Computed Tomography Curriculum

Sponsored by the American Society of Radiologic Technologists, 15000 Central Ave. SE, Albuquerque, NM 87123-3909.

Introduction

The goal of this curriculum is to provide the professional community with a cognitive base of entry-level education in the practice of computed tomography (CT). The curriculum is suitable for all programs in this specialty, including limited fellowships, short-term certificate programs and collegiate-based education programs. The curriculum recognizes that the educational components are not static, but are representative of current practice and trends in the field. It is the responsibility of educators to incorporate new concepts and trends in the curriculum as they occur.

The curriculum is divided into specific content areas representing essential components of a computed tomography educational program. No particular sequence is suggested. The content and objectives should be organized to meet the mission, goals and needs of each program. Faculty members are encouraged to expand and broaden these fundamental objectives as they incorporate them into their curricula. Specific instructional methods are intentionally omitted to allow for programmatic prerogative as well as creativity in instructional delivery.

The curriculum document consists of three sections: foundations, core content and clinical experience requirements. The foundations section represents an inventory of pre-existing knowledge and skills gained through an entry-level educational experience and reinforced through professional practice. The content in the foundations section is intended to aid technologists in career planning and program managers in the development of preassessment tools for candidate selection.

The professional practice of computed tomography requires specific knowledge and skills generally not obtained in basic educational programs. The core content section represents curriculum elements that are considered essential in educating technologists in the postprimary practice of computed tomography.

The clinical experience requirements section is intended as a guide to developing a well-rounded clinical experience and to aid in meeting the eligibility requirements for a postprimary certification examination in computed tomography.

Curriculum Revision Workgroup

We would like to extend special recognition to the individuals who volunteered their time as members of the curriculum revision project:

Jeff Berry, M.S., R.T.(R)(CT)
Alisha Borchardt, M.S., R.T.(R)(CT)
Charles Garrett, B.S., R.T.(R)(CT)
Joseph Hewes, M.B.A., R.T.(R)(CT), CIIP, CPAS
Rebecca Keith, M.S., R.T.(R)(CT)
Joseph Lohnes, B.S., R.T.(R)(CT)
Kimberly Onstott, M.S.R.S., R.T.(R)(CT)(MR)
Carolyn Palazzolo, M.S., R.T.(R)(CT)(QM)
Julie Sealey, M.S., R.T.(R)(CT)
Sharlene Snowdon, M.S.Ed., R.T.(R)(M)(CT)
Rhonda Weaver, M.H.A., R.T.(R)(M)(CT)(BD)
Carolyn Whitt, M.S.A.H., R.T.(R)(CT)

We also wish to express our sincere appreciation for the many contributions and suggestions from the professional community over the lifespan of this project.

Contents

Foundations

The foundations section represents an inventory of pre-existing knowledge and skills gained through an entry-level 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.

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 medical imaging 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 focus on patient care and assessment, competent performance of medical imaging procedures and total quality management. Levels of competency and outcomes measurement ensure the well-being of the patient before, during and following the procedure.

Digital Image Acquisition and Display
Content imparts 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. Principles of digital system quality assurance and maintenance are presented.

Ethics and Law in the Radiologic Sciences
Content provides a foundation in ethics and law related to the practice of medical imaging. Content should include an introduction to terminology, concepts and principles. Students will examine a variety of ethical and legal issues found in clinical practice.

Human Anatomy and Physiology
Content establishes a knowledge base in anatomy and physiology. Components of the cells, tissues, organs and systems are described and discussed. The fundamentals of sectional anatomy relative to routine imaging are addressed.

Introduction to Computed Tomography
Content is designed to provide entry-level students with an introduction to and basic understanding of the operation of a computed tomography (CT) device. Content is not intended to result in clinical competency.

Medical Terminology
Content provides an introduction to the origins of medical terminology. A word-building system is introduced and abbreviations and symbols are discussed. Also introduced is an orientation to understanding medical imaging orders and diagnostic report interpretation. Related terminology is addressed.

Pathophysiology
Content introduces concepts related to disease and its origins with emphasis on the radiographic appearance of diseases and correct exposure factor selection.

Patient Care in Radiologic Sciences
Content introduces the concepts of optimal patient care, including consideration for the 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 technologist in patient education is explained.

Pharmacology and Venipuncture
Content provides basic concepts of pharmacology, venipuncture and administration of diagnostic contrast agents and intravenous medications. The appropriate delivery of patient care during these procedures is emphasized.

Radiation Biology
Content provides an overview of the principles of the interaction of radiation with living systems. Radiation effects on molecules, cells, tissues and the body as a whole are presented. Factors affecting biological response are presented, including acute and chronic effects of radiation.

Radiation Physics
Content is designed to establish a basic knowledge of physics pertinent to developing an understanding of radiations used in the clinical setting. Fundamental physical units, measurements, principles, atomic structure and types of radiation are emphasized. Also presented are the fundamentals of x-ray generating equipment, x-ray production and its interaction with matter.

Radiation Protection
Content presents an overview of the principles of radiation protection, including the responsibilities of the technologist for protection of patients, personnel and the public. Radiation health and safety requirements of federal and state regulatory agencies, accreditation agencies and health care organizations are incorporated.

Refer to the Appendix for a detailed list of objectives for each content area.

Core Content

The professional practice of computed tomography requires specific knowledge and skills generally not obtained in basic educational programs. The core content section represents curriculum elements that are considered essential in educating technologists in the postprimary practice of computed tomography.

CT Procedures

Description

Content provides detailed coverage of procedures for CT imaging of adults and pediatric patients. The procedures section includes, but is not limited to, indications for the procedure, patient education, preparation, orientation and positioning, patient history and assessment, contrast media usage, localizer image, selectable scan parameters and archiving of the images. CT procedures will be taught for differentiation of specific structures, patient symptomology and pathology. CT exam images will be reviewed for quality, anatomy and pathology. CT procedures vary from facility to facility and normally are dependent on the preferences of the radiologists.

Objectives

1. List the CT scanner and scan room preparation steps necessary for CT procedures.
2. Identify the appropriate CT procedure for specific anatomical structures, symptoms or pathology.
3. Describe proper procedures for patient screening.
4. Educate the patient on the general aspects of CT and the specifics of the CT procedure.
5. Specify the patient preparation required for each procedure.
6. Determine if contrast media is indicated for a specific procedure.
7. If indicated, name the type of contrast medium and specify the dosage and route of administration.
8. Determine from patient medical laboratory results, patient history and charted information if the use of contrast media is contraindicated and explain why.
9. Describe the conditions that require a patient to grant informed consent in writing for a CT procedure.
10. Apply appropriate modifications to standard protocols on the basis of patient age or weight.
11. List the range, anatomical landmarks, patient orientation and position for adults and pediatric patients used to produce scout and scan images for a given procedure.
12. Define the scan field of view (SFOV), display field of view (DFOV), scan mode, algorithm, gantry angle, technical factors, scan range, table incrementation and slice thickness (z-axis) selection for each procedure.
13. Identify appropriate window width (WW) and window level (WL) selections for each procedure protocol.
14. Explain why different window width and levels are selected.
15. List the required imaging planes for each procedure.
16. Determine the correct matrix size selection for each procedure studied.
17. List the information that should be noted on each localizer and scan image.
18. Differentiate between scanning parameters for CT procedures.
19. Explain CT image archiving.
20. List postprocedure patient instructions for each procedure.

Content

I. CT Equipment Overview

II. Patient Care, Education and Management Review

III. Anatomy Review

A. Bones

B. Organs

C. Musculature

D. Vasculature

E. Nerves

IV. Procedure Elements

A. Indications for each protocol

B. Contraindications for each procedure

C. Venipuncture

D. Contrast media considerations
   1. Pharmacology
   2. Types of contrast media
   3. Route of administration
   4. Dosage
   5. Contraindications

E. Venous access devices
   1. Peripheral angiocatheters
   2. Diffusion tip angiocatheters
   3. Power injectable devices
      a. Subcutaneous ports
      b. PICCs
      c. Tunneled central venous catheters
      d. Nontunneled central venous catheters

F. Power injectors
   1. Types
      a. Single head injectors
      b. Dual head injectors
   2. Flow rates and PSI
   3. Multi-phase injection
      a. Studies indicated

b. Use in protocol
c. Equipment setup

4. Major components of CT equipment
5. Operation
6. Cleaning and preventive maintenance
7. Accuracy
8. Electrical safety

G. Informed consent requirements and charting

H. Patient preparation and postprocedure instructions

I. Procedure parameters
1. Range
2. Anatomical landmarks
3. Patient orientation
4. Patient position
5. Localizer image parameters
6. SFOV
7. DFOV
8. Mode
a. Axial/sequential
b. Helical/spiral
9. Algorithm
10. Pitch
a. Single detector
b. Multidetector
11. Gantry angle
12. Technical factor selection
a. kVp
b. mAs
c. Table indexing
d. Slice thickness
e. Window level
f. Window width
g. Matrix size
13. Image annotation parameters
14. Imaging planes
15. Helical/spiral application
16. Image archiving
17. Identification of pathology
18. Charting and documentation requirements
19. Bolus parameters and timing
20. Workstation
21. Other (e.g. dual energy application)

V. Procedures of the Head and Neck

A. CT brain
   1. Brain with and/or without contrast
   2. Sella turcica/pituitary fossa
   3. Trauma
   4. Circle of Willis (COW)
   5. CTV brain
   6. Thalamus and hypothalamus
   7. Brain perfusion

B. CT maxillofacial
   1. Trauma
   2. Orbits
   3. Nasal bones
   4. Facial bones
   5. Mandible
   6. Temporomandibular joints

C. CT paranasal sinuses

D. CT temporal bone
   1. Internal auditory canals
   2. Posterior fossa

E. CT soft tissue neck (STN)
   1. With and/or without contrast
      a. Phases of injection
   2. Nasopharynx, oropharynx and larynx with and/or without contrast
   3. Submandibular, parotid and sublingual glands with and/or without contrast
   4. Thyroid and parathyroid glands
   5. CTA carotid

F. Others as determined by program and clinical faculty

VI. Procedures for the Thorax, Spine and Musculoskeletal System

A. High resolution CT (HRCT) chest
   1. Axial/sequential
   2. Helical/spiral

B. CT thorax
   1. With and/or without contrast
   2. Thorax routine imaging
      a. Mediastinum
      b. Lung
   3. CTA of the thorax
      a. Aorta

b. Pulmonary
4. Trauma
5. Low-dose lung screening

C. CT sternum

D. CT spine
1. Cervical spine
2. Thoracic spine
3. Lumbar spine
4. Trauma spine
5. CT post-myelogram spine (cervical, thoracic or lumbar)

E. CT extremity
1. Upper extremity
2. Lower extremity
3. CTV

F. CT pelvic girdle

G. CTA runoff

VII. Procedures for the Abdomen and Pelvis

A. CT abdomen
1. With and/or without contrast
2. Pancreatic mass
3. Liver
a. Hemangioma perfusion
4. Renal system (renal stone, urogram)
5. Adrenal glands
6. Aortic dissection
7. Vascular abdomen (CTA, CTV)
8. Spleen
9. GI system
10. Gallbladder
11. Suspected appendicitis
12. Disease staging
13. Rule out metastasis
14. Enterography
15. Trauma
16. CT colonography

B. CT pelvis
1. With and/or without contrast
2. Pelvic cystogram
3. Vascular pelvis (CTA, CTV)

4. Reproductive organs

VIII. Additional Procedures

A. CT-guided needle biopsies

B. CT-guided abscess drains

C. CT-guided aspirations

IX. Pediatric Procedures

A. Contrast media considerations

B. Immobilization

C. Communication and education

D. Sedation

E. Radiation protection

F. Technical factor selection

X. Bariatric Procedures

XI. PET/CT

XII. Radiation Therapy Simulation Procedures

Cardiac CT

Description

Content is designed to convey an understanding of the development of cardiac CT as a viable technology for imaging of the heart and the coronary arteries. The cardiac CT topics to be covered include patient preparation, ECG set-up and evaluation, arrhythmia recognition, and IV contrast. Cardiac image acquisition will be explained along with cardiac image dose management, a comparison of prospective and retrospective cardiac scanning, cardiac image quality and artifact characteristics. A review of the cardiac cycle, phase selection, reconstruction and post-processing will be explored. Cardiac anatomy, cardiac physiology, coronary vasculature and congenital anomalies will be discussed.

Objectives

1. Identify the three main coronary arteries.
2. Define the valves of the heart and their function.
3. Define the most common anomalous coronary artery.
4. Define electrical conduction system of the heart.
5. Discuss types of arrythmias affecting a cardiac CT procedure.
6. Discuss types of heart rates affecting a cardiac CT procedure.
7. Identify the correct cardiac phase for CT acquisition of the heart.
8. Discuss medications used to alter a patient's heart rate or arrhythmias.
9. Describe one cardiac cycle.
10. Define cardiac output.
11. Define ejection fraction.
12. Define stroke volume.
13. Distinguish systole and diastole segments of the ECG wave.
14. Demonstrate the correct placement for the ECG electrodes.
15. Recognize the importance of correct skin prep for cardiac CT.
16. Describe what type of electrodes give the best skin contact for cardiac scanning.
17. Explain the purpose the proper patient breathing instructions.
18. Recognize the lead configuration most appropriate for patient radiation protection during CT image acquisition.
19. Label the different parts of the ECG wave.
20. Recognize arrythmias on ECG.
    a. Premature atrial contraction (PAC).
    b. Ventricular contraction (PVC).
21. Recognize a premature contraction on the ECG wave.
22. Describe the purpose of a calcium score scan.
23. Define Agatston score.
24. Describe prospective and retrospective gating cardiac scanning.
25. Apply the concept of ECG dose modulation to patient dose reduction.
26. Apply the concept of prospective gating to patient dose reduction.
27. Describe anatomical areas necessary to assure adequate coverage of the anatomy during a cardiac study.

28. Interpret an injection protocol for a given coronary artery.
29. Recognize the key artifacts on a CTA study of a coronary arteries.

Content

I. Anatomy and Physiology of the Heart

A. Cardiac anatomy

B. Coronary arteries

C. Cardiac physiology
   1. Electrical conduction system
   2. ECG waveform
      a. Sinus rhythm
      b. Arrhythmias

D. Cardiac cycle

II. Patient Screening and Preparation

A. Clinical history/indications for exam

B. Contraindications

C. Preprocedural medications

D. Intravenous access

E. ECG
   1. Lead configurations
   2. Skin prep and lead placement
   3. Artifacts

F. Breath holding training

G. Shielding

H. Variations in patients considerations
   1. Weight
   2. Heart rate
   3. Arrhythmias

III. Procedures

A. Advantages/disadvantages of cardiac CT

B. Hardware requirements

C. Software requirements
   1. ECG-based tube current modulation

D. Cardiac calcium scoring

1. Purpose
2. Agatston score

E. CT angiography
1. Purpose
2. Injection protocols
   a. Volume
   b. Injection rate
   c. Delivery
   d. Scan delay
   e. Phases

F. Scanning parameters
1. Slice width
2. Scan range
3. Scan speed
4. Injection timing
5. Prospective gating
6. Retrospective gating

IV. Image Reconstruction

A. Reconstruction
1. Single cycle
2. Multi-cycle

B. Field of view

C. Slice width

D. Reconstruction kernel (algorithm)

E. Cardiac phase

F. ECG editing

V. Resolution

A. Spatial

B. Contrast

C. Temporal

VI. Viewing Formats

A. 2-D
1. Two chamber view
2. Double oblique cardiac long axis

3. Four chamber
4. Cardiac short axis

B. 3-D

C. MPR/curved MPR (cMPR)

D. Volumetric

E. MIP

VII. Assessment of Images

A. Regional and global evaluations
1. Stenosis grading

B. Ventricular function

C. Cardiac output

D. Ejection fraction

E. Cardiac viability

F. Wall thickness

G. Variants
1. Stents
2. Bypass grafts

VIII. Dose Reduction Methods

IX. Artifacts

Pathology Correlation in Computed Tomography

Description
Content provides thorough coverage of common diseases that may be diagnosed with the use of CT. Each disease or traumatic process is examined from its description, etiology, associated symptoms and diagnosis with appearance on CT. 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:
   a. Describe the disorder.
   b. List the etiology.
   c. Name the associated symptoms.
   d. Name the common means of diagnosis.
   e. List characteristic CT manifestations of the pathology.
4. Identify pathological conditions studied on CT images.
5. Identify pathology resulting from trauma on CT images.
6. Identify pathology in CT images commonly associated in pediatric patients.

Content

I. Autoimmune System

A. Acquired immunodeficiency syndrome

B. Systemic lupus erythematosus

II. Cardiovascular System

A. Cardiomegaly

B. Valvular disease

C. Aortic pathology
   1. Aortic aneurysm
   2. Aortic dissection
   3. Coarctation
   4. Traumatic aortic tear

D. Congenital malformations

E. Arteriovenous malformation (AVM)

F. Aneurysm

G. Cardiac transplant

H. Congestive heart failure (CHF)/pulmonary edema

I. Coronary artery disease
   1. Calcium scoring
   2. Soft plaque atherosclerosis

J. Coronary artery bypass grafts (CABG)

K. Pericardial effusion

L. Tumors
   1. Benign (myxoma)
      a. Papillary fibroelastoma
      b. Rhabdomyoma
      c. Fibroma
      d. Hemangioma
      e. Teratoma
      f. Lipoma
      g. Paraganglioma
      h. Pericardial cyst
   2. Malignant

a. Sarcoma
b. Pericardial mesothelioma
c. Primary lymphoma

3. Metastatic

M. Trauma

III. Central Nervous System (CNS)

A. Terminology
1. Supratentorial
2. Infratentorial
3. Etc.

B. Tumors (benign and malignant)
1. Brain
a. Glioma
b. Cholesteatoma (inner ear)
c. Acoustic neuroma (inner ear)
d. Pineal gland disorders
e. Pituitary adenoma
f. Astrocytoma
g. Medulloblastoma
h. Craniopharyngioma
i. CNS lymphoma
j. Tumors of central nerve sheath cells

C. Spine
1. Ependymoma
2. Hemangioma
3. Meningoma
4. Astrocytoma
5. Neurofibroma

D. Metastases

E. Cysts

F. Congenital abnormalities
1. Brain
a. Agenesis of the corpus callosum
b. Dandy Walker
c. Encephalocele
d. Hydrocephalous
e. Craniosynostosis
2. Spine
a. Arnold-Chiari malformation

b. Syringomyelia
c. Hydromyelia
d. Tethered cord
e. Myelocele
f. Meningocele
g. Myelomengiocele

G. Heterotopic gray matter

H. Metastases

I. Adult onset hydrocephalus

J. Cysts

K. Infections
1. Encephalitis
2. Meningitis
3. Abscess
4. Spondylitis

L. Atrophic and degenerative disorders
1. Multiple sclerosis
2. Alzheimer disease
3. Parkinson disease
4. Intervertebral disc herniation
5. Spinal stenosis
6. Osteoarthritis

M. Toxoplasmosis

N. Trauma

IV. Head and Neck

A. Congenital anomalies
1. Cleft palate
2. Face bones
3. Nose
4. Eye
5. Ear
6. Mandible

B. Paranasal sinuses
1. Mucocele
2. Sinusitis

C. Salivary gland

D. Orbit and visual pathways

E. Larynx and hypolarynx

F. Cerebrovascular accident (CVA)
   1. Stroke syndrome
      a. Infarct
      b. Transient ischemic attack (TIA)
   2. Hemorrhage
      a. Intracerebral

G. Trauma
   1. Hematoma
      a. Epidural
      b. Subdural
      c. Subarachnoid

V. Hematopoietic and Lymph System

A. Lymph node staging

B. Lymphoma (Hodgkin and non-Hodgkin)

C. Lymphosarcoma

D. Lymphadenopathy

E. Splenomegaly

F. Splenic trauma

VI. Endocrine System

G. Pituitary

H. Adrenal

I. Thyroid

J. Pancreas

VII. Respiratory System

A. Benign and malignant masses
   1. Adenocarcinoma
   2. Squamous cell
   3. Large cell

4. Small cell
5. Carcinoid
6. Hamartoma
7. Adenoma
8. Fibroma
9. Lipoma

B. Metastases

C. Pneumonia

D. Chronic obstructive pulmonary disease (COPD)
   1. Emphysema
   2. Chronic bronchitis
   3. Bronchiectasis

E. Pulmonary edema

F. Acute respiratory distress syndrome

G. Asbestosis

H. Pulmonary fibrosis

I. Pneumothorax

J. Hemothorax

K. Sarcoidosis

L. Pneumoconiosis

M. Tuberculosis

N. Pleural effusion

O. Atelectasis

P. Pulmonary embolism

Q. Pulmonary artery dissection

R. Other

S. Trauma

VIII. Gastrointestinal (GI) System

A. Benign and malignant masses
   1. Esophageal cancer
   2. Adenocarcinoma
   3. Gastric carcinoma
   4. Colon cancer
   5. Colorectal cancer
   6. Polyps

B. Metastases

C. Abscesses

D. Autoimmune (i.e., Crohn, Colitis)

E. Cysts

F. Ascites

G. Pneumoperitoneum (intraperitoneal air)

H. Intussusception

I. Peritonitis

J. Small and large bowel obstruction
   1. Ischemia

K. Appendicitis/appendicoliths

L. Diverticulum/diverticulitis

M. Congenital abnormalities
   1. Tracheoesophageal fistula
   2. Hemochromatosis

N. Hiatal hernia

O. Achalasia

P. Ulcers

Q. Ostomies

R. Trauma

IX. Genitourinary System

A. Masses (benign and malignant)
   1. Renal cell carcinoma
   2. Wilms tumor
   3. Cystic mass
   4. Adenocarcinoma
   5. Bladder carcinoma

B. Reproductive organ masses
   1. Female
      a. Ovarian cancer
      b. Ovarian cyst
      c. Endometrial cancer
      d. Leiomyoma
   2. Male
      a. Prostate cancer
      b. Prostate hypertrophy
      c. Seminoma
      d. Testicular cancer

C. Metastases

D. Renal infarct

E. Infection
   1. Perinephric Abscess
   2. Renal

F. Renal and urinary calculi

G. Polycystic disease

H. Pyelonephritis

I. Renal transplant

J. Renal artery stenosis

K. Hydronephrosis

L. Adrenal tumors
   1. Pheochromocytoma
   2. Cushing's syndrome
   3. Adrenal carcinoma
   4. Adrenal metastases
   5. Angiomyolipoma

M. Congenital abnormalities
    1. Horseshoe kidney

N. Trauma
    1. Laceration

X. Hepatobiliary System

A. Masses (benign and malignant)
    1. Gallbladder carcinoma
    2. Hepatic carcinoma
    3. Pancreatic carcinoma
    4. Hepatocelluar adenoma
    5. Hepatoma
    6. Fatty Liver

B. Metastasis

C. Liver/gallbladder
    1. Hepatitis
    2. Cirrhosis
    3. Cholecystitis
    4. Cholelithiasis
    5. Hemochromatosis
    6. Biliary obstruction
    7. Hepatomegaly
    8. Hemangioma

D. Spleen
    1. Splenomegaly
    2. Splenic infarction
    3. Splenic cysts, pseudocysts and hydrated cysts

E. Pancreas
    1. Pancreatic pseudocyst
    2. Pancreatitis

F. Congenital abnormalities

G. Infection

H. Transplants

I. Trauma

XI. Musculoskeletal System

A. Bone tumors
    1. Osteosarcoma
    2. Giant cell tumor
    3. Osteoid osteoma (benign osteoblastic)
    4. Ewing sarcoma
    5. Multiple myeloma

B. Cartilaginous tumors
    1. Osteochondroma
    2. Endochondroma
    3. Chondrosarcoma

C. Soft tissue tumors
    1. Liposarcoma
    2. Synovial sarcoma

D. Metastases

E. Osteoporosis

F. Bone cysts

G. Skeletal dysplasias

H. Joint disorders

I. Infections

J. Inflammatory diseases
    1. Osteomyelitis
    2. Tuberculosis
    3. Arthropathies

K. Fractures

L. Trauma

M. Spine
    1. Spinal stenosis
    2. Spondyolysis
    3. Spondylolisthesis
    4. Fractures
        a. Burst
        b. C1 (Jefferson's fracture)
        c. C2 (hangman's fracture)

XII. Pediatric Pathologies

A. Congenital abnormalities
   1. CNS
   2. GI
   3. GU
   4. Cardiac
   5. Skeletal

B. Seizures

C. Vascular and cardiac problems/malformations

D. Inflammation

E. Tumors

F. Pulmonary diseases

G. Orthopedic

H. Infection

I. Fractures

J. Non-accidental trauma
   1. Shaken baby syndrome
   2. Fractures
      a. Multiple fractures
      b. Skull fractures
      c. Bucket handle fractures
      d. Rib fractures
   3. Intracranial bleeding
      a. Subdural hematoma
      b. Epidural hematoma
      c. Intracerebral hemorrhage

Physics – Instrumentation and Imaging

Description

Content is designed to impart an understanding of the physical principles and instrumentation involved in computed tomography. The historical development and evolution of computed tomography is reviewed. Physics topics covered include x-radiation in forming the CT image, CT beam attenuation, linear attenuation coefficients, tissue characteristics and Hounsfield numbers application. Data acquisition and manipulation techniques, image reconstruction algorithms will be explained.

Computed tomography systems and operations will be explored with full coverage of radiographic tube configuration, collimator design and function, detector types, characteristics and functions of the CT computer and array processor. CT image processing and display will be examined from data acquisition through postprocessing and archiving and patient factors related to other elements affecting image quality will be explained, as well as artifact production and reduction and image communication.

Objectives

1. Describe events leading to the discovery of computed tomography and its evolution.
2. Review common computer terms applicable to CT image information.
3. Describe the components of the CT imaging system.
4. Explain the interaction of x-rays with matter as to the formation of the CT image.
5. Explain the configuration of the CT radiographic tube and its components.
6. Define the heat load capacity of the CT radiographic tube.
7. Explain the functions of collimators in CT.
8. Explain the location and function of detectors used in CT systems.
9. Trace the sequence of events in the CT acquisition process.
10. Identify the most commonly used materials in CT detectors.
11. Compare and contrast the types of CT detectors.
12. Define "attenuation."
13. Define linear attenuation coefficient.
14. Explain electronic signal formation from the detector to the analog to digital convertor.
15. Define and describe the functions of the data acquisition system (DAS).
16. List the CT computer data processing steps.
17. Name the functions of the array processor.
18. Identify filters, algorithms and kernel settings commonly used for CT.
19. Distinguish between "raw data," "image data" and “scan data.”
20. Explain the difference between reconstructing and reformatting an image.
21. Describe commonly used postprocessing techniques for various CT procedures.
22. Explain the slip ring technology used for spiral scanning.
23. Discuss the differences between low-voltage and high-voltage slip-ring CT scanners.
24. Identify the hardware needs for various CT procedures.
25. Identify the software needs for the various CT procedures.

26. Define and explain the following CT imaging parameters:
    - Pitch.
    - x, y, z coordinates.
    - Scan field of view (SFOV).
    - Display field of view (DFOV).
    - CT/Hounsfield number.
    - Partial volume averaging.
    - Window width (WW), window level (WL).
    - Annotation.
    - Scanogram/scout/pilot/topogram/survey.
    - Region of interest (ROI).
    - Axial/sequential vs. helical/spiral vs. volumetric data acquisition.
    - Half-scan, full-scan, overscan.
    - Interscan delay.
    - Rays, ray sum and view.
    - Sampling (angular and ray).
27. List the selectable scan factors and explain how each affects the CT image.
28. Name the factors affecting image quality in CT.
    a. Spatial resolution.
    b. Contrast resolution.
    c. Noise.
29. Name the common controls found on CT operator consoles and describe how and why each is used.
30. Describe the quality control steps that may be taken to assure constant high-quality CT images.
31. List the types of artifacts and name and describe the appearance of those most commonly affecting CT images.
32. Explain how CT artifacts may be eliminated or reduced.
33. Discuss the use of teleradiology with transmitting and receiving images from remote imaging centers
34. Discuss the various means of archiving images.
35. Name the radiation protection devices that may be used to reduce patient dose in CT and describe the correct application of each.
36. Identify technique selection methods and software applications that lead to a reduction in patient dose.
37. Identify current methods for measuring the patient's CT dose.

Content

I. Historical Development of Computed Tomography

A. Definition
   1. Evolution of terms

B. Research contributors in the development of CT

C. Historical development of CT

II. Computed Tomography Generations

A. First generation

B. Second generation

C. Third generation

D. Fourth generations

E. Spiral/helical

F. Multislice

G. Dual energy

III. CT Scanner Components and Operations

A. CT radiographic tube
   1. Differences from a conventional radiographic tube
   2. Heating capacity

B. CT filters

C. Collimators

D. Bore size

E. Gantry/table features
   1. Gantry tilt
   2. Table height
   3. Positioning lasers
   4. Weight limitations

F. Detectors

G. Data acquisition system (DAS)

H. Consoles

1. Work station
2. Processing/viewing station

I. Tube heating monitors

J. Archival methods

IV. Digital Imaging

A. Steps of image digitization
1. Scanning
2. Sampling
3. Quantization
4. Analog to digital conversion
5. Digital to analog conversion

B. Image characteristics

C. Scan projection radiography

D. Beam configuration

E. CT informatics
1. Picture archiving and communication systems (PACS)
2. Digital imaging and communications in medicine DICOM
3. Hospital information system (HIS) / radiology information system (RIS)

V. Computed Tomography Process

A. Data acquisition
1. Methods
   a. Axial/sequential
   b. Helical/spiral
   c. Volumetric
   d. Beam geometry
2. Data acquisition system (DAS)
   a. Components
   b. Functions
      1) Measurement of transmitted beam
      2) Encoding measurements into binary data
      3) Logarithmic conversion of data
      4) Transmission of data to computer
3. Data acquisition process
   a. Scanning/raw data/image data
      1) Rays
      2) Views
      3) Profiles
         a) Pixels

b) Matrices
c) Voxels
4) Sampling
a) Angular
b) Ray

b. Attenuation
1) Lambert-Beer law
2) Linear attenuation coefficients
3) CT/Hounsfield numbers

c. Selectable scan factors
1) Scan field of view
2) Display field of view
3) Matrix size
4) Slice thickness
5) Window width
6) Window level
7) mAs and kVp
8) Algorithm
9) Scan time and rotational arc
10) Radiographic tube output
11) Region of interest (ROI)
12) Magnification
13) Focal spot size and tube geometry
14) Pitch
15) Slice sensitivity profile (SSP)

B. Image reconstruction
1. CT computer
a. Minicomputer and microprocessors
b. Array processors

2. Reconstruction algorithms
a. Conventional CT
1) Back projection (historical only)
2) Filtered back projection

b. Single detector row spiral
1) Linear interpolation

c. Multidetector row spiral
1) Longitudinal interpolation with Z-axis filtering
2) Interlaced sampling
3) Fan-beam
4) Convolution/algorithm
5) Isotropic scanning
6) In plane resolution

d. 3-D

C. Image display, manipulation, recording and archiving

1. Display
    a. Active matrix liquid crystal displays (AMLCD)
    b. Cathode ray tube (CRT)
2. Basic tools use
    a. Pan
    b. Zoom
    c. Axial image scrolling
    d. Swivel
    e. Roll
    f. Rotate
    g. Inverse image
3. Manipulation
    a. Image reformation
    b. Image smoothing
    c. Edge enhancement
    d. Gray-scale manipulation
    e. 3-D processing
    f. Multiplanar reformation
    g. Shaded surface rendering
    h. Maximum intensity projection (MIP)
    i. Volume rendering
    j. Radiation therapy treatment planning
    k. Fusion
    l. Curved multiplanar reconstruction (cMPR)
    m. Virtual endoscopy/colonoscopy (VE)
    n. Vessel analysis (VA)
    o. Vessel tracking (VT)
4. Viewing modes
    a. 2-D
    b. Slab
    c. Planar
5. Basic use of the workstation
    a. Directory
    b. Imaging
    c. Report
    d. Delete
    e. Archive
    f. Copy
    g. Online help
6. Image station applications
    a. Cardiac
    b. Neurology
    c. Vascular
    d. GI
    e. Pulmonary
    f. Dental

g. Orthopedics
h. Bone mineral density
7. CT fluoroscopy
8. Archiving

VI. Image Quality in CT

A. Definition

B. Determining factors
1. Artifacts
2. Contrast resolution
a. Signal to noise ratio
b. Contrast to noise ratio
c. Scatter radiation reduction
3. Linearity
4. Noise
a. Quantum noise
b. Mottle
c. Electronic
5. Spatial resolution
a. Detector size
b. Matrix size
c. Reconstruction interval
6. Temporal resolution
a. Gantry rotation time
b. Acquisition mode
c. Reconstruction methods
d. Pitch

C. Influencing factors
1. Focal spot size
2. Beam geometry
3. Detector type
4. Motion
5. Subject contrast
6. Selectable factors
a. mA
b. Scan time
c. Scan field of view (SFOV)
d. Displayed field of view (DFOV)
e. Slice thickness
f. Interscan spacing
g. Filtering
h. kV
i. Window level and width presets
1) Organ mode

D. Measurements conducted by physicists
    1. Contrast transfer and response function
    2. Line spread function
    3. Point spread function
    4. Modulation transfer function
    5. Edge response function
    6. CT number calibration
    7. Standard deviation of CT number in water
    8. High-contrast resolution
    9. Low-contrast resolution
    10. Accuracy of distance measuring device
    11. CT image uniformity and symmetry
    12. CT couch indexing
    13. CT couch back lashing
    14. Slice width
    15. Localization device accuracy (light field accuracy)
    16. Display monitor quality
    17. Hard copy output distortion
    18. Patient dose
    19. Ambient lighting conditions

E. Quality control (QC) programs in CT
    1. Definition of QC
    2. ACR accreditation program for CT
    3. Intersocietal Commission for Accreditation of Computed Tomography Laboratories (ICACTL)
    4. Medicare Improvements for Patients and Providers Act (MIPPA)
    5. Principles
        a. Acceptance testing
        b. Regular performance
        c. Prompt interpretation of results
        d. Accurate and faithful records bookkeeping of patients scanned
        e. Appropriate CPT coding of exams
    6. Common QC tests
        a. Phantoms
        b. Choosing techniques
        c. Determining frequency of performance
        d. Establishing acceptable limits from test results
        e. Common QC tests performed by the technologist
            1) Air calibration
            2) Hounsfield test
            3) Tube warm-up
            4) Phantom scan (manufacturers)
    7. QC documentation
    8. CT artifacts

a. Identification of common types
    1) Partial volume averaging
    2) Aliasing artifacts
    3) Ring artifacts
    4) Ghosting
    5) Edge gradient effect
    6) Out of field artifact
    7) Beam hardening
    8) Cupping artifact
    9) Tube Arching
    10) Metal artifact
    11) Motion
b. Determination of cause
c. Correction efforts

9. Additional QC requirements for various CT procedures

VII. Radiation Protection Practices for the CT Patient

A. Measuring patient radiation dose
1. Methods
2. Procedures
3. CT dose index (CTDI)
4. $CTDI_{vol}$
5. Multiple scan average dose (MSAD)
6. Dose length product (DLP)
7. Size specific dose estimate (SSDE)
8. Effective dose
9. Dose reporting
    a. Millisievert (mSv)
    b. Milligray (mGy)

B. Reducing radiation dose
1. Methods
    a. Increased screening techniques
    b. Alternative diagnostic imaging
    c. Reduction in multi-phasic examinations
    d. Technical factor selection
        1) mA
        2) kVp
        3) Collimation
        4) Couch speed
        5) Pitch value selection
        6) Gantry rotation time
    e. Scanning geometry (partial rotation)
    f. Z-axis filtering
    g. Scanning mode
    h. Scanning length
    i. Scanner dosimetry survey

j. Filtration
k. Automatic tube current modulation
l. Anatomical parameter consideration
1) Weight of the patient
2) Cross-sectional dimension of the patient

2. Shielding
a. Bismuth shields
b. Positioning

3. Dose reduction software
a. Adaptive filtration
b. Iterative reconstruction
c. Dedicated pediatric protocol selection

4. Hardware design
a. Off-focus radiation suppression (tube)
b. Filtration – Bowtie filters
c. Collimation to prevent helical over-ranging or over-scanning
d. Data acquisition system (DAS) – detector system efficiency

C. Pediatric patients
1. Image Gently
2. Radiation dose reduction parameters
a. Weight categories (thorax and abdomen)
b. Age categories (skull and brain)
c. kVp and mA reduction

D. Ethical considerations
1. Overuse
2. Pediatrics

VIII. Helical/Spiral Computed Tomography

A. Definition

B. Differences between axial/sequential and helical/spiral CT
1. Operation
2. Advantages
3. Disadvantages

C. Multidetector Row Computed Tomography (MDCT)
1. Detector
2. Pitch ratio
3. Couch speed
4. Interpolation algorithms

D. Scanner designs
1. High-voltage and low-voltage scanners
2. Slip-ring cylinders and slip-ring disk

IX. Computed Tomography Angiography (CTA)

A. Equipment requirements
   1. Hardware
   2. Software

B. Image quality
   1. Temporal resolution
   2. Spatial resolution
   3. Contrast resolution

C. Patient dose

D. Artifacts

X. Computed Tomography Radiation Therapy Simulation

A. Replication of geometry

B. Scanning considerations
   1. DFOV
   2. Slice thickness

XI. Positron Emission Tomography/Computed Tomography (PET/CT)

A. PET imaging
   1. Isotope
      a. Synthesis of isotope
      b. Uptake
   2. Patient preparation
   3. Detection
   4. Radiation protection measures
   5. Radionuclide contamination

B. CT imaging

C. Fusion
   1. Assessment
      a. Standardized uptake value (SUV)
      b. Glucose metabolic rate calculation
   2. Attenuation correction

D. Clinical application

E. Advantages/disadvantages

F. Artifacts

XII. Virtual CT

A. CT colonography

B. Cystography

C. Endography

D. Hardware requirements

E. Software requirements

F. Postprocessing

XIII. High-Resolution Computed Tomography

A. Hardware requirements

B. Software requirements

C. Postprocessing

XIV. Technological Advances

A. Dual source scanning

B. Inverse geometry scanning

C. Detector number

D. 4-D

E. 5-D

Planar and Volumetric Postprocessing

Description

Content is designed to develop a strong understanding of multiplanar (MPR) images (axial, sagittal, coronal and oblique) of human anatomy created by CT. The historical development, the evolution and future developments of post processing will be reviewed. A working knowledge of digital image storage and retrieval, thin client architecture vs. an imaging workstation, along with archival of 3-D images with picture archiving and communications (PACS) integration will be discussed. The postprocessing image generation principles covered will be MPR, curved MPR, Surface rendering or 3-D shaded surface displays, volume rendered images, maximum, minimum and average intensity projections along with image segmentation. The imaging post processing topics to be explained include exam protocol, image display, improving image quality, recognition of artifact characteristics and minimizing artifacts. Common applications for multiplanar or volumetric images in CT will be reviewed.

Objectives

1. Describe the benefits of postprocessing of digital images.
2. Describe how to query a PACS/CT system to retrieve appropriate study.
3. Identify the imaging system requirements for 2-D planar and 3-D volumetric postprocessing.
4. Determine the requirements of source data to create 3-D reformations.
5. Differentiate classifications of postprocessing techniques
    a. Slice imaging
    b. Projective imaging
    c. Volume imaging
6. Describe the processing techniques to take 2-D axial images to construct:
    a. Multiplanar reformation (MPR)
    b. Curved planar reformation (cMPR)
    c. Surface rendering (SR) or 3-D shaded surface displays (SSD)
    d. Volume rendered images (VR)
    e. Maximum intensity projections (MIP)
    f. Minimum intensity projections (MinIP)
    g. Average intensity projections (AIP or AVE)
7. Determine the proper window/level (W/L) for display.
8. Recognize how to make 2-D and 3-D measurements.
9. Apply the 2-D and 3-D postprocessing that best demonstrates the anatomy/pathology for given CT exams.
10. Identify methods to improve image quality for postprocessed images to include errors:
    a. Acquisition of CT source images
    b. Protocol selection
    c. Patient instructions
11. Recognize the key artifacts on postprocessed images.

Content

I. Image Postprocessing

A. Definition and benefits

B. Data acquisition requirements

C. 2-D generation – axial, coronal, sagittal, orthogonal (oblique)

D. 3-D generation – data acquisition, creation of 3-D space, postprocessing, image display

II. 3-D Imaging System

A. Input – communication with configured DICOM devices to query and retrieve study

B. Workstation – identify proper series for postprocessing, manipulation and analysis

C. Output – exporting/recording DICOM images

III. 3-D Terminology

A. Coordinate systems to create 3-D space (Scene space)
   1. Scanner coordinate system
   2. Display coordinate system
   3. Object coordinate system
   4. Scene coordinate system

B. 3-D space (image space, object space, parameter space, and view space)

IV. 3-D Image Transformation

A. Modeling

B. Shading and lighting

C. Rendering

V. Classifications and Postprocessing Techniques in 2-D and 3-D Imaging

A. Slice imaging
   1. MPR
      a. Defining plane and image reformation (axial, coronal, sagittal, oblique)
      b. Determining thickness of reformatted images-sliding thin slabs (STS)
   2. Intensity projection renderings – enhancement of MPR images
      a. Average intensity projection (AIP or AVE)
      b. Maximum intensity projection (MIP)
      c. Minimum intensity projection (MinIP)
   3. Application of MPR and intensity projection renderings
      a. Anatomically corrected datasets
      b. Noise reduction
      c. Improve spatial resolution

4. Curved multiplanar reformation (cMPR)
    a. Visualization of tubular structures-straightened
    b. Manual and automatic tracking
    c. Application – vessels, ducts

B. Projective imaging
    1. Surface rendering (SR) or shaded surface display (SSD)
        a. Surface formation and rendering
        b. Selection of threshold and size
        c. Shading (shadowing effect)
        d. Lighting (virtual light source)
        e. Image rotation and viewing angle
    2. Application of SSD
        a. Visualization of complex 3-D relationships
        b. Virtual endoscopy
    3. Volume rendering (VR)
        a. Preprocessing
        b. Rendering or ray tracing
        c. Opacity/transparency curve-surface display
    4. Applications of VR
        a. CT angiography (CTA)
        b. Skeletal images
        c. Volume measurements
        d. Articular surface viewing

C. Volume imaging
    1. Virtual reality images – volume rendering with transparency
    2. Virtual CT endoscopy (VE)
        a. Perspective volume rendering (pVR) – rendering along a path
        b. Alternative viewing angles
        c. Applications – angioscopy, bronchoscopy, colonoscopy, cystoscopy

D. Segmentation
    1. Threshold techniques
    2. Automated techniques

VI. 3-D Image Display

A. 2-D screen captures – proper window/level (W/L) display

B. Cine

C. Advanced 3-D display
    1. Fusion (PET/CT)
    2. Computer Assisted Diagnosis (CAD)
    3. Tissue perfusion imaging – functional imaging (brain, cardiac, etc.)

VII. CT Measurements

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 - volume

VIII. Image Quality Issues

A. Acquisition errors
   1. Source image errors due to improper
      a. Slice thickness
      b. Image overlap
      c. Reconstruction algorithm
      d. Timing
         1) Bolus tracking
         2) Delayed images
   2. Positioning/technical errors
      a. Segmentation
      b. Curved planar centerline error
      c. Volume rendering settings
      d. Annotation errors
      e. Improper choice of 3-D imaging protocol

B. Methods to improve image quality
   1. Select proper protocol (injection, scan timing)
   2. Correct patient errors
   3. Manipulate image data

IX. 3-D Artifacts

A. CT Artifacts influencing 3-D
   1. Noise
   2. Segmentation misrepresentation
   3. Beam hardening artifact
   4. Motion

B. MPR and CPR artifacts
   1. Partial volume
   2. False stenosis
   3. Mirror artifacts (cMPR)

C. MIP and MinIP artifacts
    1. Depth perception
    2. Superimposition of structures
    3. Vessel calcification

D. SR artifacts or shaded surface display (SSD)
    1. Raising threshold selection
    2. Lowering threshold selection

E. VR artifacts
    1. Venetian blind artifacts
    2. Opacity setting error

Sectional Anatomy

Description
Content begins with a review of gross anatomy of the entire body. Detailed study of gross anatomical structures will be conducted systematically for location, relationship to other structures and function.

Gross anatomical structures are located and identified in axial (transverse), sagittal, coronal and orthogonal (oblique) planes. Illustrations and anatomy images will be compared with CT and MR images in the same imaging planes and at the same level when applicable. The characteristic appearance of each anatomical structure as it appears on CT, MR and ultrasound images, when applicable, will be stressed.

Objectives
1. Name the anatomical structures located within the head and neck.
2. Describe the relationship of each head and neck anatomical structure to surrounding structures.
3. Describe the function of each anatomical structure in the head and neck.
4. Locate each anatomical structure on CT, MR and ultrasound images in the transverse axial, coronal, sagittal and orthogonal (oblique) cross-sectional imaging planes.
5. Name the anatomical structures located within the thorax.
6. Describe the relationship of each thoracic structure to surrounding structures.
7. Describe the function of each anatomical structure located within the thorax.
8. Locate each anatomical structure of the thorax on CT, MR and ultrasound images in the transverse axial, coronal, sagittal and oblique imaging planes.
9. List and describe the function of each anatomical structure located within the abdomen and pelvis.
10. Describe the relationship of each anatomical structure in the abdomen and pelvis to surrounding structures.
11. Locate each anatomical structure of the abdomen and pelvis on CT, MR, PET and ultrasound images in the axial, coronal, sagittal and oblique planes.
12. Name and describe the function of each anatomical structure located in the upper and lower extremities.
13. Locate each anatomical structure in the upper and lower extremities on CT and MR images in the transverse axial, coronal, sagittal and oblique planes.

Content

I. Head and Brain

A. Sutures and fontanelles

B. Cranial bones
   1. Frontal
      a. Orbital plate (horizontal portion)
      b. Squamous portion (forehead)
   2. Ethmoid
      a. Cribriform plate (horizontal portion)
         1) Crista galli
      b. Perpendicular plate
      c. Bones of nasal septum
      d. Nasal conchae (turbinates)
   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) Pterygoid processes, hamulus
         2) Foramen rotundum
         3) Foramen ovale
            a) Foramen spinosum
   5. Occipital
      a. Foramen magnum
      b. Internal and external occipital protuberance
      c. Jugular foramen
      d. Occipital condyles
      e. Clivus
   6. Temporal
      a. Zygomatic process
      b. External auditory meatus (EAM)
      c. Internal auditory canal
      d. Mastoid process/air cells
      e. Petrous portion or ridge
      f. Inner and middle ear structures
      g. Foramina
         1) Carotid canals
         2) Foramen lacerum

C. 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

D. Lobes of the brain and midline cerebral hemisphere structures (cerebrum)
1. Frontal
2. Parietal
3. Occipital
4. Temporal
5. Insula (island of Reil)
6. Corpus callosum (genu, rostrum, body and splenium)
7. Septum pellucidum
8. Falx cerebri
9. Cerebral cortex (gray vs. white matter)
10. Anterior and posterior commissures (AC and PC)

E. Cerebellum
1. Cerebellar hemispheres
2. Vermis
3. Cerebellar tonsils
4. Cerebellar penduncles

F. 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

G. Cranial nerves
1. Olfactory
2. Optic
3. Oculomotor
4. Trochlear
5. Trigeminal
6. Abducens
7. Facial
8. Vestibulocochlear
9. Glossopharyngeal
10. Vagus

11. Accessory
12. Hypoglossal

H. 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

I. Basal ganglia
    1. Caudate nucleus
    2. Putamen
    3. Globus pallidus
    4. Claustrum
    5. Internal capsule
    6. External capsule
    7. Extreme capsule

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. Facial bones
    1. Mandible
    2. Maxillae
    3. Zygomas
    4. Nasal bones
    5. Lacrimal bones
    6. Palatine bones
    7. Vomer
    8. Inferior nasal conchae

L. Facial muscles
    1. Muscles of mastication

a. Masseter
b. Temporalis
c. Lateral pterygoid
d. Medial pterygoid

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

N. Orbit
1. Bony orbit
   a. Cranial bones
      1) Frontal
      2) Sphenoid
      3) Ethmoid
   b. Facial bones
      1) Lacrimal
      2) Palatine
      3) Maxilla
      4) Zygoma
2. Orbital fissures
   a. Superior orbital fissure
   b. Inferior orbital fissure
   c. Optic canal
3. Globe
4. Lens
5. Optic nerve
6. Lacrimal gland
7. Lateral rectus muscle
8. Medial rectus muscle
9. Superior rectus muscle
10. Inferior rectus muscle
11. Superior oblique muscle
12. Inferior oblique muscle
13. Orbital fat
14. Ophthalmic artery
15. Retinal vein

O. Other anatomical structures of brain
1. Diploe
2. Subcutaneous soft tissue
3. Centrum semiovale

P. Lines of angulation (imaging baselines)

1. Supraorbitomeatal line
2. Orbitomeatal line
3. Infraorbitomeatal line
4. Anterior commissure-posterior commissure (AC-PC) line (Talairach space)

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

II. Neck

A. Bones
1. Cervical vertebrae

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
5. Vagus nerve

D. Musculature
1. Anterior triangle
2. Posterior triangle
3. Sternocleidomastoid
4. Scalene
5. Trapezius

III. Chest and Mediastinum

A. Bony thorax
1. Thoracic vertebrae
2. Sternum
3. Ribs
4. Costal cartilages

5. Scapulae
6. Clavicles

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

C. Mediastinum
1. Thymus gland
2. Heart
   a. Chambers
   b. Valves
   c. Coronary vessels
3. Pulmonary vessels
4. Arterial system
   a. Ascending aorta
   b. Aortic arch
   c. Branches of the aortic arch
   d. Descending (thoracic) aorta
5. Venous system
   a. Superior and inferior vena cava
   b. Brachiocephalic veins
   c. Subclavian veins
   d. Azygos vein
   e. Hemiazygos vein
6. Esophagus
7. Trachea
8. Thoracic duct
9. Lymph nodes

D. Breasts

E. Musculature
1. Pectoralis major/minor
2. Latissimus dorsi

IV. Abdomen

A. Diaphragm and openings

1. Aortic hiatus
2. Caval hiatus
3. Esophageal hiatus
4. Diaphragmatic crura

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 hypochrondric
   2. Epigastric
   3. Right hypochondric
   4. Left lumbar
   5. Umbilical
   6. Right lumbar
   7. Left iliac
   8. Hypogastric
   9. Right iliac

D. Branches of the abdominal aorta
   1. Anterior visceral branches
      a. Celiac axis
         1) Left gastric
         2) Splenic
         3) Hepatic
      b. Superior mesenteric
         1) Jejunal and ileal
         2) Inferior pancreaticoduodenal
         3) Middle colic
         4) Right colic
         5) Ileocolic
      c. Inferior mesenteric
         1) Left colic
         2) Sigmoid
         3) Superior rectal
   2. Lateral visceral branches
      a. Suprarenal
      b. Renal
      c. Testicular or ovarian
   3. Parietal branches
      a. Inferior phrenics
      b. Lumbars

c. Middle sacral
4. Terminal branches
   a. Common iliacs

E. Tributaries of the vena cava
1. Anterior visceral
   a. Hepatic veins
2. Lateral visceral
   a. Right suprarenal
   b. Renal veins
   c. Right testicular or ovarian
3. Tributaries of origin
   a. Common iliacs
   b. Median sacral

F. Tributaries of the portal vein
1. Splenic
2. Inferior mesenteric
3. Superior mesenteric
   a. Left gastric
   b. Right gastric
   c. Cystic

G. Abdominal organs and structures
1. Bony structures
   a. Lumbar vertebrae
2. Abdominal cavity
   a. Peritoneum
   b. Peritoneal spaces
   c. Retroperitoneum
   d. Retroperitoneal spaces
3. Liver
   a. Hepatic arteries
   b. Portal venous system
   c. Lobes
4. Gallbladder and biliary system
5. Pancreas and pancreatic ducts
6. Spleen
7. Adrenal glands
8. Urinary system and tract
   a. Kidneys
   b. Ureters
9. Stomach
10. Small intestine
11. Colon
12. Musculature

a. Rectus abdominis
b. Internal/external obliques
c. Transversus abdominus
d. Psoas

V. Pelvis

A. Bony structures
1. Proximal femur
2. Ilium
3. Ischium
4. Pubis
5. Sacrum
6. Coccyx

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
d. Ovarian/testicular

C. Pelvic organs
1. Urinary bladder
a. Ureter
b. Urethra
2. Small intestine
a. Terminal ileum 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
f. Adnexa/broad ligaments
5. Male reproductive organs

a. Prostate gland
b. Seminal vesicles
c. External to pelvis
    1) Testes/scrotum
    2) 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. Vascularity
        1) Axillary artery
        2) Axillary vein
2. Elbow
    a. Bony anatomy
        1) Humerus
        2) Radius
        3) Ulnar
    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
      1) Phalanges
      2) Metacarpals
      3) Carpal bones
      4) Radius
      5) Ulna
   b. Tendons
      1) Palmar tendon group
      2) Dorsal tendon group
      3) Triangular fibrocartilage complex
   c. Neurovascular
      1) Ulnar artery
      2) Ulnar nerve
      3) Radial artery
      4) Median nerve

B. Lower Extremities
   1. Hip
      a. Bony anatomy
      b. Labrum and ligaments
      c. Muscle groups
         1) Hamstring muscles
         2) Abductor/adductor
      d. Neurovasculature
         1) Femoral nerve
         2) Femoral artery
         3) Femoral vein
         4) Great saphenous vein
   2. Knee
      a. Bony anatomy
      b. Menisci and ligaments
      c. Muscles
         1) Sartorius
         2) Tibialis anterior
      d. Vasculature
         1) Popliteal artery
         2) Anterior tibial artery
         3) Posterior tibial artery

3. Foot and Ankle
    a. Bony anatomy
    b. Ligaments
    c. Tendons
    d. Muscles
    e. Vasculature
        1) Dorsalis pedis artery
        2) Lateral plantar artery
        3) Plantar arch

Clinical Experience Requirements

The most current information regarding the eligibility requirements for a postprimary certification examination in computed tomography can be found in the ARRT Computed Tomography Clinical Experience Requirements document, located at https://www.arrt.org/arrt-reference-documents/clinical-experience-requirements.

Appendix

This section represents an inventory of pre-existing knowledge and skills gained through an entry-level 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.

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 medical imaging 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 medical imaging procedures and total quality management. Levels of competency and outcomes measurement ensure the well-being of the patient before, during and following the 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 electrocardiogram (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 technologist's practice standards into clinical practice setting.
- Maintain patient confidentiality standards and meet 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 following the ALARA principle.
- Critique images for appropriate anatomy, image quality and patient identification.
- Determine corrective measures to improve inadequate images.

Digital Image Acquisition and Display

Description
Content conveys 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. Principles of digital system quality assurance and maintenance are presented.

Special Note: Digital imaging is a rapidly evolving technology. Every effort has been made to provide a curriculum outline that reflects, as accurately as possible, the state of the art of this discipline as of publication. Educators are encouraged to modify this outline with up-to-date information as it becomes available from vendors, clinical sites, textbooks, and technical representatives.

Objectives
- Define terminology associated with digital imaging systems.
- Describe the various types of digital receptors.
- Describe the response of digital detectors to exposure variations.
- Compare the advantages and limits of each receptor type.
- Evaluate the spatial resolution of a digital imaging system.
- Define sampling frequency.
- Describe the Nyquist-Shannon theorem as it relates to sampling frequency.
- Describe the impact of sampling frequency on spatial resolution.
- Describe the impact of detector element size on spatial resolution.
- Describe detective quantum efficiency (DQE) for digital radiography detectors.
- Describe modulation transfer function (MTF) as it relates to digital radiography detectors.
- Describe the histogram and the process of histogram analysis as it relates to automatic rescaling.
- Describe the calculation of the exposure indicator (AAPM Task Group 116).
- Define region of interest (ROI).
- Relate the location and size of the ROI to the appearance of the image and exposure indicator.
- Relate how the values of interest (VOI) impact image appearance.
- Describe the process of image stitching.
- Relate the receptor exposure indicator values to technical factors, system calibration, part/beam/plate alignment and patient exposure.
- Describe the response of PSP systems to background and scatter radiation.
- Use appropriate means of scatter control.
- Avoid grid use errors associated with grid cutoff.
- Identify common limitations and technical problems encountered when using PSP systems.
- Employ appropriate beam/part/receptor alignment to avoid histogram analysis errors.
- Associate impact of image processing parameters to the image appearance.
- Apply the fundamental principles of radiographic exposure to digital detectors.

- Evaluate the effect of a given exposure change on histogram shape, data width and image appearance.
- Formulate a procedure or process to minimize histogram analysis and rescaling errors.
- Describe continuous quality improvement (CQI).
- Differentiate between quality assurance (QA) and quality control (QC).
- List the benefits of a quality control management to the patient and to the department.
- 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.
- Discuss the appropriate use of electronic masking.
- Describe picture archival and communications system (PACS) and its function.
- Identify components of a PACS.
- Define digital imaging and communications in medicine (DICOM).
- Describe HIPAA concerns with electronic information.
- Identify common problems associated with retrieving/viewing images within a PACS.
- Compare monitor types (e.g. acquisition, display).
- Describe the components of the various types of display monitors.
- Discuss the impact of viewing angle, luminance, ambient lighting, and pixel size on image display.
- Describe display monitor aspect ratio and its impact on image display.

Ethics and Law in the Radiologic Sciences

Description
Content provides a foundation in ethics and law related to the practice of medical imaging. An introduction to terminology, concepts and principles will be presented. Students will examine a variety of ethical and legal issues found in clinical practice.

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.
- 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 and 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 technologist.
- Describe the components and implications of informed consent.
- Identify standards for informed consent and disclosure of protected health information.
- Describe how consent forms are used relative to specific radiographic procedures.
- Differentiate between civil and criminal liability.
- Define tort and explain the differences between intentional and unintentional torts.

Human Anatomy and Physiology

Description
Content establishes a knowledge base in anatomy and physiology. Components of the cells, tissues, organs and systems are described and discussed. The fundamentals of sectional anatomy relative to routine imaging are addressed.

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- 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 sectional anatomical structures found within the head/neck, thorax and abdomen.

Introduction to Computed Tomography

Description
Content is designed to provide entry-level students with an introduction to and basic understanding of the operation of a computed tomography (CT) device. Content is not intended to result in clinical competency.

Objectives
- Describe the components of the CT imaging system.
- Explain the functions of collimators in CT.
- List the CT computer data processing steps.
- Define algorithm and explain its impact on image scan factors and reconstruction.
- Define raw data and image data.
- Describe the following terms in relation to the CT data acquisition process:
  - 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).
- 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.
- Name the radiation protection devices that can be used to reduce patient dose in CT and describe the correct application of each.
- Describe the general purpose of commonly performed CT studies.
- Discuss general radiation safety and protection practices associated with examinations in CT.

Medical Terminology

Description
Content provides an introduction to the origins of medical terminology. A word-building system is introduced and abbreviations and symbols are discussed. Also introduced is an orientation to understanding medical imaging orders and diagnostic report interpretation. Related terminology is addressed.

Objectives
- Apply the word-building process.
- Interpret medical abbreviations and symbols.
- Critique orders, requests and diagnostic reports.
- Define medical imaging and radiation oncology terms.
- Translate medical terms, abbreviations and symbols into common language from a medical report into layman's terms.

Pathophysiology

Description
Content introduces concepts related to disease and its origins with emphasis on the radiographic appearance of diseases and correct exposure factor selection.

Objectives
- Define basic terms related to pathology.
- Describe the basic manifestations of pathological conditions and their relevance to imaging procedures.
- Discuss the classification of trauma.
- Describe imaging procedures used in diagnosing diseases.
- List the causes of tissue disruption.
- Describe the healing process.
- Identify complications associated with the repair and replacement of tissue.
- Describe the various systemic classifications of disease in terms of etiology, types, common sites, complications and prognosis.
- Describe the radiographic appearance of diseases.
- Identify imaging procedures and interventional techniques appropriate for diseases common to each body system.
- Identify diseases caused by or associated with genetic factors.

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 technologist 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 technologist.
- Describe the practice standards for the technologist as defined by the ASRT and state licensure.
- 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 dying and death from the viewpoint of both patient and technologist.
- Identify methods for determining the correct patient for a given procedure.
- Explain the use of various communication methods.
- Explain specific aspects of an imaging 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 who have various health conditions.
- Describe 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 incident reporting.
- Describe methods to evaluate patient physical status.
- List the information to be collected prior to a patient examination.
- Describe vital signs and lab values used to assess patient condition, including sites for assessment and normal values.
- Define terms related to infection control.
- Describe the importance of standard precautions and isolation procedures, including sources and modes of transmission of infection and disease and institutional control procedures.
- Identify symptoms related to specific emergency situations.
- Describe the institution's emergency medical code system and the role of the student during a medical emergency.
- Explain the age-specific considerations necessary when performing radiographic procedures.
- Describe appropriate procedures for management of various types of trauma situations.
- Describe the symptoms and medical interventions for a patient with a contrast agent reaction.
- Explain the role of the technologist in patient education.

- Describe the patient preparation for contrast studies.
- Identify specific types of tubes, lines, catheters and collection devices.
- Outline the steps in the operation and maintenance of suction equipment.
- Outline the steps in the operation and maintenance of oxygen equipment and demonstrate proper use.
- Demonstrate competency in basic life support (BLS).
- Describe the steps in performing various mobile procedures.
- 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 Venipuncture

Description

Content provides basic concepts of pharmacology, venipuncture and administration of diagnostic contrast agents and intravenous medications. The appropriate delivery of patient care during these procedures is emphasized.

Objectives

- Distinguish among the chemical, generic and trade names of various drugs.
- Describe the pharmacokinetic, pharmacodynamic and pharmacogenetic principles of drugs.
- Explain the uses and impact on the patient of different categories of drugs.
- Define the categories of contrast agents and give specific examples for each category.
- Explain the pharmacology of contrast agents.
- Describe methods and techniques for administering various types of contrast agents.
- Identify and describe the routes of drug administration.
- Demonstrate appropriate venipuncture technique.
- Differentiate between the two major sites of intravenous drug administration.
- Identify, describe and document complications associated with venipuncture and appropriate actions to resolve these complications.
- Discuss the various elements of initiating and discontinuing intravenous access.
- 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 status and professional liability issues of the technologist's role in contrast and/or drug administration.

Radiation Biology

Description
Content provides an overview of the principles of the interaction of radiation with living systems. Radiation effects on molecules, cells, tissues and the body as a whole are presented. Factors affecting biological response are presented, including acute and chronic effects of radiation.

Objectives
- Differentiate between ionic and covalent molecular bonds.
- Describe principles of cellular biology.
- Identify sources of electromagnetic and particulate ionizing radiations.
- Discriminate between the direct and indirect effects of radiation.
- Identify sources of radiation exposure.
- Describe radiation-induced chemical reactions and potential biologic damage.
- Evaluate factors influencing radiobiologic/biophysical events at the cellular and subcellular level.
- Identify methods to measure radiation response.
- Describe physical, chemical and biologic factors influencing radiation response of cells and tissues.
- Explain factors influencing radiosensitivity.
- Recognize the clinical significance of lethal dose (LD).
- Identify the radiosensitivity of specific cell types.
- Employ dose response curves to study the relationship between radiation dose levels and the degree of biologic response.
- Examine effects of limited vs. total body exposure.
- Relate short-term and long-term effects as a consequence of high and low radiation doses.
- Differentiate between somatic and genetic radiation effects and discuss specific diseases or syndromes associated with them.
- Discuss stochastic (probabilistic) and nonstochastic (deterministic) effects.
- Discuss embryo and fetal effects of radiation exposure.
- Discuss risk estimates for radiation-induced malignancies.
- Discuss acute radiation syndromes.

Radiation Physics

Description
Content is designed to establish a basic knowledge of physics pertinent to developing an understanding of radiations used in the clinical setting. Fundamental physical units, measurements, principles, atomic structure and types of radiation are emphasized. Also presented are the fundamentals of x-ray generating equipment, x-ray production and its interaction with matter.

Objectives
- Define the fundamental units of the English, metric and Système International d'Unites (SI) systems.
- Calculate various unit conversions.
- Demonstrate applications of the general principles that relate to inertia, work, energy and momentum.
- Describe Bohr's theory of atomic structure.
- Compare the characteristics and functions of a proton, neutron and electron.
- Discuss the energy levels of the atom.
- Define the terms relating to atomic nomenclature.
- Compare covalent bonding and ionic bonding.
- Describe the process of ionization.
- Differentiate between the characteristics of a mixture, substance and element.
- Classify the characteristics of an element using the periodic table.
- Compare the characteristics of a molecule and compound.
- Describe the nature of light.
- Explain the relationship between wavelength, frequency and velocity.
- Differentiate between the radiations of the electromagnetic (EM) spectrum.
- Explain the relationship of energy and frequency to Planck's constant.
- Distinguish between electrical charge and electrical field.
- Describe the methods of electrification.
- Explain the laws of electrostatics and their application.
- Describe the properties and laws of magnetism.
- Explain the electronic spin of an element to its potential magnetic properties.
- Describe the principle of magnetic induction.
- Define potential difference, current, resistance, circuit and electric power.
- Compare the characteristics of direct and alternating currents.
- Compare electrical measuring devices.
- Discuss electrical protective devices.
- Discuss the interaction between electric and magnetic fields.
- Describe the characteristics and functions of a cathode and rotating anode.
- Describe the construction and function of tube housing.
- Identify the parts of an x-ray tube.
- Determine heat units and cooling characteristics of x-ray tube housings.

- Propose methods to extend tube life.
- Discuss application and components of automatic exposure devices.
- State the principles of x-ray production.
- Compare the production of bremsstrahlung with the production of characteristic radiations.
- Compare various photon interactions in terms of description of interaction, relation to atomic number and applications.
- Discuss relationships of wavelength and frequency to beam characteristics.
- Define units of radiation measurement and provide an example of its application.

Radiation Protection

Description
Content presents an overview of the principles of radiation protection, including the responsibilities of the technologist 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.
- 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 man-made 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.
- Describe the operation of various interlock systems for equipment.
- Identify conditions and locations evaluated in an area survey for radiation protection.
- Distinguish between controlled and non-controlled 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 qualifications 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 effective dose 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, health care personnel and family members in the room during radiographic procedures.

Resources

This list of resources will 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 one 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 collection of titles.

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