Computed Tomography Curriculum

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

Core Content

The professional practice of computed tomography (CT) 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 CT computed tomography.

CT Procedures

Objectives

- Discuss the preparation for CT procedures, including patient care, education, and documentation.
- Explain the sequence of CT procedures, including equipment and parameters.
- Describe CT procedures divided by anatomical location and body systems.
- List specialty CT procedures, including interventional, pediatric, bariatric, and more procedures.

Content

I. CT Equipment Overview

II. Patient Care, Education and Management Review

III. Safety, Radiation and Dose Review

A. Communication

B. Informed consent

C. Patient preparation

D. Patient postprocedure instructions

IV. Charting and Documentation Requirements

V. Anatomy Review

A. Skeletal system

B. Organ systems

C. Muscular system

D. Cardiovascular system

E. Central Nervous system

F. Respiratory System

VI. Procedure Elements

A. Indications for each protocol

B. Contraindications for each procedure

C. Venipuncture
    1. Site selection
    2. Access
    3. Post access
    4. Supplies
    5. Sterile and aseptic technique
    6. Documentation

D. Venous access devices
    1. Angiocatheters (e.g., peripheral, diffusion tip)
    2. Conditional power injectable devices
        a. Subcutaneous ports
        b. PICCs
        c. Tunneled central venous catheters
        d. Nontunneled central venous catheters
        e. Dialysis access ports

E. Contrast media
    1. Pharmacology
    2. Types
    3. Routes of administration
    4. Dosage
    5. Contraindications
    6. Adverse reactions
    7. Methods of delivery
        a. Power injectors
            1) Types
                a) Single head injectors
                b) Dual head injectors
            2) Equipment setup
            3) Equipment operation
                a) Pounds per square inch (PSI)
                b) Keep vein open (KVO)
            4) Flow rates
            5) Bolus (timing, tracking)
            6) Multi-phase injection
            7) Operation
            8) Cleaning and preventive maintenance
            9) Accuracy
            10) Electrical safety
        b. Manual injection

F. Procedure parameters
    1. Scan range
    2. Anatomical landmarks
    3. Patient orientation

4. Patient position
5. Localizer image parameters
6. Scan field of view (SFOV)
7. Display field of view (DFOV)
8. Mode
    a. Axial/sequential
    b. Helical/spiral
9. Algorithm
10. Gantry angle
11. Technical factor selection
    a. kVp
    b. mA
    c. scan time mAs
    d. Table indexing
    e. Pitch
    f. Slice thickness
    g. Window level
    h. Window width
    i. Matrix size/voxel size
12. Image annotation parameters
13. Imaging planes
14. Helical/spiral application
15. Image archiving
16. Charting and documentation requirements
17. Bolus parameters and timing
18. Workstation
19. Other (e.g., dual energy application)

G. Identification of pathology

VII. Procedures of the Head, Spine and Musculoskeletal System

A. CT head without and/or with contrast
    1. Routine
    2. Brain perfusion
    3. Stroke protocol
    4. Stealth/surgical planning

B. CT maxillofacial without and/or with contrast
    1. Orbits
    2. Nasal bones
    3. Facial bones
    4. Mandible
    5. Temporomandibular joints

C. CT paranasal sinuses without and/or with contrast
    1. Routine

2. Stealth/surgical planning

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

E. CT Vasculature
   1. CTA brain
   2. CTV brain
   3. CTA carotid
   4. CTV jugular

F. CT spine without and/or with contrast
   1. Cervical spine
   2. Thoracic spine
   3. Lumbar spine
   4. CT post-myelogram spine

G. CT upper extremity without and/or with contrast
   1. Shoulder girdle
   2. Humerus
   3. Elbow
   4. Forearm
   5. Wrist
   6. Hand

H. CT lower extremity without and/or with contrast
   1. Hip
   2. Femur
   3. Knee
   4. Tib/fib
   5. Ankle
   6. Foot
   7. CT post-arthrogram

I. CT Vasculature
   1. CTA upper extremity
   2. CTA lower extremity (runoff)
   3. CTV lower extremity

J. CT pelvic girdle without and/or with contrast

VIII. Procedures for the Neck and Thorax

A. CT soft tissue neck without and/or with contrast
   1. Routine
   2. Multi-phase

3. CT esophagram

B. CT thorax without and/or with contrast
   1. Routine
   2. High resolution CT (HRCT)
      a. Axial/sequential
      b. Helical/spiral
   3. CT Vasculature
      a. CTA thoracic aorta
      b. CTA pulmonary
      c. Dissection protocol
      d. CTV pulmonary veins
      e. CTV superior vena cava
   4. Cardiac
      a. Calcium scoring
      b. Coronary CTA
      c. Transcatheter aortic valve replacement (TAVR)
   5. Low-dose lung screening

IX. Procedures for the Abdomen and Pelvis

A. Routine abdominopelvic imaging

B. CT abdomen without and/or with contrast
   1. Pancreas (mass, pancreatitis)
   2. Liver
      a. Multi-phase
      b. Hemangioma perfusion
   3. Renal system
      a. Multi-phase
      b. Urogram
   4. Adrenal glands
   5. Gastrointestinal system
      a. Suspected appendicitis
      b. Colorectal study
      c. Enterography study
      d. CTA GI bleeding
   6. CT colonography

C. CT pelvis without and/or with contrast
   1. Pelvic cystogram
   2. Bladder
   3. Trauma

D. CT vasculature
   1. CTA abdomen/pelvis
   2. CTV abdomen/pelvis

X. Additional Interventional Procedures

A. CT-guided needle biopsies

B. CT-guided abscess drains

C. CT-guided aspirations

D. CT-guided percutaneous ablation (e.g., radiofrequency)

E. CT-guided device implantation
   1. Catheter placement
   2. Orthopedic instrumentation

F. CT-guided nerve root injection

G. Positron emission tomography (PET)/CT

XI. Pediatric Procedures

A. Contrast media considerations

B. Immobilization

C. Communication and education

D. Sedation

E. Radiation protection

F. Technical factor selection and modifications

XII. Bariatric Procedures

A. Contrast media considerations

B. Technical factor selection

C. CT equipment limitations

D. Radiation exposure concerns

XIII. Radiation Therapy Simulation Procedures

Cardiac CT

Objectives

- Describe the anatomy and physiology of the heart.
- Explain steps for cardiac CT procedures.
- Discuss CT image reconstruction, resolution, viewing formats, and image assessment.
- List dose reduction methods and artifacts in cardiac CT.

Content

I. Anatomy and Physiology of the Heart

A. Cardiac anatomy
   1. Chambers
   2. Coronary arteries
   3. Valves

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

C. Cardiac cycle

II. Patient Screening and Preparation

A. Clinical history

B. Indications for exam protocol

C. Contraindications for exam

D. Preprocedural medications
   1. Beta blocker
   2. Nitroglycerin

E. Intravenous access requirements

F. Electrocardiogram (ECG)
   1. Lead configurations
   2. Skin prep and lead placement
   3. Artifacts

G. Breath holding training

H. Shielding

I. Patient variations
   1. Weight
   2. Heart rate
   3. Arrhythmias

III. Procedures

A. Advantages/disadvantages of cardiac CT

B. Hardware

C. Software
   1. ECG-based tube current modulation
   2. Noninvasive fractional flow reserve (FFR)
   3. Coronary plaque characterization

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

E. Cardiac calcium scoring
   1. Indications/contraindications
   2. Scores
      a. Agatston score
      b. Weston score

F. CT heart angiography (e.g., coronary, TAVR, PVS)
   1. Indications/contraindications
   2. Injection protocols
      a. Volume
      b. Injection rate
      c. Delivery
      d. Scan delay
      e. Phases

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. Three chamber left ventricular outflow
   3. Four chamber view
   4. Double oblique cardiac long axis
   5. Cardiac short axis

B. 3-D
   1. MPR/curved MPR (cMPR)
   2. Volumetric
   3. MIP

VII. Image Assessment

A. Regional and global evaluations
   1. Stenosis grading
   2. Cardiovascular disease staging

B. Ventricular function

C. Cardiac output

D. Ejection fraction

E. Cardiac viability

F. Wall thickness

G. Variants
   1. Stents
   2. Bypass grafts

3. Congenital abnormalities

VIII. Dose Reduction Methods

IX. Artifacts

Physiology and Pathology Correlation in Computed Tomography

Objectives

- Describe diseases and pathologies of the immune, cardiovascular, and central nervous systems and their CT appearance.
- List diseases and pathologies of the hematopoietic, lymph, and respiratory systems and their CT appearance.
- Explain diseases and pathologies of the gastrointestinal, genitourinary, and hepatobiliary systems and their CT appearance.
- Discuss diseases and pathologies of the head and neck and musculoskeletal systems, and their CT appearance.
- Recognize diseases and pathologies of the affecting pediatric patients, and their CT appearance.

Content

I. Autoimmune System

A. Acquired immunodeficiency syndrome (AIDS)

B. Systemic lupus erythematosus (Lupus)

II. Cardiovascular System

A. Conditions
   1. Cardiomegaly
   2. Valvular disease
   3. Aortic pathology
      a. Aortic aneurysm
      b. Aortic dissection
      c. Coarctation
      d. Traumatic aortic tear
   4. Pulmonary pathology
      a. Pulmonary embolism
      b. Pulmonary artery dissection
   5. Congenital malformations
   6. Arteriovenous malformation (AVM)
   7. Stenosis
   8. Congestive heart failure (CHF)
   9. Coronary artery disease
      a. Calcium scoring
      b. Soft plaque atherosclerosis
   10. Pericardial effusion
   11. Tumors
      a. Benign (e.g., myxoma)
      b. Malignant (e.g., sarcoma)
      c. Metastases

B. Procedures
    1. Cardiac transplant
    2. Coronary artery bypass grafts (CABG)

C. Trauma

III. Central Nervous System (CNS)

A. Terminology of the brain (e.g., supratentorial, infratentorial)

B. Tumors
    1. Brain
        a. Benign (e.g., acoustic neuroma)
        b. Malignant (e.g., glioma)
        c. Metastases
    2. Spine
        a. Benign (e.g., hemangioma)
        b. Malignant (e.g., astrocytoma)
        c. Metastases

C. Cerebrovascular accident (CVA)
    1. Ischemic
        a. Infarct
        b. Transient ischemic attack (TIA)
    2. Hemorrhage
        a. Intracerebral

D. Trauma
    1. Spinal cord
    2. Brain

E. Cysts

F. Cranial Nerves
    1. Optic nerve (CN II)
    2. Internal auditory canal (CN VII, CN VIII)

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

a. Syringomyelia
b. Hydromyelia
c. Tethered cord
d. Myelocele
e. Meningocele
f. Myelomeningocele

H. Orbit and visual pathways

I. Heterotopic gray matter

J. Seizures/epilepsy

K. Infections and Inflammatory diseases
1. Encephalitis
2. Meningitis
3. Abscess
4. Spondylitis
5. Toxoplasmosis
6. Arthritis

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

IV. Head and Neck

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

B. Paranasal sinuses
1. Mucocele
2. Sinusitis

C. Soft tissue neck

D. Salivary gland

1. Sialadenitis
2. Salivary stone

E. Larynx and hypolarynx

F. Trauma
1. Hematoma
   a. Epidural
   b. Subdural
   c. Subarachnoid
2. Foreign body

G. Vascular pathology
1. Circle of Willis aneurysm
2. Dural venous sinus thrombosis
3. Carotid dissection
4. Carotid stenosis

V. Hematopoietic and Lymph System

A. Lymph node staging

B. Lymphoma
1. Hodgkin
2. Non-Hodgkin

C. Lymphosarcoma

D. Lymphadenopathy

E. Splenomegaly

F. Splenic trauma

VI. Endocrine System

A. Pituitary adenoma

B. Adrenal pathology
1. Addison disease
2. Tumor
   a. Benign (e.g., adrenal adenoma)
   b. Malignant (e.g., adrenal carcinoma)
   c. Metastases
3. Cushing syndrome

C. Pancreas pathology
1. Pancreatic pseudocyst

2. Pancreatitis

D. Thymus
   1. Pineal
      a. Acute
      b. Chronic
   2. Tumor
      a. Benign (e.g., thymomas)
      b. Malignant (e.g., thymus carcinoma)
      c. Metastases

VII. Respiratory System

A. Masses
   1. Benign (e.g., hamartoma)
   2. Malignant (e.g., adenocarcinoma)
   3. Metastases

B. Infectious lung diseases
   1. Pneumonia
   2. Tuberculosis

C. Chronic lung diseases
   1. Asbestosis
   2. Chronic obstructive pulmonary disease (COPD)
      a. Emphysema
      b. Chronic bronchitis
   3. Bronchiectasis

D. Pulmonary edema

E. Acute respiratory distress syndrome (ARDS)

F. Pulmonary fibrosis

G. Pneumothorax

H. Hemothorax

I. Sarcoidosis

J. Pneumoconiosis

K. Pleural effusion

L. Atelectasis

M. Transplants

N. Trauma

O. Cystic Fibrosis

VIII. Gastrointestinal (GI) System

A. Masses
   1. Benign (e.g., adenoma)
   2. Malignant (e.g., colorectal cancer)
   3. Metastases

B. Abscesses/infections

C. Autoimmune (e.g., ulcerative colitis)

D. Cysts

E. Ascites

F. Pneumoperitoneum (intraperitoneal air)

G. Intussusception

H. Bowel obstruction

I. Appendicitis/appendicoliths/fecaliths

J. Diverticula/diverticulosis/diverticulitis

K. Congenital abnormalities (e.g., tracheoesophageal fistula)

L. Hiatal hernia

M. Ulcers

N. Ostomies

O. Fistula

P. Trauma

IX. Genitourinary (GU) System

A. Urinary masses
   1. Benign (e.g., renal angiomyolipoma)

2. Malignant (e.g., Wilms tumor)
3. Metastases

B. Infection

C. Renal and urinary calculi

D. Polycystic disease

E. Renal transplant

F. Hydronephrosis

G. Congenital abnormalities

H. Trauma

I. Reproductive conditions
   1. Female
      a. Masses
         1) Benign (e.g., teratoma)
         2) Malignant (e.g., ovarian cancer)
         3) Metastases
      b. Cyst
      c. Infections
   2. Male
      a. Masses
         a. Benign (e.g., prostate hyperplasia)
         b. Malignant (e.g., testicular cancer)
         c. Metastases
      b. Infections
      c. Trauma

X. Hepatobiliary System

A. Masses
   1. Benign (e.g., hemangioma)
   2. Malignant (e.g., hepatocellular carcinoma)
   3. Metastases

B. Liver conditions
   1. Hepatitis
   2. Cirrhosis
   3. Hepatomegaly

C. Gallbladder conditions

1. Cholecystitis
2. Cholelithiasis
3. Hemochromatosis
4. Biliary obstruction

D. Congenital abnormalities

E. Infection

F. Transplants

G. Trauma

XI. Musculoskeletal System

A. Tumors
1. Bone tumors (e.g., Ewing sarcoma)
2. Cartilaginous tumors (e.g., osteochondroma)
3. Soft tissue tumors (e.g., liposarcoma)
4. Metastases

B. Osteoporosis

C. Bone cysts

D. Skeletal dysplasia

E. Joint disorders

F. Infections

G. Inflammatory diseases

H. Arthritis/Gout

I. Fractures

J. Trauma

K. Spinal conditions
1. Stenosis
2. Scoliosis
3. Spondylolysis
4. Spondylolisthesis
5. Fractures
6. Herniated nucleus pulposus (HNP)
7. Infections

XII. Pediatric Pathologies

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

B. Seizures

C. Vascular and cardiac diseases/malformations

D. Inflammation

E. Tumors

F. Pulmonary diseases

G. Orthopedic abnormalities

H. Infection

I. Fractures

J. Trauma

K. Non-accidental trauma/Child abuse
   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

Objectives

- Recall the historical development of CT and the generations of CT scanners.
- Describe CT scanner components and operations.
- Explain the digital imaging and CT imaging steps, and their effect on image quality.
- List radiation protection practices for CT.
- Discuss helical CT, CTA, PET/CT, and other unique CT applications.

Content

I. Historical Development of Computed Tomography

A. Definition and evolution of terms

B. Research contributors to the development of CT

C. Historical development of CT

II. Computed Tomography Generations

A. First generation

B. Second generation

C. Third generation

D. Fourth generation

E. Fifth/Sixth generations

F. Spiral/helical CT

G. Multi-slice CT

H. Dual-source CT

III. CT Scanner Components and Operations

A. CT x-ray tube
   1. Differences from a conventional x-ray tube
   2. Heating capacity

B. CT filters

C. Collimators

D. Aperture size

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

F. Detectors
   1. Types
   2. Detector arrays

G. Data acquisition system (DAS)

H. Consoles
   1. Workstation
   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
   1. Resolution
   2. Contrast

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)
   4. Radiology information system (RIS)

V. Computed Tomography Process

A. Data acquisition

1. Methods
    a. Axial/sequential
    b. Helical/spiral
    c. Volumetric
    d. CT Fluoroscopy
2. Data acquisition system (DAS)
    a. Components
        1) Gantry
            a) Tube
            b) Generator
            c) Slip Ring
            d) Detectors
                i) Solid state
                ii) Dual layer
                iii) Photon counting
            e) Filters
            f) Collimators
        2) Analog-to-digital conversion (ADC)
    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) Ray sums
        2) Views
        3) Profiles/image data
            a) Pixels
            b) Matrices
            c) Voxels
        4) Sampling
            a) Angular
            b) Ray
    b. Attenuation
        1) Lambert-Beer law
        2) Linear attenuation coefficients
        3) CT numbers/Hounsfield numbers
    c. Selectable scan factors
        1) Scan field of view (SFOV)
        2) Display field of view (CFOV)
        3) Matrix size/pixel size
        4) Slice thickness
        5) Window width
        6) Window level
        7) mA and kVp

8) Scan time and rotational arc
9) Kernel/filter algorithm
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. Iterative reconstruction
c. Single detector row spiral
1) Linear interpolation
d. 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
e. 3-D

C. Image display, manipulation, recording and archiving
1. Image display
2. Display monitors
a. Active-matrix liquid crystal displays (AMLCD)
b. Cathode ray tube (CRT)
3. Computer console basic tools use
a. Pan
b. Zoom
c. Axial image scrolling
d. Swivel
e. Roll
f. Rotate
g. Inverse image
h. Workstation basic tools
1) Directory
2) Imaging
3) Report

4) Delete
5) Archive
6) Copy
7) Online help

i. Image station application tool
1) Cardiac
2) Neurology
3) Vascular
4) GI
5) Pulmonary
6) Dental
7) Orthopedics
8) Bone mineral density

j. Image viewing modes
1) 2-D
2) Slab
3) Planar
4) CT fluoroscopy

k. Magnify

4. Manipulation
a. Image reformation
1) Multiplanar reformation (MPR)
2) Curved multiplanar reconstruction (cMPR)
3) Retrospective reconstruction

b. Image smoothing
c. Edge enhancement
d. Gray-scale manipulation
e. 3-D processing
f. Shaded surface rendering (SR)/display (SSD)
g. Maximum intensity projection (MIP)
h. Minimum intensity projection (MinIP)
i. Volume rendering (VR)
1) Virtual endoscopy/colonoscopy (VE)
2) Vessel analysis (VA)
3) Vessel tracking (VT)

j. Radiation therapy treatment planning
k. Fusion
l. Segmentation

5. Viewing modes
a. 2-D
b. Slab
c. Planar

6. CT fluoroscopy

7. Recording and archiving
a. DICOM
b. PACS

c. Data storage

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/pixel size
      c. DFOV reconstruction interval
   6. Temporal resolution
      a. Gantry rotation time
      b. Acquisition mode
      c. Reconstruction methods
      d. Pitch
      e. Dual source/Spectral CT

C. Influencing factors
   1. Focal spot size
   2. Beam geometry
      a. Parallel
      b. Fan
      c. Cone
   3. Detector type
   4. Motion
   5. Subject contrast
   6. Iterative reconstruction methods
   7. 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. CT artifacts
1. Identification of common types
a. Partial volume averaging
b. Aliasing artifacts
c. Ring artifacts
d. Ghosting
e. Edge gradient effect
f. Out of field artifact
g. Beam hardening
h. Cupping artifact
i. Tube arcing
j. Metal artifact
k. Motion
l. Noise
2. Determination of cause
3. Correction

E. Quality control (QC) programs in CT
1. Definition of QC
2. QC accreditation programs
a. ACR accreditation program for CT
b. Intersocietal Commission for Accreditation Commission of Computed Tomography Laboratories (ICACTL) (IAC)
c. Medicare Improvements for Patients and Providers Act (MIPPA)
d. The Joint Commission (TJC)
3. Principles
a. Acceptance testing
b. Regular performance
c. Problem testing
d. Prompt interpretation of results
e. Accurate and faithful records (bookkeeping of patients scanned)
f. Appropriate CPT coding of exams
4. Common QC test requirements
a. Utilizing phantoms
b. Choosing techniques
c. Determining frequency
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)
f. CT number calibration

g. Standard deviation of CT number in water

5. Common QC measurements conducted by the physicists
   a. Contrast transfer and response function
   b. Line spread function
   c. Point spread function
   d. Modulation transfer function
   e. Edge response function
   f. High-contrast resolution
   g. Low-contrast resolution
   h. Accuracy of distance measuring device
   i. CT image uniformity and symmetry
   j. CT couch indexing
   k. CT couch back lashing
   l. Slice width
   m. Localization device accuracy (light field accuracy)
   n. Display monitor quality
   o. Hard copy output distortion
   p. Patient dose
   q. Ambient lighting conditions
6. QC documentation
7. CT artifacts
8. Additional QC requirements for various CT procedures

VII. Radiation Protection Practices for the CT Patient

A. Measuring patient radiation dose
   1. Dosimetry methods
      a. Thermoluminescent dosimeters (TLDs)
      b. Pencil ionization chamber
      c. CT dose measurement phantom
   2. CT dose metrics
   3. CT dose index (CTDI)
   4. CT dose index volume (CTDIvol)
   5. Multiple scan average dose (MSAD)
   6. Dose length product (DLP)
      a. Effective dose
   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
    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
m. Dual source/dual energy scanners

2. Shielding
    a. Bismuth shields
    b. Shield positioning
3. Dose Awareness Systems
    a. Dose notification
    b. Dose Alert
4. Dose reduction software
    a. Adaptive filtration
    b. Iterative reconstruction
    c. Dedicated pediatric protocols
5. 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
        e. Weight categories (thorax and abdomen)
        f. Age categories (skull and brain)
        g. kVp and mA reduction

D. Ethical considerations in overuse of CT imaging
    1. Need for education
    2. Lack of awareness
    3. Image Gently
    4. Image Wisely

5. 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 configurations
   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. Additional CT Procedures

X. Computed Tomography Angiography (CTA)

A. Equipment requirements
   1. Hardware
   2. Software
      a. Automated injection triggering
      b. ECG gating
      c. Postprocessing

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

C. Patient dose

D. Common artifacts in CTA
   1. Motion
   2. Beam hardening
   3. Stair-step

XI. Computed Tomography Radiation Therapy Simulation

A. Replication of geometry

B. Scanning considerations

1. DFOV
2. Slice thickness

XII. 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
   1. Attenuation correction
   2. Oncology
   3. Neurology
   4. Cardiac

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

D. Clinical application

E. Advantages/disadvantages

F. Common artifacts in PET/CT
   1. Metallic
   2. Motion
   3. Truncation

XIII. Virtual CT

A. CT colonography

B. Cystography

C. Hardware requirements

D. Software requirements

E. Postprocessing

XIV. High-Resolution Computed Tomography

A. Hardware requirements

B. Software requirements

C. Postprocessing

XV. Technological Advances

A. Dual source scanning

B. Photon counting

C. Inverse geometry scanning

D. Detector number

E. Artificial intelligence (AI)

F. 4-D

G. 5-D

H. Photon-counting detector

I. Dark-field CT

Planar and Volumetric Postprocessing

Objectives

- Discuss image postprocessing and 2-D techniques in CT.
- Describe 3-D imaging and display techniques in CT.
- Recognize image quality concerns and CT artifacts.

Content

I. Image Postprocessing

A. Definition and benefits

B. Data acquisition requirements
   1. 2-D generation
      a. Axial
      b. Coronal
      c. Sagittal
      d. Orthogonal (oblique)
   2. 3-D generation
      a. Data acquisition, creation of 3-D space
         1) Coordinate systems to create 3-D (scene) space
            a) Scanner coordinate system
            b) Display coordinate system
            c) Object coordinate system
            d) Scene coordinate system
         2) 3-D space
            a) Image space
            b) Object space
            c) Parameter space
            d) View space
      b. Postprocessing

C. 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

IV. 3-D Image Transformation

A. Modeling

B. Shading and lighting

C. Rendering

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

A. Slice imaging
   1. MPR
      a. Planes and image reformation (axial, coronal, sagittal, oblique)
      b. Thickness of reformatted images/sliding thin slabs (STS)
   2. Intensity projection renderings
      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
         1) Vessels
         2) 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. SSD Applications
      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. VR Applications
      a. CT angiography (CTA)
      b. Skeletal images
      c. Volume measurements
      d. Articular surface viewing
      e. Extremity images

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
        d. Applications
            1) Angiography
            2) Bronchoscopy
            3) Colonoscopy
        c. 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. Tissue perfusion (functional) imaging
    3. Artificial intelligence (AI)
        a. Computer -aided diagnosis (CAD)

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 volume measurements

VIII. Image Quality

A. Acquisition errors
    1. Source image errors
        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 3-D imaging protocol

B. Improving image quality
   1. Protocol selection (injection, scan timing)
   2. Patient motion
   3. Image data manipulation

IX. 3-D Artifacts

A. CT artifacts in 3-D image postprocessing
   1. Noise
   2. Segmentation misrepresentation
   3. Beam hardening
   4. Motion
   5. Patient size

B. Multiplanar reconstruction (MPR) and curved multiplanar reconstruction (cMPR) artifacts
   1. Partial volume
   2. False stenosis
   3. Mirror artifacts (cMPR)

C. Maximum intensity projection (MIP) and minimum intensity projection (MinIP) artifacts
   1. Depth perception
   2. Superimposition of structures
   3. Vessel calcification

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

E. Volume rendering (VR) artifacts
   1. Venetian blind
   2. Opacity setting error

Sectional Anatomy

Objectives

- Explain the anatomical nomenclature used to describe anatomy and body locations.
- Describe the anatomy and landmarks of the:
    - Head and brain
    - Neck
    - Chest and mediastinum
    - Abdomen
    - Pelvis
    - Spine
    - Musculoskeletal system

Content

I. Anatomical Nomenclature

A. Directional references

B. Body planes
1. Sagittal/midsagittal
2. Coronal/midcoronal
3. Axial/transverse
4. Longitudinal

C. Body cavities
1. Dorsal
    a. Cranial
    b. Vertebral
2. Ventral
    a. Thoracic
    b. Abdominal
    c. Pelvic

II. Head and Brain

A. Sutures and fontanelles

B. Cranial bones
1. Frontal
2. Ethmoid
3. Parietal
4. Sphenoid
5. Occipital
6. Temporal

C. Surface anatomy of the brain

1. Fissures (sulci)
2. Convolutions (gyri)

D. Lobes of the brain and midline structures
   1. Forebrain
   2. Midbrain
   3. Hindbrain

E. Meninges
   1. Dura mater
   2. Arachnoid
   3. Pia mater

F. 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

G. Ventricular system
   1. Ventricles
   2. Choroid plexus
   3. Cerebrospinal fluid

H. Basal ganglia

K. Circle of Willis

I. Dural sinuses

J. Facial bones
   1. Mandible
   2. Maxillae
   3. Zygomas
   4. Nasal bones
   5. Lacrimal bones
   6. Palatine bones
   7. Vomer

8. Inferior nasal conchae

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

L. Orbit
   1. Bony orbit
   2. Orbital fissures
   3. Globe
   4. Lens
   5. Optic nerve
   6. Lacrimal gland
   7. Orbital muscles

M. Lines of angulation (imaging baselines)
   1. Orbitomeatal line (OML)
   2. Infraorbitomeatal line (IOML)
   3. Interpupillary line (IPL)

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

II. Neck

A. Structures
   1. Hyoid bone
   2. Esophagus
   3. Trachea
   4. Glands
   5. Lymph nodes

B. Neurovasculature

C. Musculature

III. Chest and Mediastinum

A. Bony thorax

B. Pulmonary
   1. Lungs

2. Diaphragm
3. Bronchi
4. Pleural lining

C. Mediastinum
1. Thymus gland
2. Heart
3. Vasculature
4. Esophagus
5. Trachea
6. Thoracic duct
7. Lymph nodes

D. Breasts

IV. Abdomen

A. Diaphragm

B. Quadrants and regions
1. Abdominal cavity
a. Peritoneum
b. Peritoneal spaces
c. Retroperitoneum
d. Retroperitoneal spaces

C. Vasculature
1. Abdominal aorta
2. Inferior vena cava
3. Portal venous system

D. Abdominal organs and systems
1. Liver
2. Gallbladder and biliary system
3. Pancreas and pancreatic ducts
4. Spleen
5. Adrenal glands
6. Urinary system and tract
7. Stomach
8. Small intestine
9. Colon

E. Musculature

V. Pelvis

A. Bony structures

B. Vasculature

C. Pelvic organs
   1. Urinary bladder
      a. Ureter
      b. Urethra
   2. Small intestine
   3. Colon
   4. Reproductive organs

VI. Spine

A. Cervical vertebrae

B. Thoracic vertebrae

C. Lumbar vertebrae

D. Sacrum/coccyx

VI. Musculoskeletal System

A. Upper extremities
   1. Shoulder
      a. Bony anatomy
      b. Muscles and tendons
      c. Labrum and ligaments
      d. Vasculature
   2. Elbow
      a. Bony anatomy
      b. Muscles and tendons
      c. Ligaments
      d. Vasculature
   3. Hand and wrist
      a. Bony anatomy
      b. Tendons
      c. Vasculature

B. Lower Extremities
   1. Hip
      a. Bony anatomy
      b. Muscles and tendons
      c. Labrum and ligaments
      d. Vasculature
   2. Knee
      a. Bony anatomy
      b. Muscles and tendons
      c. Menisci and ligaments

    d. Vasculature
3. Foot and ankle
    a. Bony anatomy
    b. Muscles and tendons
    c. Ligaments
    d. Vasculature

Artificial Intelligence

Objectives

- Define terminology associated with artificial intelligence.
- Explain the principles of machine learning, deep learning, natural language processing, and neural networks.
- List applications of AI in health care, medical imaging, and CT specifically.
- Recognize the standards and ethics applicable to artificial intelligence in medical imaging.
- Describe artificial intelligence regulation and workflow integration.

Content

I. Terminology and concepts

A. Algorithm

B. Automation

C. Artificial intelligence (AI)
   1. Artificial narrow intelligence
   2. Artificial general intelligence
   3. Artificial super intelligence

D. AI-enabled

E. AI-bias

F. Machine learning (ML)
   1. Supervised
   2. Unsupervised
   3. Deep learning (DL)

G. Neural network models
   1. Artificial neural networks (ANN)
   2. Convolutional neural networks (CNN)
   3. Recurrent neural networks (RNN)

H. Software as a medical device (SaMD)

I. Recursion

J. Natural language processing (NLP)
    1. Pattern recognition
    2. Visual perception
    3. Decision making

II. Data and Data Sets

III. AI Applications in Healthcare

A. Diagnosis and treatment recommendation

B. Patient engagement

C. Administrative activities

IV. AI Applications in Medical Imaging

A. Order scheduling and patient screening

B. Exam protocoling

C. Image acquisition

D. Image analysis
    1. Automated detection of findings
    2. Automated interpretation of findings

E. Automated clinical decision support (CDS)

V. Additional AI Applications in CT

A. Deep learning image reconstruction

B. Image segmentation

VI. Ethics, Legality and Liability

VII. Regulation and Workflow Integration

VIII. Precision Medicine

Optional Content

I. PET/CT Hybrid Imaging

A. Radiation safety
   1. Handling and disposal of radioisotopes
   2. Contamination and decontamination 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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Appendix

Curriculum Revision Workgroup

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

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