. Cervix
  - c. Uterus
  - d. Fallopian tubes
  - e. Ovaries
- 5. Male reproductive organs
  - a. Testes/scrotum
  - b. Prostate gland
  - c. Seminal vesicles
  - d. External to pelvis
    - 1) Penis

## **VI. Musculoskeletal**

- A. Upper extremities
  - 1. Shoulder
    - a. Bony anatomy
      - 1) Clavicle
      - 2) Scapula
      - 3) Humerus
      - 4) Acromioclavicular joint
    - b. Muscles and tendons
      - 1) Deltoid
      - 2) Supraspinatus
      - 3) Infraspinatus
      - 4) Teres minor
      - 5) Subscapularis
      - 6) Supraspinatus tendon
      - 7) Biceps tendon
    - c. Labrum and ligaments
      - 1) Glenoid labrum
      - 2) Glenohumeral ligaments
      - 3) Coracoacromial ligament
      - 4) Coracoclavicular ligaments
      - 5) Bursa (subacromial and subdeltoid)
    - d. Vasculature

- 1) Axillary artery
  - 2) Thoracodorsal artery
  - 3) Lateral thoracic artery
  - 4) Subscapular artery
  - 5) Thoracoacromial artery
  - 6) Axillary vein
2. Elbow
- a. Bony anatomy
    - 1) Humerus
    - 2) Radius
    - 3) Ulna
  - b. Muscles and tendons
    - 1) Anterior group
    - 2) Posterior group
    - 3) Lateral group
    - 4) Medial group
  - c. Ligaments
    - 1) Ulnar collateral
    - 2) Radial collateral
    - 3) Annular
  - d. Neurovasculature
    - 1) Brachial artery
    - 2) Radial artery
    - 3) Ulnar artery
    - 4) Basilic vein
    - 5) Cephalic vein
    - 6) Median cubital vein
    - 7) Ulnar nerve
3. Hand and wrist
- a. Bony anatomy
  - b. Phalanges
  - c. Metacarpals
    - 1) Carpal bones
    - 2) Radius
    - 3) Ulnar
  - d. Tendons
    - 1) Palmar tendon group
    - 2) Dorsal tendon group
    - 3) Triangular fibrocartilage complex
  - e. Neurovascular
    - 1) Ulnar artery
    - 2) Ulnar nerve
    - 3) Radial artery
    - 4) Median nerve
    - 5) Deep palmar arch
    - 6) Superficial palmar arch

## B. Lower extremities

1. Hip/thigh
  - a. Bony anatomy
  - b. Labrum and ligaments
  - c. Muscle groups
    - 1) Hamstring muscles
    - 2) Abductor/adductor
  - d. Neurovasculature
    - 1) Femoral nerve
    - 2) Sciatic nerve
    - 3) Femoral artery
    - 4) Profunda artery
    - 5) Femoral vein
    - 6) Great saphenous vein
2. Knee
  - a. Bony anatomy
  - b. Menisci and ligaments
  - c. Muscles
    - 1) Gastrocnemius
    - 2) Soleus
    - 3) Sartorius
    - 4) Tibialis anterior
  - d. Vasculature
    - 1) Popliteal artery
    - 2) Anterior tibial artery
    - 3) Posterior tibial artery
    - 4) Fibular artery
    - 5) Variations in pedal arterial supply
3. Foot and ankle
  - a. Bony anatomy
  - b. Ligaments
  - c. Tendons
  - d. Muscles
    - 1) Abductor hallucis/digiti
  - e. Vasculature
    - 1) Dorsalis pedis artery
    - 2) Lateral plantar artery
    - 3) Plantar arch

# Image Postprocessing

## Description

Content is designed to establish a knowledge base in the fundamentals of digital image postprocessing that support guided skill development using clinical based image workstations.

## Objectives

1. Describe the benefits of postprocessing of digital images.
2. Describe the requirements of the source data used to create 3-D reformations.
3. Describe fundamentals of image data retrieval stored on Digital Imaging and Communications in Medicine (DICOM) enabled archive systems.
4. Describe techniques and procedures for recording postprocessed images/image sets.
5. Describe how 3-D images are generated.
6. Describe various methods for 3-D image viewing.
7. Describe the principles of correct ergonomics for workstation use.
8. Describe the principles, techniques and applications of:
  - a. Multiplanar and curved reformations.
  - b. Shaded surface displays.
  - c. Volume-rendered images.
  - d. Maximum, minimum and average intensity projections.
  - e. Image segmentation.
  - f. Virtual endoscopy.
  - g. 3-D fusion imaging.
  - h. 4-D imaging.
9. Identify methods of acquiring quantitative data from a normal and temporal volumetric data set.
10. Identify sources of postprocessing image noise and image artifacts, as well as techniques to reduce their presence.

## Content

- I. Image Postprocessing**
  - A. Definition
  - B. Benefits to the observer
  - C. Source data requirements
  - D. How 3-D images are generated
- II. Retrieval and Exporting Image Data**
  - A. Communication with configured DICOM devices
    - 1. Query to retrieve study
  - B. Preview images as acquired by scanner
    - 1. Identify proper series for postprocessing
  - C. Exporting/recording DICOM images
- III. Viewing 3-D Images**
  - A. 2-D screen captures
    - 1. Proper window/level (W/L) display
  - B. Cine
    - 1. Maximum intensity projection (MIP)
    - 2. Temporal images
  - C. Transmission display
    - 1. Computer monitor
    - 2. Holography
    - 3. Stereoscopic viewing
  - D. Workstation ergonomics
- IV. Postprocessing Techniques**
  - A. Multiplanar reformation (MPR)
    - 1. Definition/description
    - 2. Defining the plane of image reformation
    - 3. Thick vs. thin MPR
      - a. Ray-sum projection
      - b. MIP
      - c. Minimum intensity projection (MinIP)
      - d. Average intensity projection (AVE)
    - 4. Curved planar reformation (CPR)
      - a. Manual and automatic vessel tracking

5. MPR and CPR artifacts
    - a. Partial volume
    - b. False stenosis
  6. MPR applications
    - a. Anatomically corrected datasets
    - b. Fast anatomical segmentation
    - c. Noise reduction in standard displays
    - d. Improvement in spatial resolution
- B. 3-D surface rendering (shaded surface display [SSD])
1. Principles
    - a. Illumination with virtual light sources(s)
    - b. Shadowing effect
    - c. Color encoding
      - 1) Orthographic vs. perspective rendering
    - d. Threshold selection and size representation
    - e. Image rotation and viewing angle
    - f. Impact of lowering or raising the threshold
      - 1) “Flying pixels”
      - 2) “Pseudo-stenosis”
  2. Applications
    - a. Clarification of complex 3-D relationships
    - b. Virtual endoscopy
- C. Volume rendering techniques
1. Principles
    - a. Opacity curve
    - b. Surface display
    - c. Lighting
    - d. Color coding
    - e. Spatial resolution, voxel and matrix size
    - f. Interactive rendering-movie scripting
    - g. Special techniques
      - 1) Air casts (inverted opacity curves)
      - 2) Orthographic vs. perspective rendering
      - 3) Vessel endoscopic rendering
      - 4) MPR volume rendering
  2. Artifacts and pitfalls
    - a. Venetian blind artifacts
    - b. Image noise
    - c. Opacity setting error
  3. Applications
    - a. CT/MR angiography
    - b. Skeletal imaging

- c. Tracheobronchial imaging
  - d. Liver
  - e. Lungs
  - f. Colon
  - g. Pancreas
  - 4. Genitourinary
- D. MIP and MinIP
- 1. Principles
    - a. Ray tracing
    - b. Defining the volume of interest (VOI)
    - c. Image contrast
    - d. Viewing angle
    - e. Cine loop to improve 3-D orientation
  - 2. Artifacts and pitfalls
    - a. Depth perception
    - b. Superimposition of structures
    - c. Calcium in vessels
  - 3. Applications
    - a. CT/MR angiography
    - b. Central tracheobronchial system
    - c. Intrahepatic bile ducts
    - d. Pancreatic duct
- E. Average/ray sum projection
- 1. Applications
    - a. Soft-tissue display
    - b. Radiographic projections
- F. Segmentation
- 1. Principle
    - a. Cutting functions
    - b. Threshold techniques
    - c. Connectivity
    - d. Morphologic operators
      - 1) Erosion
      - 2) Dilation
      - 3) Closing functions (removal of holes)
      - 4) Boolean operators
      - 5) Removal of flying pixels
  - 2. Automated techniques
    - a. Region growing
    - b. Bone removal
    - c. Vessel analysis
  - 3. Applications
    - a. Angiography

- b. Volume measurement
  - c. Articular surface viewing
- G. Virtual endoscopy
- 1. Principle
    - a. Perspective rendering along a path
    - b. Viewing angles
    - c. SSD vs. volume rendering
  - 2. Alternative viewing techniques
    - a. Virtual dissection
    - b. Scripting flight paths for movies
  - 3. Artifacts and pitfalls
    - a. Poor patient preparation
    - b. Poor vessel bolus
    - c. Breathing and pulsations
  - 4. Virtual applications
    - a. Colonoscopy
    - b. Bronchoscopy
    - c. Cystoscopy
    - d. Angioscopy
- H. Advanced 3-D displays
- 1. 3-D fusion
    - a. PET-CT
  - 2. Computer-assisted diagnosis
  - 3. Tissue perfusion imaging
- I. 4-D imaging
- a. Cardiac cycles
- V. **Quantitative Analysis**
- A. 2-D measurements
- 1. Angle
  - 2. Centerline length
  - 3. Area
  - 4. Circumference
  - 5. Diameter
  - 6. Histogram
  - 7. Profile
  - 8. Calcium scoring
- B. 3-D measurements
- 1. Volume
    - a. Tumors
    - b. Aneurysms



- C. 4-D measurements
  - 1. Ejection fraction
  - 2. Mass analysis
  - 3. CV flow

**VI. 3-D Artifacts**

- A. Noise
- B. Segmentation misrepresentation
- C. False stenosis
- D. Beam hardening artifacts (CT)
- E. Wrap artifacts (MR)
- F. Motion
- G. Mirror artifacts (CPR)

ASRT

## **Pathology Correlation in 3-D Postprocessing**

### **Description**

Content provides thorough coverage of common diseases diagnosable via CT or MR 3-D images. Each disease or trauma process is examined from its description, etiology, associated symptoms and diagnosis with appearance on CT or MR 3-D images. Terms associated with these pathologies will be included.

### **Objectives**

1. Define common terms used in the study of pathology.
2. Name the common pathological conditions affecting any of the body systems studied in this course.
3. For each common pathological condition identified in the course:
  - Describe the disorder.
  - List the etiology.
  - Name the associated symptoms.
  - Name the common means of diagnosis.
  - List characteristic CT manifestations of the pathology.
4. Identify each of the pathological conditions studied on CT images.
5. Identify pathology resulting from trauma on CT images.
6. Identify pathology common only in pediatric patients.

## Content

The following is a comprehensive, but not inclusive, list of disease processes or conditions that may be displayed on 3-D images.

### I. Cardiovascular System

- A. Atherosclerosis
  - 1. Vascular calcifications
  - 2. Calcified and noncalcified plaque
  - 3. Atherosclerotic ulcers
  - 4. Arterial embolic disorder
  - 5. Stenoses
  - 6. Occlusions
  
- B. Aneurysms
  - 1. Cardiac
  - 2. Thoracic aorta
    - a. Aortic root
  - 3. Abdominal aorta
  - 4. All major branch arteries
  - 5. Types
    - a. Fusiform
    - b. Saccular
    - c. Pseudoaneurysms
    - d. Mycotic
  - 6. Aneurysm rupture
  
- C. Aortic dissection
  - 1. Dissection flaps
  - 2. True/false lumen
  - 3. Intramural hematoma
  
- D. Vascular malformations
  - 1. Arteriovenous malformations (AVM)
    - a. Pulmonary AVM
  - 2. Arteriovenous fistulas
  
- E. Vasculopathy
  - 1. Fibromuscular dysplasia (FMD)
  
- F. Congenital defects
  - 1. Cardiac
    - a. Tetralogy of Fallot
    - b. Atrial septal defect (ASD)
      - 1) Patent foramen ovale
    - c. Ventricular septal defect (VSD)
    - d. Anomalous coronary arteries

- e. Transposition of great arteries
  - f. Pulmonary atresia
  - 2. Vascular
    - a. Coarctation
    - b. Vascular rings
    - c. Patent ductus arteriosus
    - d. Pulmonary sling
    - e. Anomalous pulmonary venous return
    - f. Popliteal entrapment
  - 3. Marfan syndrome
- G. Cardiac disease
- 1. Cardiac transplant
  - 2. Coronary artery disease
    - a. Calcified and noncalcified plaque
    - b. Aneurysms
    - c. Stenoses
  - 3. Myocardial infarction
  - 4. Valvular heart disease
    - a. Stenosis
    - b. Regurgitation
    - c. Prolapse
    - d. Vegetation
  - 5. Myocarditis
  - 6. Pericarditis
  - 7. Cardiomyopathy
    - a. Dilated
    - b. Hypertrophic
    - c. Restrictive
- H. Pulmonary vascular disease
- 1. Pulmonary embolus
  - 2. Pulmonary artery stenosis
  - 3. Pulmonary artery aneurysm
  - 4. Pulmonary vein stenosis
- I. Tumors
- 1. Masses vs. cysts
  - 2. Myxomas
  - 3. Lipoma
  - 4. Rhabdomyoma
  - 5. Fibroma
  - 6. Pericardial cysts
  - 7. Post-treatment tumor volumes
- J. Vasculitis

1. Takayasu's arteritis
  2. Fibromuscular dysplasia
  3. Polyarteritis nodosa
  4. Giant cell arteritis
  5. Infections
- K. Trauma
1. Aortic transection
  2. Large artery pseudoaneurysms
  3. Traumatic dissections
  4. Iatrogenic injuries (catheter)
  5. Traumatic peripheral artery injuries
- L. Venous
1. Thrombosis
  2. Occlusion
- M. Stent grafts
1. Fractures
    - a. Suture breaks
    - b. Strut fractures
  2. Endo leaks
    - a. Types I, II, III, IV
  3. Migration
  4. Stenosis
  5. Infection
- N. Surgical
1. Cardiac
    - a. Mechanical valves
    - b. Bioprosthetic valves
      - 1) Homograft
    - c. Coronary artery bypass graft
      - 1) Saphenous vein graft
      - 2) Arterial graft
        - a) Lima
        - b) Rima
  2. Vascular
    - a. Tube graft
    - b. Bifurcating graft
      - 1) Aorto bi-iliac graft
      - 2) Femoropopliteal (fem-pop) bypass graft
      - 3) Femoro-femoro (fem-fem) bypass graft
    - c. Valved graft
      - 1) Composite
      - 2) Conduit

d. Patch

## II. Central Nervous System

### A. Tumors (benign and malignant)

1. Intra-axial
  - a. Glioma
  - b. Metastasis
2. Extra-axial
  - a. Meningioma
  - b. Cerebellopontine angle (APA)
    - 1) Acoustic neuroma
3. Temporal bone
  - a. Cholesteatoma
4. Head and neck cancers
  - a. Laryngeal cancer
  - b. Pharyngeal cancer
  - c. Nonmucosal cancers

### B. Vascular (head and neck vessels)

1. Aneurysms
2. Dissections
3. Cerebrovascular accident (CVA)
  - a. Cerebral thrombosis
  - b. Hemorrhage
4. Atherosclerosis
5. Encasement
6. Narrowing/stenoses
7. Arteriovenous malformation
8. Arteriovenous fistula
9. Venous sinus thrombosis

### C. Seizures

1. Temporal lobes

### D. Spine

1. Tumors
2. Stenosis
  - a. Degenerative disc disease
  - b. Congenital anomalies
3. Herniated nucleus pulposus
4. Degenerative disease
  - a. Spondylolisthesis
5. Dural ectasia
6. Trauma
  - a. Spine fractures
    - 1) Burst

- 2) C1
- 3) Compression
- 4) Subluxation
- b. Spinal misalignment
- c. Postsurgical hardware
  - 1) Alignment
- 7. Spinal vascular malformations
  - a. AV fistula
  - b. AV malformations
- E. Craniofacial
  - 1. Temporal bone malformations
    - a. Enlargement vestibular aqueduct
    - b. Superior semicircular canal dehiscence
  - 2. Craniofacial deformities
  - 3. Craniosynostosis
  - 4. Facial trauma
    - a. Surgical trauma
      - 1) Inferior alveolar nerve damage

### III. Respiratory System

- A. Airways
  - 1. Normal anatomy
  - 2. Anatomic variants
    - a. Anomalous (tracheal bronchus)
    - b. Supernumerary (accessory cardiac bronchus)
    - c. Agenesis
    - d. Bronchial atresia
  - 3. Congenital lobar emphysema
  - 4. Trachea and mainstem bronchi
    - a. Focal disease
      - 1) Strictures
        - a) Congenital
          - i) Complete vascular ring
          - ii) Pulmonary sling
        - b) Acquired
          - i) Lung transplant anastomosis
          - ii) Postintubation
        - c) Dynamic narrowing
          - i) Tracheomalacia
          - ii) Bronchomalacia
        - d) Stents (for treatment)
      - 2) Infection
      - 3) Neoplasms
        - a) Benign (papilloma)
        - b) Malignant

- i) Primary
        - ii) Metastatic
      - 4) Trauma
        - a) Laceration
        - b) Dehiscence (post-lung transplant)
    - b. Diffuse disease
      - 1) Increased diameter
        - a) Tracheobronchomegaly
      - 2) Decreased diameter
        - a) Relapsing polychondritis
        - b) Amyloid
        - c) Sarcoid
        - d) Wegener's
    - c. Other congenital anomalies
      - 1) Complete or deformed tracheal rings
      - 2) Tracheoesophageal fistula
      - 3) Tracheal and bronchogenic cysts
      - 4) Tracheal webs
  - 5. Lobar bronchi
    - a. Obstruction
      - 1) Endobronchial lesions
        - a) Neoplastic (benign and malignant)
        - b) Non-neoplastic
          - i) Mucus plugs
          - ii) Foreign body
          - iii) Broncholithiasis
      - 2) Extrinsic bronchial obstruction
        - a) Enlarged hilar lymph nodes
        - b) Aortic aneurysm
      - 3) Patterns of lobar atelectasis
  - 6. Peripheral airways
    - a. Bronchiectasis
    - b. Bronchial wall thickening
    - c. Muroid impaction
    - d. Bronchiolitis
- B. Lung volumes
  - 1. Increased
    - a. Emphysema
      - 1) Centrilobular
      - 2) Paraseptal
      - 3) Panlobular (alpha 1 antitrypsin)
    - b. Air-trapping
      - 1) Bronchiolitis obliterans
      - 2) Asthma
  - 2. Decreased



- a. Fibrotic lung disease
  - b. Pleural disease
    - 1) Fibrothorax
- C. Solitary pulmonary nodule
- 1. Morphology
    - a. Density
      - 1) Solid
      - 2) Pure ground glass
      - 3) Mixed ground glass/solid
    - b. Calcification patterns
      - 1) Benign
      - 2) Malignant
    - c. Fat
    - d. Fluid
    - e. Air
    - f. Contrast enhancement
    - g. Rate of growth
- D. Lung cancer
- 1. Precancerous lesions
  - 2. Nonsmall cell lung cancer
  - 3. Small cell lung cancer
  - 4. New tumor node metastasis staging
- E. Trauma
- 1. Pneumothorax
  - 2. Postintubation stenosis

#### **IV. Gastrointestinal System**

- A. Primary neoplasms
- B. Metastases
- C. Tumors
  - 1. Pancreas
    - a. Adenocarcinoma
    - b. Islet cell tumor
    - c. Pancreatic cyst
    - d. Periapillary mass
  - 2. Esophageal cancer
  - 3. Gastric cancer
  - 4. Duodenal cancer
    - a. Adenocarcinoma
  - 5. Colon
    - a. Polyps

- b. Diverticula
  - c. Rectal cancer
- D. Benign bowel lesions
  - 1. Abscesses
  - 2. Fistula
  - 3. Mucosal inflammation
    - a. Mural hyperenhancement
    - b. Soft tissue stranding
    - c. Mural stratification
- E. Inflammatory bowel disease
  - 1. Crohn's disease
  - 2. Ulcerative colitis
- F. Mesenteric ischemia
- G. Gastrointestinal (GI) bleed
- H. Appendicitis
  - 1. Appendicolith
- I. Pancreatitis
- J. Biliary disease
  - 1. Dilatation
  - 2. Obstruction
  - 3. Cholelithiasis
  - 4. Cholangiocarcinoma
- K. Trauma
  - 1. Liver/spleen laceration
- L. Congenital
  - 1. Biliary atresia
  - 2. Pancreatic divisum
  - 3. Annular pancreas
  - 4. Intestinal malrotation
- M. Gaucher disease
  - 1. Liver/spleen enlargement
- V. Genitourinary System**
  - A. Masses (benign and malignant)
    - 1. Renal cell carcinoma
    - 2. Transitional cell carcinoma

3. Wilms tumor
  4. Cystic mass
  5. Metastases
- B. Renal calculi
- C. Renal cysts
1. Polycystic kidney disease
- D. Renal abscess
- E. Bladder carcinoma
- F. Renal transplant
- G. Vascular disorders
1. Renal artery stenosis
  2. Aneurysms
  3. Renal infarct
- H. Hydronephrosis
- I. Reflux
- J. Congenital abnormalities (i.e., anatomical anomalies)
1. Horseshoe kidney
  2. Renal agenesis
  3. Malrotation
  4. Ectopic kidney
  5. Double renal pelvis
  6. Double ureter
  7. Accessory renal arteries
  8. Accessory renal veins
  9. Medullary sponge kidney
- K. Trauma
1. Perinephric hematoma

## **VI. Musculoskeletal System**

- A. Masses
1. Bone tumors
  2. Soft tissue tumors
  3. Infection/abscess
  4. Hematoma
- B. Joint disorders

1. Prosthetic joints
    - a. Preoperative planning
      - 1) Deformities
      - 2) Bone stock
  2. Surgical hardware
    - a. Postoperative heterotopic bone
  3. Chronic joint deformities
    - a. Perthes disease
    - b. Achondroplasia
    - c. Loosening
  4. Bony impingement
    - a. Femoroacetabular impingement
  5. Joint bodies
- C. Anatomical anomalies
1. Hand malformations
  2. Foot malformations
- D. Fractures
1. Malunion
  2. Nonunion
  3. Bony fragments
- E. Trauma
1. Fractures
    - a. Displacement
    - b. Angulation
    - c. Joint involvement
    - d. Degree of depression or distraction
    - e. Soft tissue involvement
      - 1) Tendon entrapment
  2. Dislocation

## **Procedures for 3-D Image Postprocessing**

### **Description**

Content provides a framework of CT and MR procedures that would benefit from the added value of 3-D postprocessing. Included are indications for the 3-D procedures, proper patient preparation for the CT/MR examination, patient history and assessment, contrast media usage, selection of proper 3-D imaging tools and filming/archival of the 3-D images with picture archiving and communication (PACs) integration. 3-D images will be reviewed for quality and proper demonstration of anatomy and pathology. 3-D procedures vary by facility and are dependent on the preference of the radiologist and referring physician.

### **Objectives**

1. Describe the 3-D imaging protocol that best demonstrates anatomy/pathology for a given CT/MR examination.
2. Differentiate both normal and diseased structures on the 3-D images.
3. Describe the proper patient preparation to assure a successful 3-D procedure.
4. Determine if contrast media would be indicated for each 3-D procedure.
5. Determine from patient history and prior imaging the key views to best demonstrate patient's clinical concern.
6. Identify image artifacts and ways to avoid or alleviate them on 3-D images.

## **Content**

- I. Indications for 3-D Procedures**
  - A. Value-added indicators
  - B. General types of studies that benefit from postprocessing
  - C. Patient history and assessment
- II. Contrast media for Best Quality 3-D Images**
  - A. Types of contrast media
    - 1. CT
    - 2. MR
    - 3. PET-CT
  - B. Methods and routes of contrast introduction
- III. Selection of Proper 3-D Imaging Tools**
  - A. Appropriate use of:
    - 1. Multiplanar reformations (MPR)
    - 2. Volume rendering (VR)
    - 3. Maximum intensity projections (MIP)
    - 4. Minimum intensity projections (MinIP)
    - 5. Average projections
    - 6. Shaded surface displays (SSD)
    - 7. Virtual endoscopy
- IV. Storage/Retrieval of 3-D Images**
  - A. PACS integration with source images
- V. 3-D Imaging Procedures**
  - A. CT angiography
    - 1. CT thoracic angiogram
      - a. Pulmonary vein mapping
      - b. Pulmonary embolus
      - c. Cardiac
      - d. Trauma chest
      - e. Non-IV contrast chest
    - 2. CT abdomen/pelvis angiogram
      - a. Mesenteric ischemia
      - b. Trauma abdomen/pelvis
      - c. Renal
      - d. Living hepatic donor
      - e. Living kidney donor
      - f. Non-IV contrast abdomen/pelvis
    - 3. CT extremity angiogram

- a. Aorto-iliac runoff
- b. Lower extremity
- c. Upper extremity
- d. Lower extremity/vena cava venogram
- 4. CT head and neck angiogram
  - a. CT brain perfusion
- B. CT body
  - 1. CT airway
  - 2. CT intravenous pyelogram (IVP)
  - 3. CT Bowel
    - a. CT rectum
    - b. CT enterography
    - c. CT virtual colonography
  - 4. CT pancreas/bile ducts
- C. CT musculoskeletal
  - 1. CT lower extremity
  - 2. CT upper extremity
  - 3. CT pelvis
  - 4. CT spine
    - a. Post CT myelography
- D. CT craniofacial
  - 1. CT head
  - 2. CT facial bones
  - 3. CT dental scan
- E. MR procedures
  - 1. MR chest angiogram
    - a. Cardiac
  - 2. MR abdomen/pelvis angiogram
    - a. Mesenteric ischemia
  - 3. MR renal angiogram
  - 4. MR extremity angiogram
    - a. Aorto-iliac runoff
    - b. Lower extremity
    - c. Upper extremity
  - 5. MR head and neck angiogram
  - 6. MR breast
- F. PET-CT
  - 1. Head
  - 2. Chest
  - 3. Abdomen/pelvis

## G. Quantification

1. Cardiac
  - a. CT and MR ejection fractions
  - b. Left ventricle mass analysis
2. Aortic root measurements
3. CT and MR renal measurements
  - a. Volumes
  - b. Lengths
  - c. Cortical volumes
4. MR cardiovascular flow measurements
  - a. Aorta
  - b. Pulmonary artery
  - c. Superior mesenteric vein (SMV)
  - d. Superior vena cava (SVC)
  - e. Inferior vena cava (IVC)
5. CT and MR vessel wall measurements
  - a. Vessel widening
  - b. Vessel narrowing
  - c. Normal vessel diameter values
6. Stent graft measurements
  - a. Prestent
  - b. Poststent
  - c. Diameters, angles, volumes, centerline path lengths
  - d. Stent migration analysis
  - e. Stent fracture imaging
7. Volume measurements
  - a. Organs
  - b. Tumors



## Quality Assurance in 3-D Image Postprocessing

### Description

Content is designed to focus on the components of a quality assurance program for all aspects of 3-D imaging, from initial CT/MR scanning protocols through final reporting of 3-D findings. 3-D imaging is dependent on the skills of the operator to effectively delineate anatomy and characterize pathology. Therefore it is important to implement a quality assurance program to assure 3-D images are error free on a consistent basis.

### Objectives

1. Discuss the purpose and importance of 3-D quality assurance.
2. Discuss components of a 3-D quality assurance program.
3. Identify errors in acquisition of CT/MR source images.
4. Identify common errors in 3-D imaging.
5. Identify causes of errors in 3-D imaging.
6. Identify methods for improving quality in 3-D imaging.

## **Content**

### **I. Purpose of 3-D Quality Assurance**

- A. Definition of quality assurance/quality control
- B. Impact of imaging errors on patient care

### **II. Components of 3-D Quality Assurance Program**

- A. Methods for interdepartmental and intradepartmental communication
  - 1. Ensure proper requirements are met for CT/MR source images
  - 2. Ensure all personnel are aware of protocol changes
- B. Checklist of core competencies for novice 3-D technologists
- C. Continuous training and updates for 3-D technologists
- D. Consistent quality control measures integrated into workflow
- E. Use of 3-D clinical software with Food and Drug Administration (FDA) medical device 510(k) approval
- F. Checks for interoperator/intraoperator variability
- G. Checks for intermanufacturer/intramanufacturer variability

### **III. Common Errors in 3-D Images**

- A. Source image errors due to improper
  - 1. Slice thickness
  - 2. Image overlap
  - 3. Reconstruction algorithm
  - 4. Timing
    - a. Bolus tracking
    - b. Delayed images
- B. Positioning/technical errors
  - 1. Segmentation
  - 2. Curved planar centerline error
  - 3. Volume rendering settings
  - 4. Annotation errors
  - 5. Improper choice of 3-D imaging protocol
- C. Measurement errors
  - 1. Incomplete comparisons with prior measurements
  - 2. Improper measuring technique
- D. Reporting errors

1. Measurement data entry errors
2. Improper 3-D documentation in exam report

E. Image networking failures

**IV. Causes of Errors in 3-D Imaging**

A. Insufficient training/direction

B. Fatigue, distractions

C. Rushing, increase in workload

**V. Quality Improvement in 3-D Imaging**

A. Frequent image monitoring and quality control checks

B. Error rate measurement and documentation

C. Training/interventions and effect on error rate

D. Documentation of 3-D department standard operating procedures

## Appendix A

ASRT

## Basic Principles of Computed Tomography

### Description

Content is designed to provide entry-level radiography students with principles related to computed tomography (CT) imaging.

### Objectives

- Describe the components of the CT imaging system.
- Differentiate between conventional and spiral/helical CT scanning.
- Explain the functions of collimators in CT.
- List the CT computer data processing steps.
- Name the functions of the array processor used for image reconstruction.
- Define the term "algorithm" and explain its impact on image scan factors and reconstruction.
- Define the terms "raw data" and "image data."
- Explain the difference between reconstructing and reformatting an image.
- Describe the application of the following terms to CT:
  - Pixel.
  - Matrix.
  - Voxel.
  - Linear attenuation coefficient.
  - CT/Hounsfield number.
  - Partial volume averaging.
  - Window width (ww) and window level (wl).
  - Spatial resolution.
  - Contrast resolution.
  - Noise.
  - Annotation.
  - Region of interest (ROI).
  - Standard vs. volumetric data acquisition.
- Name the common controls found on CT operator consoles and describe how and why each is used.
- Identify the types and appearance of artifacts most commonly affecting CT images.
- Explain how artifacts can be reduced or eliminated.
- List and describe current data storage techniques used in CT.
- Name the radiation protection devices that can be used to reduce patient dose in CT and describe the correct application of each.

## Basic Principles of Magnetic Resonance

### Description

Content is designed to provide entry-level radiography students with principles related to magnetic resonance (MR) image acquisition, display and detection of image artifacts.

### Objectives

- Discuss the scientific discovery of the principles of nuclear magnetic resonance.
- Discuss the development of MR imaging.
- Explore future developments of MR imaging.
- Define nuclear magnetic resonance.
- Discuss the concepts of nuclear magnetic resonance (NMR).
- Discuss the production and measurement of the NMR signal.
- Describe the concept of Fourier transformation of information.
- Define basic MR terminology used routinely in the clinical setting.
- Explain the concept of variations in pulse sequences and parameters on the resultant image.
- Identify sources of image artifacts and techniques used to reduce their frequency/appearance.
- Compare and contrast manufacturer-specific terminology.

## Clinical Practice

### Description

Content and clinical practice experiences should be designed to sequentially develop, apply, critically analyze, integrate, synthesize and evaluate concepts and theories in the performance of radiologic procedures. Through structured, sequential, competency-based clinical assignments, concepts of team practice, patient-centered clinical practice and professional development are discussed, examined and evaluated.

Clinical practice experiences should be designed to provide patient care and assessment, competent performance of radiologic imaging and total quality management. Levels of competency and outcomes measurement ensure the well-being of the patient preparatory to, during and following the radiologic procedure.

### Objectives

- Exercise the priorities required in daily clinical practice.
- Execute medical imaging procedures under the appropriate level of supervision.
- Adhere to team practice concepts that focus on organizational theories, roles of team members and conflict resolution.
- Adapt to changes and varying clinical situations.
- Describe the role of health care team members in responding/reacting to a local or national emergency.
- Provide patient-centered clinically effective care for all patients regardless of age, gender, disability, special needs, ethnicity or culture.
- Integrate the use of appropriate and effective written, oral and nonverbal communication with patients, the public and members of the health care team in the clinical setting.
- Integrate appropriate personal and professional values into clinical practice.
- Recognize the influence of professional values on patient care.
- Explain how a person's cultural beliefs toward illness and health affect his or her health status.
- Use patient and family education strategies appropriate to the comprehension level of the patient/family.
- Provide desired psychosocial support to the patient and family.
- Demonstrate competent assessment skills through effective management of the patient's physical and mental status.
- Respond appropriately to medical emergencies.
- Examine demographic factors that influence patient compliance with medical care.
- Adapt procedures to meet age-specific, disease-specific and cultural needs of patients.
- Assess the patient and record clinical history.
- Demonstrate basic life support procedures.
- Use appropriate charting methods.
- Recognize life-threatening ECG tracing.
- Apply standard and transmission-based precautions.
- Apply the appropriate medical asepsis and sterile technique.

- Demonstrate competency in the principles of radiation protection standards.
- Apply the principles of total quality management.
- Report equipment malfunctions.
- Examine procedure orders for accuracy and make corrective actions when applicable.
- Demonstrate safe, ethical and legal practices.
- Integrate the radiographer's practice standards into clinical practice setting.
- Maintain patient confidentiality standards and meet Health Insurance Portability and Accountability Act (HIPAA) requirements.
- Demonstrate the principles of transferring, positioning and immobilizing patients.
- Comply with departmental and institutional response to emergencies, disasters and accidents.
- Differentiate between emergency and nonemergency procedures.
- Adhere to national, institutional and departmental standards, policies and procedures regarding care of patients, providing radiologic procedures and reducing medical errors.
- Select technical factors to produce quality diagnostic images with the lowest radiation exposure possible.
- Critique images for appropriate anatomy, image quality and patient identification.
- Determine corrective measures to improve inadequate images.



## Digital Image Acquisition and Display

### Description

Content is designed to impart an understanding of the components, principles and operation of digital imaging systems found in diagnostic radiology. Factors that impact image acquisition, display, archiving and retrieval are discussed. Guidelines for selecting exposure factors and evaluating images within a digital system assist students to bridge between film-based and digital imaging systems. Principles of digital system quality assurance and maintenance are presented.

### Objectives

- Define terminology associated with digital imaging systems.
- Describe the various types of digital receptors.
- Discuss the fundamentals of digital radiography, distinguishing between cassette-based systems and cassette-less systems.
- Compare the image acquisition and extraction of cassette-based vs. cassette-less systems, including detector mechanism, initial image processing, histogram analysis, automatic rescaling and exposure index determination.
- Describe the evaluative criteria for digital radiography detectors.
- Describe the response of digital detectors to exposure variations.
- Compare the advantages and limits of each system.
- Given the performance criteria for a digital radiography detector, evaluate the spatial resolution and dose effectiveness.
- Compare dynamic range to latitude of a film-screen receptor system to that of a digital radiography system.
- Describe the histogram and the process or histogram analysis as it relates to automatic rescaling and determining an exposure indicator.
- Describe or identify the exposure indices used by each photostimulable phosphor (PSP)-based system.
- Describe the difference between dose area product (DAP) measured with a flat panel system vs. the exposure index for a PSP-based system.
- Relate the receptor exposure indicator values to technical factors, system calibration, part/beam/plate alignment and patient exposure.
- Describe image acquisition precautions necessary for CR imaging.
- Describe the response of PSP systems to background and scatter radiation.
- Utilize appropriate means of scatter control.
- Avoid grid use errors associated with grid cutoff and Moiré effect.
- Identify common limitations and technical problems encountered when using PSP systems.
- Employ appropriate beam/part/receptor alignment to avoid histogram analysis errors.
- Describe the various image processing employed for digital images.
- Associate impact of image processing parameters to the image appearance.
- Associate effects of inappropriate processing on image clarity or conspicuity.
- Describe the fundamental physical principles of exposure for digital detectors.
- Apply the fundamental principles to digital detectors.

- Describe the selection of technical factors and technical factor systems to ensure appropriate receptor exposure levels for digital detectors.
- Evaluate the effect of a given exposure change on histogram shape, data width and image appearance.
- Describe the conditions that cause quantum mottle in a digital image.
- Formulate a procedure or process to minimize histogram analysis and rescaling errors.
- Describe the exposure precautions and limitations associated with PSP-based systems.
- Avoid poor quality images by observing acquisition precautions.
- Examine the potential impact of digital radiographic systems on patient exposure and methods of practicing the as low as reasonably achievable (ALARA) concept with digital systems.
- Describe PACS and its function.
- Identify components of a PACS system.
- Describe patient benefits gained through the use of teleradiology.
- Identify modality types that may be incorporated into a PACS.
- Define accession number.
- Describe worklist and correct usage.
- Define digital imaging and communications in medicine (DICOM).
- Describe how an image is associated with a radiology order to create a DICOM image.
- Describe data flow for a DICOM image from an imaging modality to a PACS.
- Describe Health Insurance Portability and Accountability Act (HIPAA) concerns with electronic information.
- Identify common problems associated with retrieving/viewing images within a PACS.
- Identify the primary uses of the diagnostic display workstation and clinical display workstation.

## Ethics and Law in the Radiologic Sciences

### Description

Content is designed to provide a fundamental background in ethics. The historical and philosophical bases of ethics, as well as the elements of ethical behavior, are discussed. The student will examine a variety of ethical issues and dilemmas found in clinical practice.

An introduction to legal terminology, concepts and principles also will be presented. Topics include misconduct, malpractice, legal and professional standards and the ASRT scope of practice. The importance of proper documentation and informed consent is emphasized.

### Objectives

- Discuss the origins of medical ethics.
- Apply medical/professional ethics in the context of a broader societal ethic.
- Explain the role of ethical behavior in health care delivery.
- Differentiate between empathetic rapport and sympathetic involvement in relationships with patients and relate these to ethical conduct.
- Explain concepts of personal honesty, integrity, accountability, competence and compassion as ethical imperatives in health care.
- Identify legal and professional standards and relate each to practice in health professions.
- Identify specific situations and conditions that give rise to ethical dilemmas in health care.
- Explain select concepts embodied in the principles of patients' rights, the doctrine of informed (patient) consent and other issues related to patients' rights.
- Explain the legal implications of professional liability, malpractice, professional negligence and other legal doctrines applicable to professional practice.
- Describe the importance of accurate, complete, correct methods of documentation as a legal/ethical imperative.
- Explore theoretical situations and questions relating to the ethics of care and health care delivery.
- Explain legal terms, principles, doctrines and laws specific to the radiologic sciences.
- Outline the conditions necessary for a valid malpractice claim.
- Describe institutional and professional liability protection typically available to the radiographer.
- Describe the components and implications of informed consent.
- Identify standards for disclosure relative to informed consent.
- Describe how consent forms are used relative to specific radiographic procedures.
- Identify the four sources of law to include statutory, administrative, common and constitutional.
- Differentiate between civil and criminal liability.
- Define tort and explain the differences between intentional and unintentional torts.
- Exhibit critical data research retrieval and analysis skills composing an evidence-based narrative that addresses an ethical dilemma found in the patient care setting.

# Human Structure and Function

## Description

Content is designed to establish a knowledge base in anatomy and physiology. Components of the cells, tissues, organs and systems are described and discussed.

## Objectives

- Discuss the basics of anatomical nomenclature.
- Describe the chemical composition of the human body.
- Identify cell structure and elements of genetic control.
- Explain the essentials of human metabolism.
- Describe the types and functions of human tissues.
- Classify tissue types, describe the functional characteristics of each and give examples of their location within the human body.
- Describe the composition and characteristics of bone.
- Identify and locate the bones of the human skeleton.
- Identify bony processes and depressions found on the human skeleton.
- Describe articulations of the axial and appendicular skeleton.
- Differentiate the primary and secondary curves of the spine.
- Summarize the functions of the skeletal system.
- Label different types of articulations.
- Compare the types, locations and movements permitted by the different types of articulations.
- Examine how muscle is organized at the gross and microscopic levels.
- Differentiate between the structures of each type of muscle tissue.
- State the function of each type of muscle tissue.
- Name and locate the major muscles of the skeleton.
- Differentiate between the structure and function of different types of nerve cells.
- State the structure of the brain and the relationship of its component parts.
- Describe brain functions.
- List the meninges and describe the function of each.
- Outline how cerebrospinal fluid forms, circulates and functions.
- Describe the structure and function of the spinal cord.
- Determine the distribution and function of cranial and spinal nerves.
- Summarize the structure and function of components that comprise the autonomic nervous system.
- Describe the structures and functions of the components that comprise the human eye and ear.
- List the component body parts involved in the senses of smell and taste.
- List the somatic senses.
- Define endocrine.
- Describe the characteristics and functions of the components that comprise the endocrine system.

- Describe the hard and soft palates.
- Describe the structure and function of the tongue.
- Identify the structure, function and locations of the salivary glands.
- Describe the composition and characteristics of the primary organs of the digestive system.
- Describe the function(s) of each primary organ of the digestive system.
- Differentiate between the layers of tissue that comprise the esophagus, stomach, small intestine, large intestine and rectum.
- Differentiate between peritoneum, omentum and mesentery.
- List and label the accessory organs of the digestive system and describe their function.
- Identify the secretions and function of each accessory organ of the digestive system.
- Explain the purpose of digestion.
- List the digestive processes that occur in the body.
- Describe the composition and characteristics of blood.
- List the types of blood cells and state their functions.
- Differentiate between blood plasma and serum.
- Outline the clotting mechanism.
- List the blood types.
- Explain the term Rh factor.
- Explain the antigen/antibody relationship and its use in blood typing.
- Label the parts of the human heart.
- Describe the flow of blood through the body and identify the main vessels.
- Describe the structure and function of arteries, veins and capillaries.
- Differentiate between arterial blood in systemic circulation and arterial blood in pulmonary circulation.
- Outline the major pathways of lymphatic circulation.
- Correlate cardiac electrophysiology to a normal ECG tracing.
- Differentiate between nonspecific defenses and specific immunity.
- Explain antibody production and function.
- List the different types and functions of T-cells and B-cells and explain their functions.
- Label the components of the respiratory system.
- Describe the physiology and regulation of respiration.
- Label the parts of the kidneys, ureters, bladder and urethra.
- Describe the function of each organ of the urinary system.
- Describe the composition and formation of urine.
- Explain micturition.
- Label the anatomy of the male and female reproductive organs.
- Analyze the function of each of the male and female reproductive organs.
- Identify major anatomical structures found within sectional images.

## Patient Care in Radiologic Sciences

### Description

Content is designed to provide the basic concepts of patient care, including consideration for the physical and psychological needs of the patient and family. Routine and emergency patient care procedures are described, as well as infection control procedures using standard precautions. The role of the radiographer in patient education is identified.

### Objectives

- Identify the responsibilities of the health care facility and members of the health care team.
- List the general responsibilities of the radiographer.
- Describe the practice standards for the radiographer as defined by the ASRT and state licensure.
- Discuss the interrelationship between personal, community and societal values.
- Explain the influence a person's value system has on his or her behavior.
- Discuss the development of personal and professional values.
- Describe how professional values influence patient care.
- Differentiate between culture and ethnicity.
- Explain how a person's cultural beliefs toward illness and health affect his or her health status.
- Explain perceptions of death and dying from the viewpoint of both patient and radiographer.
- Describe ethical, emotional, personal and physical aspects of death.
- List the stages of dying and describe the characteristics of each stage.
- Identify the support mechanisms available to the terminally ill.
- Identify methods for determining the correct patient for a given procedure.
- Explain the use of various communication devices and systems.
- Explain specific aspects of a radiographic procedure to the patient.
- Demonstrate correct principles of body mechanics applicable to patient care.
- Demonstrate techniques for specific types of patient transfer.
- Demonstrate select procedures to turn patients with various health conditions.
- Describe select immobilization techniques for various types of procedures and patient conditions.
- Describe specific patient safety measures and concerns.
- Explain the purpose, legal considerations and procedures for reporting an accident or incident.
- Describe methods to evaluate patient physical status.
- List the information to be collected prior to a patient examination.
- Describe vital signs used to assess patient condition that include sites for assessment and normal values.
- Recognize and describe abnormal respiratory patterns.
- State the terms used to describe respiratory rates that are above and below normal values.
- Identify terms used to describe above and below normal pulse rates.
- Assess patient vital signs.

- List the normal ranges for specific laboratory studies.
- Define terms related to infection control.
- Describe the importance of standard precautions and isolation procedures that includes sources and modes of transmission of infection and disease and institutional control procedures.
- Identify symptoms related to specific emergency situations.
- Describe the emergency medical code system for the institution and the role of the student during a medical emergency.
- Explain the special considerations necessary when performing radiographic procedures on an infant or child.
- Explain the special considerations necessary when performing radiographic procedures on a geriatric patient.
- Describe the symptoms and precautions taken for a patient with a head injury.
- Describe three areas that are assessed by the Glasgow Coma Scale and the numbers associated with each area.
- Explain the types, immobilization devices and positioning for upper and lower extremity fractures.
- Describe the symptoms and precautions taken for a patient with traumatic injury.
- Describe the symptoms and medical interventions for a patient with a contrast agent reaction.
- Explain the role of the radiographer in patient education.
- Discuss family dynamics, culture, social, ethnic and lifestyle considerations and their impact on health status.
- Describe the patient preparation for barium studies.
- Identify specific types of tubes, lines, catheters and collection devices.
- Outline the steps in the operation and maintenance of suction and oxygen equipment and demonstrate their use.
- Demonstrate competency in basic life support (BLS).
- Demonstrate the use of specific medical emergency equipment and supplies.
- Describe the monitoring, preprocedure and postprocedure care, drug administration and special precautions for a patient undergoing invasive procedures.
- Demonstrate the appropriate procedure for gathering information prior to performing a mobile radiographic examination.
- Describe the initial steps in performing a mobile procedure.
- Explain the procedure for placing an image receptor under a patient in an orthopedic bed frame.
- Describe the special problems faced in performing procedures on a patient with a tracheotomy and specific tubes, drains and catheters.
- Describe the procedure for producing diagnostic images in the surgical suite.
- Explain the appropriate radiation protection required when performing mobile/surgical radiography.

## Pharmacology and Drug Administration

### Description

Content is designed to provide basic concepts of pharmacology. The theory and practice of basic techniques of venipuncture and administration of diagnostic contrast agents and/or intravenous medications is included. The appropriate delivery of patient care during these procedures is emphasized.

### Objectives

- Distinguish between the chemical, generic and trade names for select drugs.
- Describe pharmacokinetic and pharmacodynamic principles of drugs.
- Classify drugs according to specific categories.
- Explain the actions, uses and side effects for select drugs.
- Explain the effects of select drugs on medical imaging procedures.
- Define the categories of contrast agents and give specific examples for each category.
- Explain the pharmacology of barium and iodine compounds.
- Describe methods and techniques for administering various types of contrast agents.
- Identify and describe the routes of drug administration.
- Discuss the purposes and advantages of intravenous drug administration over other routes.
- Demonstrate appropriate venipuncture technique.
- Differentiate between the two major sites of intravenous drug administration.
- Identify, describe and document complications associated with intravenous drug therapy and appropriate actions to resolve these complications.
- Discuss the various elements of initiating and discontinuing intravenous drug therapy.
- Differentiate and document dose calculations for adult and pediatric patients.
- Prepare for injection of contrast agents/intravenous medications using aseptic technique.
- Explain the current legal and ethical status of the radiographer's role in drug administration.
- Explain a radiographer's professional liability concerning drug administration.



# Radiation Protection

## Description

Content is designed to present an overview of the principles of radiation protection, including the responsibilities of the radiographer for patients, personnel and the public. Radiation health and safety requirements of federal and state regulatory agencies, accreditation agencies and health care organizations are incorporated.

## Objectives

- Identify and justify the need to minimize unnecessary radiation exposure of humans.
- Distinguish between somatic and genetic radiation effects.
- Differentiate between the stochastic (probabilistic) and nonstochastic (deterministic) effects of radiation exposure.
- Explain the objectives of a radiation protection program.
- Define radiation and radioactivity units of measurement.
- Identify effective dose limits (EDL) for occupational and nonoccupational radiation exposure.
- Describe the ALARA concept.
- Identify the basis for occupational exposure limits.
- Distinguish between perceived risk and comparable risk.
- Describe the concept of the negligible individual dose (NID).
- Identify ionizing radiation sources from natural and artificial sources.
- Comply with legal and ethical radiation protection responsibilities of radiation workers.
- Describe the relationship between irradiated area and effective dose.
- Describe the theory and operation of radiation detection devices.
- Identify appropriate applications and limitations for each radiation detection device.
- Describe how isoexposure curves are used for radiation protection.
- Identify performance standards for beam-limiting devices.
- Describe procedures used to verify performance standards for equipment and indicate the potential consequences if the performance standards fail.
- Describe the operation of various interlocking systems for equipment and indicate potential consequences of interlock system failure.
- Identify conditions and locations evaluated in an area survey for radiation protection.
- Distinguish between controlled and noncontrolled areas and list acceptable exposure levels.
- Describe “Radiation Area” signs and identify appropriate placement sites.
- Describe the function of federal, state and local regulations governing radiation protection practices.
- Describe the requirements for and responsibilities of a radiation safety officer.
- Express the need and importance of personnel monitoring for radiation workers.
- Describe personnel monitoring devices, including applications, advantages and limitations for each device.
- Interpret personnel monitoring reports.
- Compare values for individual effective dose limits for occupational radiation exposures (annual and lifetime).

- Identify anatomical structures that are considered critical for potential late effects of whole body irradiation exposure.
- Identify dose equivalent limits for the embryo and fetus in occupationally exposed women.
- Distinguish between primary and secondary radiation barriers.
- Demonstrate how the operation of various x-ray and ancillary equipment influences radiation safety and describe the potential consequences of equipment failure.
- Perform calculations of exposure with varying time, distance and shielding.
- Discuss the relationship between workload, energy, half-value layer (HVL), tenth-value layer (TVL), use factor and shielding design.
- Identify emergency procedures to be followed during failures of x-ray equipment.
- Demonstrate how time, distance and shielding can be manipulated to keep radiation exposures to a minimum.
- Explain the relationship of beam-limiting devices to patient radiation protection.
- Discuss added and inherent filtration in terms of the effect on patient dosage.
- Explain the purpose and importance of patient shielding.
- Identify various types of patient shielding and state the advantages and disadvantages of each type.
- Use the appropriate method of shielding for a given radiographic procedure.
- Explain the relationship of exposure factors to patient dosage.
- Explain how patient position affects dose to radiosensitive organs.
- Identify the appropriate image receptor that will result in an optimum diagnostic image with the minimum radiation exposure to the patient.
- Select the immobilization techniques used to eliminate voluntary motion.
- Describe the minimum source-to-tabletop distances for fixed and mobile fluoroscopic devices.
- Apply safety factors for the patient (and others) in the room during mobile radiographic procedures.

## Resources

### Textbooks

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