

National Education Curriculum

Specialty Curricula

*Abdomen and Superficial Structures
Including Introductory Pediatric and
Musculoskeletal*

Abdomen and Superficial Structures Including Introductory Pediatric and Musculoskeletal

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Abdomen and Superficial Structures Including Introductory Pediatric and Musculoskeletal

Rationale: The sonographer is required to perform sonographic studies of the abdomen and superficial structures. Thorough knowledge of relational anatomy, physiology, pathophysiology, sonographic technique and appearances is required. The sonographer will determine normal from artifactual or pathologic conditions, modify or extend the scope of the examination as necessary, prioritize differential diagnoses, and complete a technical report.

Section I: Biliary

1. Describe the normal anatomy, function, sonographic technique and appearance of the biliary system
 2. Correlate clinical indications and laboratory values associated with biliary disease
 3. Identify biliary pathology in terms of sonographic appearances, sequelae and associated pathologies
 4. Describe associated pathologies and sequelae relative to biliary disease
 5. Identify normal and abnormal flow characteristics and waveforms
-

I. BILIARY

- A. Embryology
- B. Anatomy
 1. Gallbladder
 - a. Intraperitoneal
 - b. Three segments
 - i) Fundus
 - ii) Body
 - iii) Neck
 - c. Layers
 - i) Epithelial mucosa
 - ii) Muscular
 - iii) Subserous
 - iv) Serosal
 - d. Relational anatomy
 2. Biliary ducts
 - a. Intrahepatic
 - b. Extrahepatic
 - i) Common hepatic duct (CHD)
 - ii) Cystic duct
 - iii) Common bile duct (CBD)
- C. Variants of Normal and Congenital Anomalies
 1. Gallbladder
 - a. Hartman's pouch
 - b. Junctional fold
 - c. Phrygian cap

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- d. Septated
- e. Agenesis
- f. Duplication
- g. Hourglass shape
- h. Intrahepatic
- i. Microgallbladder
- j. Left-sided with situs inversus

D. Function

- 1. Gallbladder
 - a. Concentrates, stores and releases bile upon the digestion of a meal
- 2. Biliary ducts
 - a. Transport bile
- 3. Laboratory values
 - a. White blood count (WBC)
 - b. Serum bilirubin; direct, indirect and total
 - c. Serum alkaline phosphatase (ALP)
 - d. Liver function tests (LFTs)
 - i) Aspartate aminotransferase (AST)
 - ii) Alanine aminotransferase (ALT)
 - iii) Prothrombin time (PT)
 - iv) Lactic acid dehydrogenase (LDH)
 - v) Gamma glutamyl transpeptidase (GGT)

E. Indications for Examination

- 1. Pain
 - a. Right upper quadrant (RUQ) pain, epigastric pain
 - b. Right shoulder pain (with inflammation)
 - c. Post prandial pain
- 2. Positive Murphy's sign
- 3. Nausea
- 4. Vomiting
- 5. Intolerance to fatty foods and dairy products
- 6. Jaundice
- 7. Fever

F. Technique

- 1. Patient preparation
- 2. Transducer selection

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3. Patient positioning
4. Image optimization
5. Examination protocol
6. Examination limitations
- G. Sonographic Findings
 1. Gallbladder
 - a. Anechoic lumen
 - b. Thin (<3 mm), smooth walls
 - c. Pear shape
 2. Biliary ducts
 - a. Measurement
 - i) Location of measurement
 - ii) Anatomic variants of CBD may confuse location of measurement
 - iii) Normal diameters
 - Variation
- H. Pathophysiology
 1. Cholelithiasis
 - a. Definition
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - i) May be asymptomatic
 - ii) Right upper quadrant (RUQ) pain
 - iii) Nausea
 - iv) Vomiting
 - v) Fever
 - e. Sonographic findings
 - i) Highly reflective echogenic focus
 - ii) Acoustic shadow
 - iii) Gravity-dependent gallstone movement with change in body position
 - iv) Floating stones secondary to an increase in the specific gravity/viscosity of the bile
 - v) May demonstrate twinkle artifact on color Doppler
 - f. Correlative and/or prior imaging
 - g. Treatment
 2. Mirizzi syndrome

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- a. Definition
 - i) Impacted stone in cystic duct, cystic duct remnant, or gallbladder neck
 - ii) Partial mechanical obstruction of the CHD by compression of inflammatory reaction around the impacted stone
 - iii) Sequelae of jaundice, recurrent cholangitis, formation of biliary fistulas, or cholangitis cirrhosis
 - b. Incidence
 - i) Rare
 - c. Risk factors
 - d. Clinical presentation
 - e. Sonographic findings
 - i) 2-D
 - Dilated intrahepatic bile ducts
 - Normal or mildly dilated common bile duct
 - ii) Doppler for vessel differentiation
 - f. Correlative and/or prior imaging
 - i) Magnetic resonance cholangiopancreatography (MRCP) or computed tomography (CT) may be warranted for better delineation of the biliary anatomy and to confirm the diagnosis
 - g. Treatment
3. Contracted or non-visualization of gallbladder
 - a. Definition
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - e. Sonographic findings
 - i) Dependent on etiology
 - The “double arc” sign, or “WES” sign (W=wall, E=Echo [stone], S=Shadow)
 - f. Correlative and/or prior imaging
 - g. Treatment
 4. Sludge
 - a. Definition
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - e. Sonographic findings

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- i) Gravity-dependent, non-shadowing echoes
 - ii) Fluid-fluid level
 - iii) Gallbladder isoechoic with liver when sludge fills gallbladder lumen
 - iv) Atypical appearances
 - Polypoid mass or pseudotumor
 - Sludge balls
 - v) Correlative and/or prior imaging
 - vi) Treatment
- 5. Acute cholecystitis
 - a. Definition
 - i) Acute or chronic inflammation of the gallbladder
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - i) RUQ pain radiating to the shoulder
 - ii) Biliary colic
 - iii) Palpable RUQ mass
 - iv) Tender right subcostal region
 - v) Fever
 - vi) Nausea
 - vii) Vomiting
 - e. Laboratory findings
 - i) Mild elevation of serum bilirubin
 - ii) Elevated aspartate aminotransferase (AST)
 - iii) Elevated alanine aminotransferase (ALT)
 - iv) Elevated alkaline phosphatase (ALP)
 - v) Elevated WBC and C-reactive protein (CRP)
 - f. Sonographic findings
 - i) 2-D
 - Cholelithiasis
 - Diffuse gallbladder wall thickening
 - “Halo-sign” suggesting subserosal edema
 - Distended gallbladder
 - Positive sonographic Murphy’s sign
 - Sludge may be present

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- Pericholecystic fluid
 - Peritonitis
 - ii) Doppler
 - Cystic artery and gallbladder wall flow
 - g. Complications
 - i) Empyema
 - ii) Emphysematous cholecystitis
 - iii) Gangrenous cholecystitis
 - iv) Perforation of the gallbladder
 - v) Pericholecystic fluid
 - vi) Ascending cholangitis
 - vii) Liver abscess
 - viii) Septicemia
 - ix) Bouveret syndrome
 - h. Correlative and/or prior imaging
 - i. Treatment
- 6. Acalculous cholecystitis
 - a. Definition
 - i) Inflammation of the gallbladder in the absence of cholelithiasis
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - e. Sonographic findings
 - i) Distended gallbladder
 - ii) Wall thickening
 - iii) Sludge
 - iv) Pericholecystic fluid and/or edema
 - f. Correlative and/or prior imaging
 - g. Treatment
- 7. Chronic cholecystitis
 - a. Definition
 - i) Recurrent inflammatory changes in gallbladder secondary to infection, obstruction, or metabolic disorders
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation

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- i) Intermittent RUQ and epigastric pain; may radiate to scapula
 - ii) Intolerance to fatty and fried foods
 - iii) Intermittent nausea and vomiting
 - e. Laboratory findings
 - i) Elevated aspartate aminotransferase (AST)
 - ii) Elevated alanine aminotransferase (ALT)
 - iii) Elevated alkaline phosphatase (ALP)
 - iv) Elevated white blood count
 - f. Sonographic findings
 - i) Contracted gallbladder with acoustic shadowing from cholelithiasis
 - ii) Thick, echogenic gallbladder wall
 - iii) Sludge may be present
 - iv) Non-contraction or decreased response to cholecystokinin
 - g. Correlative and/or prior imaging
 - h. Treatment
- 8. Complications of surgical treatment of cholecystitis
 - a. Laparoscopic versus open treatment
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - i) Fever
 - ii) New or increasing abdominal pain
 - iii) Increased bile drainage
 - iv) Decreasing hematocrit
 - e. Sonographic findings
 - i) Bile leak, biloma, choleperitoneum
 - ii) Subhepatic abscess
 - iii) Hemorrhage
 - iv) Retained stone
 - f. Correlative imaging
 - g. Treatment
- 9. Hydrops of the gallbladder (mucocele)
 - a. Definition
 - i) Abnormal accumulation of fluid within gallbladder
 - b. Incidence
 - c. Risk factors

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- d. Clinical presentation
 - i) Asymptomatic
 - ii) Palpable RUQ mass
 - iii) Epigastric pain
 - iv) Nausea
 - v) Vomiting
 - e. Sonographic findings
 - i) Markedly dilated gallbladder
 - ii) Thin gallbladder wall
 - iii) Possible stone in gallbladder neck or cystic duct
 - f. Correlative and/or prior imaging
 - g. Treatment
10. Courvoisier's gallbladder
- a. Definition
 - i) Prolonged complete obstruction of the distal bile duct
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - i) Possibly asymptomatic
 - ii) Palpable RUQ mass
 - iii) Painless jaundice
 - e. Sonographic findings
 - i) Markedly dilated gallbladder
 - ii) Thin walls
 - f. Correlative and/or prior imaging
 - g. Treatment
11. Porcelain gallbladder
- a. Definition
 - i) Rare manifestation of chronic cholecystitis
 - ii) Calcification of gallbladder wall
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - i) Stones
 - ii) Female predominance
 - iii) Associated with increased incidence of gallbladder carcinoma

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- e. Sonographic findings
 - i) Hyperechoic semilunar structure with posterior acoustic shadow
 - ii) May simulate stone-filled gallbladder devoid of bile
 - iii) Produces biconvex, curvilinear, echogenic structure with variable acoustic shadowing
 - f. Correlative and/or prior imaging
 - g. Treatment
12. Benign neoplasms
- a. Adenoma
 - i) Definition
 - Benign epithelial tumor
 - ii) Incidence
 - iii) Clinical presentation
 - Asymptomatic
 - iv) Sonographic findings
 - Polypoid, soft-tissue masses pedunculated from the gallbladder wall protruding into the gallbladder lumen
 - Typically small
 - No acoustic shadow
 - Not gravity dependent
 - Typical location is near the fundus of the gallbladder
 - Doppler for any flow in stalk or mass
 - v) Correlative and/or prior imaging
 - vi) Treatment
 - b. Adenomyomatosis
 - i) Definition
 - A form of hyperplastic cholecystosis
 - Proliferation of the surface epithelium of the gallbladder wall with gland-like formation and diverticula of mucosa into or through a thickened muscular layer
 - ii) Incidence
 - iii) Clinical presentation
 - iv) Sonographic findings
 - Diffuse or segmental thickening of the gallbladder wall
 - Intraluminal diverticula
 - Cholesterol stones/crystals lodged between diverticula (Rokitansky-Aschoff sinuses)

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- Comet-tail artifact
 - Twinkle artifact on color Doppler
 - v) Correlative and/or prior imaging
 - vi) Treatment
 - c. Cholesterolosis
 - i) Definition
 - A form of hyperplastic cholecystosis
 - Types
 - Cholesterolosis (strawberry gallbladder)
 - Cholesterol polyps
 - ii) Incidence
 - iii) Risk factors
 - iv) Clinical presentation
 - v) Sonographic findings
 - Non-shadowing single or multiple fixed small echo dense masses projecting into the lumen of the gallbladder
13. Malignant neoplasms
- a. Primary gallbladder carcinoma
 - i) Definition
 - ii) Incidence
 - iii) Risk factors
 - iv) Clinical presentation
 - May be asymptomatic
 - Loss of appetite, anorexia
 - Unintended weight loss
 - Nausea
 - Vomiting
 - Intolerance to fatty foods
 - Belching
 - Jaundice may be present in the later stage
 - RUQ mass and pain
 - v) Laboratory findings
 - vi) Sonographic findings
 - Wall thickening; focal or diffuse
 - Intraluminal mass

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- Tumor extension to liver
 - Regional lymphadenopathy
 - Ascites
 - Spectral, color, and power Doppler may be useful for determining evidence of arterial and/or venous flow within the specific area
 - vii) Correlative and/or prior imaging
 - viii) Treatment
 - b. Metastatic disease to the gallbladder
 - i) Definition
 - ii) Incidence
 - iii) Risk factors
 - iv) Clinical presentation
 - v) Sonographic findings
 - Focal thickening of the gallbladder wall
 - Intraluminal mass without shadowing
 - Polypoid or irregular intraluminal mass
 - Indistinct walls
 - Spectral, color, and power Doppler may be useful for determining evidence of arterial and/or venous flow within the specific area
 - vi) Correlative and/or prior imaging
 - vii) Treatment
14. Non-inflammatory causes of gallbladder wall thickening
- a. Definition
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - e. Sonographic findings
 - i) Diffuse thickening
 - Hypoalbuminemia – hypoproteinemia
 - Ascites
 - Acute hepatitis
 - Congestive heart failure
 - Renal disease
 - AIDS
 - Pancreatitis
 - Cirrhosis

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- Portal node lymphatic obstruction
- Sepsis
- ii) Focal thickening
 - Adenomyomatosis
 - Adenomatous polyp
 - Cholesterol polyp
 - Papillary adenomas
 - Gallbladder carcinoma
 - Metastatic wall masses

I. Bile Ducts Pathophysiology

1. Ductal dilatation

- a. Definition
 - i) Extrahepatic
 - ii) Intrahepatic
- b. Incidence
- c. Risk factors
- d. Clinical presentation
 - i) Jaundice
 - ii) Elevated LFT's
- e. Sonographic findings
 - i) 2-D
 - Dilated CBD
 - Dilated CHD
 - “Parallel channel sign” or “double channel sign”
 - Intrahepatic anechoic tubular structure(s) with stellate branching pattern
 - Acoustic enhancement posterior to dilated ducts
 - ii) Doppler
 - Identification of vessel versus duct
- f. Correlative and/or prior imaging
- g. Treatment

2. Choledocholithiasis

- a. Definition
 - i) Bile duct stone(s)
- b. Incidence
- c. Risk factors

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- d. Clinical presentation
 - i) RUQ and/or epigastric pain
 - ii) Jaundice
 - e. Sonographic findings
 - i) Dilated duct proximal to obstruction
 - ii) Dilated gallbladder
 - iii) Intraductal hyperechoic focus with posterior shadowing
 - iv) Hydropic gallbladder
 - f. Correlative and/or prior imaging
 - g. Treatment
3. Cholangitis
- a. Definition
 - i) Inflammation of bile ducts
 - b. Types
 - i) Acute bacterial
 - ii) Recurrent pyogenic
 - iii) AIDS
 - iv) Sclerosing
 - Primary
 - Secondary
 - c. Incidence
 - d. Risk factors
 - e. Clinical presentation
 - i) Classic: fever, RUQ pain, jaundice (Charcot triad)
 - f. Laboratory values
 - i) Elevated bilirubin
 - ii) Elevated ALP
 - iii) Elevated AST
 - iv) Elevated ALT
 - v) Elevated WBC
 - g. Sonographic findings
 - i) Dilated ducts
 - ii) Focal strictures
 - iii) Thickened duct walls
 - iv) Brightly echogenic portal triad
 - v) Intraductal sludge

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- vi) Intrahepatic ductal stones - may not shadow
 - vii) Hydropic gallbladder in 30% of cases
 - viii) Pneumobilia
 - ix) Hepatic abscess
 - x) Portal hypertension
 - xi) Doppler may detect hyperemia around bile ducts
- h. Correlative and/or prior imaging
- i. Treatment
- 4. Ascariasis
 - a. Definition
 - i) Infection by roundworm ascariasis lumbricoides
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - i) Usually asymptomatic
 - ii) Biliary colic
 - iii) Cholangitis
 - iv) Acalculous cholecystitis
 - e. Sonographic findings
 - i) Intraductal parallel echogenic lines
 - ii) Worms visualized in any portion of the biliary system
 - f. Correlative and/or prior imaging
 - g. Treatment
- 5. Hemobilia
 - a. Definition
 - i) Blood within the biliary tree
 - b. Incidence
 - c. Risk factors
 - i) Interventional procedures
 - ii) Infection
 - iii) Vascular malformation
 - iv) Trauma
 - v) Malignancy
 - d. Clinical presentation
 - e. Sonographic findings
 - i) Fluid - low level echoes, gravity dependent, layering

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- ii) Clot - varying echogenicity, mobile
 - f. Correlative and/or prior imaging
 - g. Treatment
- 6. Pneumobilia
 - a. Definition
 - i) Air (gas) within biliary tree
 - b. Incidence
 - c. Risk factors
 - i) Biliary intervention
 - ii) Emphysematous cholecystitis
 - iii) Biliary/GI tract fistula
 - d. Clinical presentation
 - e. Sonographic findings
 - i) Non-dependent, hyperechoic linear structures within biliary tree
 - ii) Dirty shadowing and ring-down artifact
 - iii) Changing the patient position may result in the movement of bubbles
 - f. Correlative and/or prior imaging
 - g. Treatment
- 7. Malignant neoplasia
 - a. Cholangiocarcinoma
 - i) Definition
 - Uncommon neoplasm, typically adenocarcinoma arising from the epithelium of the bile ducts
 - b. Incidence
 - c. Risk factors
 - i) Biliary stones
 - ii) Chronic inflammation
 - iii) Caroli's disease
 - iv) Choledochal cysts
 - v) Pancreatitis
 - d. Types - defined by location
 - i) Intrahepatic
 - Arise within hepatic parenchyma
 - ii) Hilar (Klatskin's)
 - Located at porta hepatis
 - iii) Distal

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- Arising in distal extrahepatic ducts
- e. Clinical presentation
 - i) Pruritus
 - ii) Jaundice
 - iii) Weight loss; anorexia
 - iv) Fatigue
 - v) RUQ pain
 - vi) Biliary colic
 - vii) Palpable mass
- f. Laboratory findings
 - i) Elevated alkaline phosphatase (ALP)
 - ii) Elevated gamma-glutamyl transferase (GGT)
 - iii) Elevated bilirubin – total and direct
- g. Tumor markers
 - i) Carbohydrate antigen 19-9 (CA 19-9)
 - ii) Carcinoembryonic antigen (CEA)
- h. Sonographic findings
 - i) Biliary dilation (without sonographic evidence of obstruction)
 - ii) Non-union of the right and left biliary ducts
 - iii) Intraductal polypoid mass
 - iv) Irregular soft tissue mass
 - v) Soft tissue extension into ducts
 - vi) Tumor extension to adjacent vasculature
 - vii) Nodal extension to porta hepatis and preaortic regions
- i. Correlative and/or prior imaging
- j. Treatment
- 8. Metastases
 - a. Definition
 - b. Risk factors
 - c. Incidence
 - d. Clinical presentation
 - e. Sonographic findings
 - f. Correlative and/or prior imaging
 - g. Treatment

J. Congenital Abnormalities of Biliary System

1. Biliary atresia

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- a. Definition
 - i) Congenital obliteration of one or more components of the bile ducts
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - i) Dependent on the extent of the atresia
 - ii) Persistent jaundice
 - iii) Portal hypertension
 - iv) Cirrhosis
 - v) Hepatic failure
 - e. Sonographic findings
 - i) 2-D – differentiating biliary atresia from neonatal hepatitis is critical
 - Biliary duct dilation is not present
 - Small gallbladder or non-visualization of the gallbladder
 - May have a portal cyst
 - Variable depending on disease stage
 - Portal hypertension
 - “Triangular Cord” sign
 - ii) Doppler
 - Portal hypertension findings
 - f. Correlative and/or prior imaging
 - g. Treatment
2. Caroli’s disease
 - a. Definition
 - i) Congenital intrahepatic biliary duct dilation
 - b. Risk factors
 - c. Incidence
 - d. Clinical presentation
 - i) Pain
 - ii) Fever
 - iii) Intermittent jaundice
 - e. Sonographic findings
 - i) 2-D
 - Multiple cystic structures in the liver that communicate with the biliary tree
 - Calculi or sludge may be present

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- ii) Doppler
 - Absence of spectral Doppler or color flow in dilated structures
 - Central dot sign: small portal venous branches surrounded by dilated ducts
- 3. Choledochal cyst
 - a. Definition
 - i) Congenital cystic dilation of the extrahepatic bile ducts
 - b. Incidence
 - c. Risk factors
 - d. Types are classified based on their location and morphology
 - i) Type I: Fusiform dilation of the common bile duct (most common).
 - ii) Type II: Diverticulum protruding from the common bile duct
 - iii) Type III: Cystic dilation of the distal common bile duct within the duodenal wall (choledochocele)
 - iv) Type IV: Multiple cystic dilations of the intrahepatic and extrahepatic bile ducts
 - v) Type V: Cystic dilation of the intrahepatic bile ducts (Caroli's disease)
 - e. Clinical presentation
 - i) Congenital dilation of common bile duct
 - ii) Failure to thrive
 - iii) Combination of pain, intermittent jaundice, and palpable mass
 - iv) Fever
 - f. Sonographic findings
 - i) 2-D
 - Large, cystic mass in the porta hepatis separate from gallbladder
 - Dilated CHD or CBD entering a cystic mass
 - Intrahepatic bile duct dilatation
 - Possible calculi
 - ii) Doppler
 - Absence of spectral Doppler or color flow in dilated structures
 - g. Correlative and/or prior imaging
 - h. Treatment

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Section II: Liver

1. Describe the normal anatomy and variants, function, sonographic technique and normal sonographic appearances of the liver
 2. Evaluate the clinical indication(s) of the study and laboratory values associated with the liver pathology
 3. Discuss the sonographic appearances of the various liver pathologies
 4. Differentiate liver neoplasia based on their contrast enhanced ultrasound appearance
 5. Describe the performance and evaluation of shear wave elastography (SWE) of the liver for evaluation of liver fibrosis
 6. Describe the complications of different liver pathologies and their sonographic appearance.
 7. Differentiate normal and abnormal flow characteristics and waveforms in the portal and hepatic venous systems and hepatic arterial system
-

II. LIVER

- A. Embryology
- B. Anatomy
 1. Micro
 - a. Lobule
 2. Macro
 - a. Peritoneal
 - i) Exception: bare area
 - b. Glisson's capsule
 - c. Right upper quadrant (RUQ)
 - d. Right and left hemiliver and sections
 - e. Lobes and segments
 - i) Right
 - Anterior
 - Posterior
 - ii) Left
 - Medial
 - Lateral
 - iii) Caudate
 - Caudate process
 - Papillary process
 - f. Couinaud's segmental anatomy
 - i) Segment I: caudate
 - ii) Segment II: lateral segment of left lobe (superior)
 - iii) Segment III: lateral segment of left lobe (inferior)
 - iv) Segment IV: medial segment of the left lobe (quadrate)

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- v) Segment V: anterior segment of the right lobe (inferior)
- vi) Segment VI: posterior segment of the right lobe (inferior)
- vii) Segment VII: posterior segment of the right lobe (superior)
- viii) Segment VIII: anterior segment of the right lobe (superior)
- g. Fissures
 - i) Main lobar/interlobar fissure
 - ii) Right intersegmental
 - iii) Left intersegmental
 - iv) Fissure for ligamentum venosum
- h. Ligaments
 - i) Coronary
 - ii) Falciform
 - iii) Gastrohepatic
 - iv) Hepatoduodenal
 - v) Left triangular (lateral)
 - vi) Right triangular (lateral)
 - vii) Round (ligamentum teres)
- i. Vasculature
 - i) Hepatic artery
 - Common
 - Proper
 - Right
 - Left
 - ii) Hepatic veins
 - Left
 - Middle
 - Right
 - iii) Portal veins
 - Main
 - Left
 - Right
 - Branches and tributaries
 - Collateral pathways
 - iv) Normal variants
- j. Relational anatomy

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- C. Variants
 - 1. Riedel's lobe
 - 2. Situs inversus
 - 3. Diaphragmatic indentations (pseudofissures)
- D. Functions
 - 1. Formation of bile
 - 2. Activity of reticuloendothelial tissues
 - 3. Metabolism
 - 4. Storage
 - 5. Blood reservoir
 - 6. Heat production
 - 7. Detoxification
- E. Laboratory Values for Liver Function (LFTs)
 - 1. Aspartate aminotransferase (AST)
 - 2. Alanine aminotransferase (ALT)
 - 3. Bilirubin
 - a. Direct (conjugated)
 - b. Indirect (unconjugated/free)
 - 4. Serum protein
 - 5. Alkaline phosphatase (ALP)
 - 6. Lactic dehydrogenase (LDH)
 - 7. Prothrombin time (PT)
 - 8. Alpha-fetal protein (AFP)
- F. Indications for Examination
 - 1. Suspicion for stenosis, thrombosis of the hepatic vasculature
 - 2. Screening (chronic hepatitis/cirrhosis) for hepatocellular carcinoma
 - 3. Fatigue and weakness
 - 4. Abdominal discomfort
 - 5. Fever
 - 6. Abnormal (LFTs)
 - 7. Jaundice
 - 8. Hepatomegaly
 - 9. Others
- G. Technique
 - 1. Patient preparation
 - 2. Transducer selection

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3. Patient positioning
4. Image optimization
5. Image protocol
- H. Normal Sonographic Findings
 1. 2-D
 - a. Homogeneous
 - b. Isoechoic or hyperechoic to renal parenchyma
 - c. Smooth contour
 2. Doppler
 - a. Portal veins (hepatopetal, monophasic, no significant pulsatility)
 - b. Hepatic veins (pulsatile)
 - c. Hepatic arteries (low resistance forward flow)
 3. Contrast-enhanced ultrasound (CEUS)
 - a. Liver phases
 - i) Arterial
 - ii) Portal venous
 - iii) Late
 - b. Terminology
 - i) Enhancement pattern relative to liver parenchyma
 - Hyper-enhanced, hypo-enhanced, iso-enhanced, heterogeneous
 - Peripheral nodular enhancement, rim-like enhancement
 - Centrifugal and centripetal enhancement pattern
 - Wash-in, wash-out
 - c. CEUS LI-RADS
 - d. ACR Appropriateness Criteria
 - i) Indeterminate liver masses
- I. Pathophysiology
 1. Diffuse disease
 - a. Fatty infiltration
 - i) Definition
 - Acquired, reversible condition resulting in accumulation/deposition of fatty triglycerides within liver cells
 - ii) Risk factors
 - iii) Clinical presentation
 - Asymptomatic
 - Hepatomegaly

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- RUQ discomfort or pain
 - Fatigue
 - Nausea or a loss of appetite
 - iv) Sonographic findings
 - Normal size or hepatomegaly
 - Diffuse or focal increase in liver parenchymal echogenicity
 - Focal sparing
 - Impaired visualization of hepatic vessels
 - v) Correlative and/or prior imaging to assess the extent of fat infiltration
 - CT
 - MRI
- b. Hepatitis
- i) Definition
 - Inflammation of the liver
 - ii) Types
 - Hepatitis A
 - Hepatitis B
 - Hepatitis C
 - iii) Clinical presentation
 - Acute
 - Elevated LFTs
 - Jaundice
 - Hepatomegaly
 - Right upper quadrant pain
 - Nausea and vomiting
 - Fever
 - Other
 - Chronic
 - Variable and dependent on length and severity
 - iv) Sonographic findings
 - Acute hepatitis
 - 2-D
 - Normal
 - Decrease in liver echogenicity

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- Portal vein (PV) walls may appear more echogenic relative to the liver parenchyma, “starry sky” appearance
 - Hepatomegaly
 - Associated gallbladder wall thickening
 - Chronic hepatitis
 - 2-D
 - Increased liver echogenicity may be present
 - Coarse echotexture
 - Decreased echogenicity of portal vein walls
 - Portal hypertension and sequelae
 - Associated findings of cirrhosis
 - Doppler
 - Portal hypertension and sequelae
 - v) Correlative and/or prior imaging
 - vi) Treatment
- c. Cirrhosis
- i) Definition
 - Irreversible and often progressive fibrosis, scarring, parenchymal necrosis, and nodular regeneration
 - ii) Laboratory values – elevated LFTs
 - iii) Clinical presentation
 - Early signs
 - Fatigue
 - Weakness
 - Loss of appetite
 - Nausea/vomiting
 - Weight loss
 - Abdominal distension
 - Later signs
 - Jaundice
 - Coagulopathy
 - Hypoalbuminemia
 - Encephalopathy
 - iv) Sonographic findings
 - Early stage
 - Hepatomegaly

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- Fatty infiltration may be present
 - Surface undulations and development of macronodularity
 - Later stage
 - Smaller heterogeneous liver (anterior right and medial left sections)
 - Relative caudate lobe enlargement with possible IVC compression
 - Coarse liver texture with surface nodularity
 - Portal hypertension and sequelae
 - Ascites
 - Increased risk hepatocellular carcinoma (HCC)
 - Doppler findings
 - Portal Vein
 - Decreased or hepatofugal flow
 - Dilated portal vein
 - Slow flow velocity
 - Collateral vessels
 - Esophageal varices
 - Splenorenal shunts
 - Caput medusa
 - v) Correlative and/or prior imaging
 - Shear wave elastography (SWE) of the liver to evaluate for fibrosis
 - vi) Treatment
- d. Hemochromatosis
- i) Definition
 - Inherited condition of excessive storage of iron in organs
 - ii) Clinical presentation
 - Fatigue
 - Joint pain
 - Abdominal pain
 - Hepatomegaly
 - iii) Sonographic findings
 - Increased echogenicity of the liver
 - Decreased echogenicity of the vascular walls
 - iv) Correlating and/or prior imaging
 - v) Treatment
2. Vascular abnormalities

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- a. Hepatic artery aneurysm
 - i) Definition
 - Focal dilation of the common hepatic artery
 - ii) Clinical presentation
 - Epigastric pain
 - Hematemesis
 - iii) Sonographic findings
 - 2-D and Doppler
 - Focal dilation of hepatic artery
 - Turbulent flow seen with color and spectral Doppler
 - iv) Correlative and/or prior imaging
 - Angiography
 - CTA
 - v) Treatment
 - Embolization
- b. Portal hypertension (PH)
 - i) Definition
 - Increased pressure within the portal venous system
 - ii) Types
 - Prehepatic portal hypertension – obstruction or increased resistance to blood flow in the portal vein before it reaches the liver
 - Intrahepatic portal hypertension – increased resistance to blood flow with the liver itself, most common type
 - Presinusoidal
 - Sinusoidal
 - Postsinusoidal
 - Posthepatic portal hypertension – obstruction to blood flow after it leaves the liver
 - iii) Clinical presentation
 - iv) Sonographic findings
 - 2-D
 - Portal vein may be dilated
 - Cavernous transformation of the portal vein
 - Ascites
 - May have splenomegaly
 - Splenic varices

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- Doppler
 - Hepatopetal or slow hepatofugal flow
 - Low velocity continuous flow
 - Bidirectional flow
 - Recanalized umbilical vein
- Correlative and/or prior imaging
- Treatment
 - Transjugular intrahepatic portosystemic shunt (TIPS)
- Sonographic findings post-TIPS
 - 2-D
 - Echogenic stent - most commonly placed between the right portal vein and right hepatic vein
 - Doppler
 - Patency of the shunt without signs of stenosis or obstruction
 - Hepatofugal flow in the shunt
 - Normal shunt velocity (90-190 cm/sec)
 - Reduced or reversed portal vein flow
 - Normal hepatic vein flow
- c. Portal vein thrombosis
 - i) Definition
 - Narrowing or complete occlusion by a blood clot
 - ii) Clinical presentation
 - Asymptomatic
 - Abdomen pain
 - Fever
 - Ascites
 - iii) Risk factors
 - History of cirrhosis
 - Blood clotting disorders
 - iv) Sonographic findings
 - 2-D and Doppler
 - Low-level echoes within PV
 - Cavernosa transformation
 - Splenomegaly
 - Decreased or absent color and spectral Doppler
 - v) Correlative and/or prior imaging

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- vi) Treatment
 - Anticoagulation
 - Thrombolysis
 - Thrombectomy
- d. Portal vein varix
 - i) Definition
 - Focal dilation of the portal vein
 - ii) Clinical presentation
 - Asymptomatic
 - Non-specific abdominal pain
 - Can be congenital or acquired
 - iii) Sonographic findings
 - 2-D and Doppler
 - Focal portal vein diameter greater than 20 mm
 - Color Doppler helical flow
 - iv) Correlative and/or prior imaging
 - v) Treatment
- e. Budd-Chiari syndrome
 - i) Definition
 - Obstruction of hepatic vein(s) outflow
 - May or may not involve IVC
 - Etiology (primary or secondary)
 - Congenital
 - Obstructing membranes, webs
 - Tumor extension from primary hepatic carcinoma
 - Polycythemia vera
 - ii) Clinical presentation
 - Right upper quadrant pain
 - Ascites
 - Hepatomegaly
 - iii) Sonographic findings
 - 2-D
 - Enlarged caudate lobe
 - Hepatic veins small in diameter or may not be visible
 - Hepatic vein intraluminal echoes

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- Collateral vessels
 - Doppler
 - Lack of flow in one or more hepatic veins
 - Normal direction of flow should be hepatofugal
 - Normal IVC flow is phasic
- 3. Glycogen storage disease (GSD)
 - a. Definition
 - b. Types
 - i) Type 1, Von Gierke's disease is the most common type
 - Typically affects the liver
 - ii) Type 2, Pompe disease
 - Typically affects skeletal muscle and heart
 - c. Clinical presentation
 - d. Sonographic findings
 - e. Correlative and/or prior imaging
 - f. Treatment
- 4. Focal versus diffuse liver disease
 - a. Definitions and distinctions
 - b. Focal lesions
 - i) Cysts
 - ii) Hemangiomas
 - iii) Hepatocellular carcinoma
 - iv) Abscess
 - c. Diffuse processes
 - i) Steatosis
 - ii) Cirrhosis
 - d. Sonographic findings
 - i) Intrahepatic versus extrahepatic
- 5. Cysts
 - a. Definition
 - i) Fluid-filled mass with epithelial lining
 - b. True liver cysts versus acquired
 - c. Autosomal dominant polycystic liver disease
 - d. Clinical presentation
 - i) Often asymptomatic
 - e. Sonographic findings

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- i) Anechoic
 - ii) Well-defined or well circumscribed
 - iii) Posterior acoustic enhancement
 - iv) Correlative and/or prior imaging
 - f. Treatment
 - J. Infections
 - 1. Pyogenic (bacterial) abscess
 - a. Definition
 - i) Localized collection of pus
 - b. Clinical presentation
 - i) Fever (varied)
 - ii) Pain
 - iii) Pleuritic pain
 - iv) Nausea
 - v) Vomiting
 - vi) Diarrhea
 - vii) Leukocytosis
 - viii) Elevated (LFTs)
 - ix) Anemia
 - x) Other
 - c. Sonographic findings
 - i) Commonly located in the right lobe
 - ii) Typically, solitary
 - iii) Typical round or ovoid shape
 - iv) Irregular, poorly defined walls
 - v) Variable echogenicity, may appear solid
 - vi) Possible acoustic enhancement
 - vii) Microbubbles, air
 - viii) Calcification, if healed
 - d. Contrast Enhanced Ultrasound (CEUS)
 - i) Enhancement pattern: Heterogeneous or rim enhancement in the arterial phase followed by rapid washout in the portal phase. Frequent internal, non-enhancing liquefied areas.
 - e. Correlative and/or prior imaging
 - f. Treatment
 - i) Aspiration to determine organisms responsible for abscess

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- ii) Drainage
 - iii) Antibiotics
- 2. Amebic (parasitic) abscess
 - a. Definition
 - i) Localized cavity caused by parasite *entamoeba histolytica*
 - b. Clinical presentation
 - i) Abdominal pain
 - ii) Diarrhea
 - iii) Leukocytosis
 - iv) Fever
 - v) Nausea and vomiting
 - vi) Typically, abnormal LFTs
 - c. Sonographic findings
 - i) Echogenicity varies over time
 - ii) Typical peripheral location contiguous with liver capsule
 - iii) Lack of significant wall echoes
 - iv) Round or oval configuration
 - v) Distal acoustic enhancement
 - d. Correlative and/or prior imaging
- 3. Fungal infection
 - a. Definition
 - i) Candidiasis (*candida albicans*)
 - b. Clinical presentation
 - i) Increased risk for immunocompromised patients
 - ii) Fever and chills
 - iii) Abdominal pain
 - iv) Nausea and vomiting
 - v) Elevated LFT's
 - vi) Positive blood cultures - *candida* species identified in blood cultures, confirming systemic infection.
 - c. Sonographic findings
 - i) Possible hepatomegaly
 - ii) "Wheel within a wheel" type lesions early
 - iii) Multiple "bull's-eye" target lesions
 - iv) Uniform hypoechoic lesions
 - v) Echogenic foci with variable posterior acoustic shadowing in late-stage

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- d. Correlative and/or prior imaging
- e. Treatment
- 4. Schistosomiasis
 - a. Definition
 - i) Granulomatous portal vein reaction to parasitic invasion
 - ii) Common parasitic infection associated with contaminated water
 - b. Clinical presentation
 - i) Pain
 - ii) Fever
 - iii) Abnormal WBC and LFT laboratory values
 - iv) Presinusoidal portal hypertension
 - c. Sonographic findings
 - i) 2-D
 - Enlarged portal vein tracts with echogenic lumen
 - Hepatomegaly in acute phase
 - Decreased size of liver with progression
 - ii) Doppler
 - Evaluate for patency of portal vein
 - d. Correlative and/or prior imaging
 - e. Treatment
- 5. Echinococcal cyst
 - a. Definition
 - i) Hydatid disease
 - ii) Parasitic infection
 - b. Clinical presentation
 - i) Abdominal pain
 - ii) Fever
 - iii) WBC and LFT
 - c. Sonographic findings
 - i) Variable in appearance
 - Simple cyst(s) with fine textured particles within
 - Floating membranes, water lily sign
 - Cysts with daughter cyst appearance
 - Densely calcified mass
 - d. Correlative and/or prior imaging

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- e. Treatment
- K. Benign Neoplasms
 - 1. Adenoma
 - a. Definition
 - i) Benign neoplasm of normal or slightly atypical hepatocytes frequently containing areas of bile stasis and focal hemorrhage or necrosis
 - b. Incidence
 - i) Less common
 - c. Risk factors
 - i) Oral contraceptives
 - ii) Anabolic steroids
 - iii) Associated with type I glycogen storage disease
 - d. Clinical presentation
 - i) Asymptomatic
 - ii) Palpable mass
 - iii) Severe right upper quadrant pain with bleeding or infarct within lesion
 - iv) Shock due to rupture of lesion and hemoperitoneum
 - e. Sonographic findings
 - i) 2-D
 - Mass of variable echogenicity
 - Similar to focal nodular hyperplasia, heterogeneous if intratumoral bleeding
 - Usually seen in right lobe
 - ii) Doppler
 - Peritumoral flow
 - Intratumoral flow
 - iii) Contrast enhanced ultrasound
 - Enhancement pattern: heterogeneous, typically originating from the periphery towards the center in the arterial phase, no wash-out
 - d. Correlative and/or prior imaging
 - e. Treatment
 - 2. Cavernous hemangioma
 - a. Definition
 - i) Congenital vascular malformation consists of a large network of vascular spaces
 - b. Incidence
 - i) Most common benign tumor of liver, may be multiple
 - c. Risk factor

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- i) Female predominance
 - d. Clinical presentation
 - i) Usually asymptomatic
 - ii) Large lesions can be associated with hemorrhage
 - e. Sonographic findings
 - i) Usually round, echogenic, homogeneous, well defined
 - ii) Larger lesions may be more complex
 - iii) More common in right lobe
 - iv) Usually solitary
 - v) May demonstrate acoustic enhancement
 - f. Contrast enhanced ultrasound
 - i) Enhancement pattern: peripheral discontinuous globular arterial phase hyperenhancement with progressive filling, no washout
 - g. Correlative and/or prior imaging
 - h. Treatment
- 3. Focal nodular hyperplasia (FNH)
 - a. Definition
 - i) Benign neoplasm composed of abnormally arranged hepatocytes, Kupffer cells, bile duct elements, and fibrous connective tissue
 - b. Incidence
 - i) Rare
 - ii) Female predominance
 - iii) Less than 40 years of age
 - c. Clinical presentation
 - i) Usually asymptomatic
 - d. Sonographic findings
 - i) 2-D
 - Variable echogenicity, homogeneous
 - Isoechoic most common
 - Prevalence to right lobe
 - ii) Doppler
 - Hypervascular with a stellate arterial pattern
 - iii) Contrast enhanced ultrasound
 - Enhancement pattern: Large feeding vessel with rapid contrast propagation from the center to periphery of the lesion, commonly spoke-wheel pattern, lesion typically remains hyper-enhanced in portal phase with no washout
 - e. Correlative and/or prior imaging

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- f. Treatment
- 4. Infantile (hepatic) hemangioma, previously hemangioendothelioma
 - a. Definition
 - i) Benign vascular liver tumor
 - b. Incidence
 - i) Most common benign primary liver tumor in infancy
 - c. Risk factors
 - d. Clinical presentation
 - i) Hepatomegaly
 - ii) Congestive heart failure
 - iii) Cutaneous infantile hemangiomas
 - e. Sonographic findings
 - i) 2-D
 - Variable echogenicity
 - Solitary large heterogeneous or multiple small homogeneous lesions
 - Hepatomegaly
 - ii) Doppler
 - Increased flow in mass
 - f. Correlative and/or prior imaging
 - g. Treatment
 - i) May regress spontaneously
- L. Malignant Neoplasms
 - 1. Hepatoblastoma
 - a. Definition
 - i) Malignant tumor of embryonal origin
 - b. Incidence
 - i) Most common malignant liver tumor in childhood
 - c. Risk factors
 - i) Beckwith-Wiedemann syndrome
 - ii) Premature birth
 - iii) Sporadic aniridia
 - iv) Familial adenomatous polyposis and Gardner syndrome
 - d. Clinical presentation
 - i) Increased girth
 - ii) Hepatomegaly
 - iii) Weight loss, nausea, and vomiting

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- iv) Rarely precocious puberty
 - v) Elevated serum alpha-fetoprotein (AFP)
 - e. Sonographic findings
 - i) 2-D
 - Heterogeneous solid mass
 - Poorly marginated
 - Calcifications may be identified
 - ii) Doppler
 - Provides information about tumor vascularity and blood flow characteristics
 - iii) Contrast Enhanced Ultrasound
 - Enhancement pattern: arterial phase shows rapid and intense enhancement; the portal venous phase may begin to wash out. late phase shows hypoenhancement.
 - Tumor margins are delineated
 - f. Correlative and/or prior imaging
 - g. Treatment
- 2. Hepatocellular carcinoma (HCC) – hepatoma
 - a. Definition
 - i) Primary liver malignancy
 - b. Incidence
 - i) Most common primary malignancy
 - c. Risk factors
 - i) Cirrhosis
 - ii) Hepatocarcinogens in food
 - iii) Chronic hepatitis B and hepatitis C
 - iv) Wilson's disease
 - v) Hemochromatosis
 - vi) Metabolic disorders
 - d. Clinical presentation
 - i) Palpable mass
 - ii) Rapid liver enlargement
 - iii) Unexplained mild fever
 - iv) Symptoms associated with cirrhosis
 - v) Elevated serum α -fetoprotein
 - e. Sonographic findings
 - i) Variable in pattern

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- Solitary
 - Multiple
 - Dominant mass with satellite lesions
 - Diffuse parenchymal infiltration
 - ii) Variable echogenicity
 - iii) Hepatomegaly
 - iv) Associated ascites
 - v) Portal/hepatic vein invasion
 - vi) Occasional bile duct invasion
 - vii) Contrast enhanced ultrasound
 - Enhancement pattern: arterial phase hyperenhancement, followed by late washout (onset greater than 60sec from injection) with mild washout degree.
 - f. Correlative and/or prior imaging
 - g. Treatment
3. Hemangiosarcoma
- a. Definition
 - i) Malignant neoplasm comprised of endothelial and fibroblastic tissue and surrounds vessels
 - b. Incidence
 - i) Rare
 - c. Risk factors
 - i) Advanced age
 - ii) Exposure to carcinogens
 - d. Clinical presentation
 - e. Sonographic findings
 - i) Large mass
 - ii) Mixed echogenicity
 - f. Correlative and/or prior imaging
 - g. Treatment
4. Metastasis
- a. Definition
 - i) Dissemination of tumor cells to liver from primary malignant neoplasm
 - b. Incidence
 - i) Common site for metastatic change
 - ii) Most common liver malignancy
 - c. Risk factors

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- i) Common primary carcinomas metastasize to liver
 - Gastrointestinal
 - Breast
 - Lung
 - d. Clinical presentation
 - i) Hepatomegaly
 - ii) Jaundice
 - iii) Pain
 - iv) Weight loss
 - v) Abnormal laboratory tests
 - e. Sonographic findings
 - i) Variable in pattern
 - Hypoechoic
 - Hyperechoic
 - Target lesion
 - Diffusely heterogeneous
 - Calcifications
 - Cystic degeneration
 - ii) Contrast enhanced ultrasound
 - Enhancement pattern: rim arterial phase hyperenhancement or variable arterial phase enhancement, followed by rapid washout (onset greater than 60 sec from injection) with mild washout degree.
 - f. Correlative and/or prior imaging
 - g. Treatment
- M. Trauma
 - 1. Definition
 - a. Hematoma may be due to trauma, post-operative, post-biopsy or rupture of a neoplasm such as an adenoma, metastatic choriocarcinoma, or giant cavernous hemangioma, hepatocellular carcinoma, angiosarcoma
 - 2. Categories
 - a. Rupture of the liver and capsule
 - b. Separation of the capsule and the subcapsular hematoma
 - c. Central rupture of the liver
 - 3. Clinical presentation
 - a. Pain
 - b. Hypotension
 - c. Possible decreased hematocrit

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- 4. Sonographic findings
 - a. Typically posterior segment of right lobe
 - b. Varied appearance depending on the age of the hematoma
 - c. Subcapsular - potential fluid bordering the liver
 - d. Capsular rupture - free fluid in peritoneal cavity
- N. Benign Causes of Hyperechoic Foci in the Liver Region
 - 1. Calcification
 - a. Old granulomatous disease
 - b. Healed abscess or hematoma
 - 2. Air in bile ducts
 - a. Post-operative biliary surgery: endoscopic retrograde cholangiopancreatography (ERCP) with sphincterotomy, patulous sphincter of Oddi, biliary-enteric fistula
 - b. Cause “comet-tail,” ring-down artifact
 - c. May move with change in patient position

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Section III: Pancreas

1. Describe the normal anatomy, function, sonographic technique and appearance of the pancreas
 2. Correlate clinical indications and laboratory values associated with pancreatic disease
 3. Discuss pancreatic pathology in terms of sonographic appearances, sequelae and associated pathologies
-

III. PANCREAS

- A. Embryology
 1. Ventral and dorsal buds
- B. Anatomy
 1. Retroperitoneal
 2. Head
 3. Neck
 4. Uncinate
 5. Body
 6. Tail
 7. Vascular landmarks
 8. Size
 9. Ducts
 10. Shape
- C. Relational Anatomy
- D. Normal Variants
 1. Annular pancreas
 2. Ectopic pancreatic tissue
 3. Pancreatic divisum
- E. Function
 1. Exocrine function
 - a. Secretions by the pancreas
 - i) Pancreatic polypeptide
 - b. Hormone influence from the GI system
 - i) Cholecystokinin
 - ii) Gastrin
 - iii) Secretin
 2. Endocrine function
 - a. Islet cells of Langerhans
 - i) Alpha cells secrete glucagon
 - ii) Beta cells secrete insulin

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iii) Delta cells secrete somatostatin

F. Indications for Examination

1. Severe epigastric pain
2. Abdominal pain radiating to back
3. Abdominal distension with hypoactive bowel sounds
4. Acute pancreatitis
5. Chronic pancreatitis
6. Biliary disease
7. Abnormal pancreatic enzymes
8. Pancreatic neoplasm

G. Laboratory Values

1. Amylase
 - a. Serum
 - b. Urine
2. Glucose
3. Lipase

H. Normal Sonographic Findings

1. Homogeneous, coarse echotexture
2. Echogenicity should be compared to liver
3. Size varies with shape
4. Pancreatic duct: echogenic parallel lines, single echogenic line

I. Technique

1. Patient preparation
2. Transducer selection
3. Patient positioning
4. Image optimization
5. Image protocol

J. Pathophysiology

1. Congenital diseases
 - a. Cystic fibrosis
 - i) Definition
 - Autonomic recessive exocrine gland disorder
 - Distention of ductules and acini with degeneration and replacement by small cysts
 - ii) Incidence
 - iii) Risk factors

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- iv) Clinical presentation
 - v) Sonographic findings
 - Poor visualization
 - Hyperechoic gland compared to normal
 - Associated liver changes
 - Associated gastrointestinal (GI) tract change
 - Associated gallbladder changes
 - vi) Correlative and/or prior imaging
 - vii) Treatment
2. Inflammation
- a. Acute pancreatitis
 - i) Definition
 - ii) Incidence
 - iii) Risk factors
 - Cholelithiasis
 - Pancreatic hypersecretions
 - Alcohol intake
 - Smoking
 - Obesity
 - Duodenal reflux
 - Blunt abdominal trauma
 - Surgery and/or interventional procedures
 - Metabolic disorders
 - Viral and parasitic infections
 - Drug exposure
 - Pancreatic carcinoma
 - Hereditary (idiopathic pancreatitis)
 - iv) Clinical presentation
 - Severe pain
 - Constant and intense pain radiating to the back
 - Fever
 - Sweating
 - Tachycardia
 - Abdominal tenderness
 - Nausea

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- Vomiting
- Gaseous distention
- Ileus
- Acute respiratory distress syndrome (ARDS)
- Acute tubular necrosis
- v) Laboratory values
 - Serum and urine amylase
 - Serum lipase
 - Elevated white blood cell count
 - Possible elevated bilirubin
- vi) Sonographic findings
 - Normal
 - Diffuse enlargement with loss of normal sonographic texture
 - Focal enlargement
 - Echogenicity as compared to liver
 - Poor visualization of the splenic vein
 - Dilatation or compression of pancreatic duct
- vii) Complications
 - Pseudocyst formation
 - Phlegmon
 - Abscess
 - Hemorrhage
 - Renal failure
 - Biliary and duodenal obstruction
 - Fluid collections
 - Edema
 - Acute peritonitis
 - Thrombosis of the portal-splenic veins and SMV
 - Left pleural effusion
 - Acute respiratory distress syndrome
 - Hyperglycemia and diabetes
- viii) Correlative and/or prior imaging
- ix) Treatment

3. Hemorrhagic pancreatitis

a. Definition

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- b. Risk factors
 - c. Incidence
 - d. Clinical presentation
 - i) Severe abdominal pain
 - ii) Nausea
 - iii) Vomiting
 - iv) Abdominal distention and varying degrees of ileus
 - e. Complications
 - f. Laboratory findings
 - i) Increased serum amylase and serum lipase
 - ii) Decreased hematocrit and serum calcium
 - g. Sonographic findings
 - i) Acute, initial changes with progression of disease
 - h. Correlative and/or prior imaging
 - i. Treatment
4. Phlegmonous pancreatitis
- a. Definition
 - i) Severe complication of acute pancreatitis
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - e. Sonographic findings
 - i) Hypoechoic
 - f. Correlative and/or prior imaging
 - g. Treatment
5. Abscess
- a. Definition
 - b. Incidence
 - c. Risk factors
 - d. Clinical presentation
 - e. Sonographic findings
 - i) Smooth walls with little or no internal echoes
 - ii) Irregular walls with increased internal echoes
 - iii) Ranges from completely echo-free to echo-dense
 - f. Correlative and/or prior imaging
 - g. Treatment

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6. Pseudocyst
 - a. Definition
 - i) Fluid collections that arise from inflammatory processes, necrosis, or hemorrhage
 - b. Incidence
 - i) Complication of pancreatitis or trauma
 - c. Risk factors
 - d. Clinical presentation
 - e. Sonographic findings
 - i) Usually anechoic with acoustic enhancement
 - ii) Variable
 - Complex
 - Debris with the cystic component
 - Multiloculated
 - f. Complications
 - g. Correlative and/or prior imaging
 - h. Treatment
7. Chronic pancreatitis
 - a. Definition
 - i) Relapsing pancreatitis
 - ii) Irreversible damage to the gland due to progressive destruction
 - b. Incidence
 - i) Male predominance
 - c. Risk factors
 - i) Alcoholism
 - ii) Hypercalcemia
 - iii) Hyperlipidemia
 - iv) Medications
 - d. Clinical presentation
 - i) Persistent epigastric and radiating back pain
 - ii) Nausea
 - iii) Vomiting
 - iv) Flatulence
 - v) Weight loss
 - vi) Diabetes mellitus (later stages)
 - e. Laboratory values

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- i) Steatorrhea
 - ii) Abnormal glucose-tolerance test
 - f. Sonographic findings
 - i) 2-D
 - Heterogeneous
 - Increased echogenicity and attenuation
 - Calcifications
 - Ductal dilatation
 - Irregular contour to the gland or pancreatic duct
 - Focal or diffuse enlargement of gland
 - Complications
 - ~ Pseudocyst
 - ~ Dilatation of the biliary system
 - ~ Associated pancreatic carcinoma
 - ii) Doppler
 - Possible thrombosis of the splenic vein and/or portal vein
 - g. Correlative and/or prior imaging
 - h. Treatment
- K. Neoplasia
 - 1. Cystadenoma/cystadenocarcinoma
 - a. Definition
 - i) Microcystic adenoma
 - ii) Macrocystic adenoma
 - b. Incidence
 - i) Female predominance
 - c. Risk factors
 - d. Clinical presentation
 - e. Sonographic findings
 - i) Microcystic
 - ii) Macrocystic
 - iii) Associated findings
 - f. Correlative and/or prior imaging
 - g. Treatment
 - 2. Adenocarcinoma
 - a. Definition

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- b. Incidence
 - i) Most common malignancy of pancreas
 - ii) Male predominance
- c. Risk factors
- d. Clinical presentation
 - i) Late onset of symptoms
 - ii) Weight loss
 - iii) Painless jaundice
 - iv) Abdominal pain with progression of disease
 - v) Back pain
 - vi) Anorexia
 - vii) Nausea
 - viii) Vomiting
 - ix) Generalized malaise
 - x) Weakness
 - xi) New onset of diabetes
- e. Sonographic findings
 - i) 2-D
 - Enlargement
 - Mass with irregular borders
 - Enlarged pancreatic duct
 - Biliary duct dilatation: secondary to involvement of pancreatic head
 - Enlarged gallbladder (Courvoisier's sign)
 - Metastasis to liver
 - Ascites
 - Regional lymph node involvement with SMA displacement
 - Encasement of mesenteric vessels
 - Other
 - ii) Doppler
 - Portal vein
 - Splenic vein
- f. Correlative and/or prior imaging
- g. Treatment
- 3. Islet cell tumors
 - a. Definition

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- i) Functional or nonfunctional; either benign or malignant neoplasms
 - Insulinoma
 - Gastrinoma
 - Other
- b. Incidence
- c. Risk factors
- d. Clinical presentation
- e. Laboratory values
- f. Sonographic findings
 - i) Typical locations
 - ii) Size
 - iii) Associated echogenicity
- g. Correlative and/or prior imaging
- h. Treatment

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Section IV: Renal and Lower Urinary Tract

1. Describe the normal anatomy and variants, function, sonographic technique and normal sonographic appearances of the kidneys and lower urinary tract
 2. Correlate the clinical indications and laboratory values associated with urinary tract disease
 3. Describe urinary tract pathology in terms of sonographic appearances
 4. Describe associated pathologies and sequelae relative to urinary tract disease
 5. Identify normal and abnormal flow characteristics and waveforms
 6. Discuss current diagnostic Doppler criteria
 7. Discuss contrast-enhanced ultrasound (CEUS) patterns
-

IV. RENAL AND LOWER URINARY TRACT

- A. Embryology
- B. Anatomy
 - 1. Micro
 - a. Nephrons
 - 2. Macro – kidneys
 - a. Paired
 - b. Retroperitoneal
 - c. Encapsulated
 - i) Fibrous renal capsule
 - True capsule
 - ii) Adipose capsule
 - Perirenal fat
 - iii) Renal fascia
 - Gerota's
 - d. Structure
 - i) Cortex
 - ii) Medulla
 - iii) Pyramids
 - iv) Calyces
 - v) Pelvis
 - 3. Vascular anatomy
 - a. Arterial
 - i) Main renal artery
 - ii) Segmental
 - iii) Interlobar
 - iv) Arcuate

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- v) Interlobular arteries
 - vi) Arterioles
 - b. Venous
 - i) Main renal vein
 - ii) Segmental
 - iii) Interlobar
 - iv) Arcuate
 - v) Interlobular
 - 4. Macro - lower urinary (LU) tract
 - a. Retroperitoneal or extraperitoneal
 - b. Ureters
 - c. Urinary bladder
 - i) Wall layers
 - Serosa
 - Muscle
 - Mucosa
 - ii) Trigone
 - d. Urethra
 - 5. Relational anatomy
- C. Variants
- 1. Renal structure
 - a. Hypertrophied column of Bertin
 - b. Dromedary hump
 - c. Junctional parenchymal defect (JPD)
 - d. Persistent fetal lobulation (PFL)
 - e. Extrarenal pelvis
 - f. Horseshoe kidney
 - g. Cake kidney (fused pelvic kidney)
 - 2. Renal number
 - a. Bilateral renal agenesis
 - b. Unilateral renal agenesis
 - c. Supernumerary kidney
 - 3. Renal position
 - a. Ectopic
 - b. Crossed fused renal ectopia
 - 4. Renal hypoplasia

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5. Renal malrotation
6. Duplex collecting system
7. Congenital renal dysplasia
 - a. Dysplastic renal hypoplasia
 - b. Unilateral dysplastic kidney
8. Congenital renal and medullary cystic disease
 - a. Autosomal recessive polycystic kidney disease (ARPKD)
 - b. Autosomal dominant polycystic kidney disease (ADPKD)
 - c. Multicystic dysplastic kidney (MCDK)
 - d. Medullary cystic disease
9. Lower urinary tract
 - a. Bladder diverticulum
 - b. Bladder duplication
 - c. Bladder exstrophy
 - d. Posterior urethral valves (PUV)
 - e. Urachal anomalies
 - f. Ureterocele
- D. Function
 1. Excretion of waste products of metabolism; urine production
 2. Renin-angiotensin system influences blood pressure, blood volume, and intake/excretion of salt and water
 3. Regulation of acid-base balance
 4. Regulation of serum electrolytes
 5. Renal production of erythropoietin
 6. Convey urine to the bladder
 7. Reservoir for urine
 8. Convey urine from the body
- E. Laboratory Values
 1. Serum creatinine
 2. Blood urea nitrogen (BUN)
 3. Urinalysis
 4. Glomerular filtration rate (GFR)
- F. Indications
 1. Urinary tract infection (UTI)
 2. Palpable mass
 3. Elevated serum creatinine, BUN levels

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4. Severe flank pain
5. Hematuria
6. Proteinuria
7. Oliguria
8. Azotemia
9. Assessment of mass visualized on CT
10. Assessment of non-visualization of kidney on intravenous pyelogram (IVP)
11. Assessment of enlarged or small kidney
12. Hypertension
13. Acute renal injury
14. Trauma or post-surgical complication
- G. Sonographic Technique
 1. Patient preparation
 2. Transducer selection
 3. Patient positioning
 4. Imaging optimization
 5. Imaging protocol
- H. Normal Sonographic Findings
 1. Measurements
 - a. Length
 - b. Width
 - c. Thickness
 - d. Cortical thickness
 - e. Relative renal size
 - i) Pediatric
 - ii) Solitary kidney
 2. Renal cortex
 - a. Homogeneous
 - b. Low to medium-level echogenicity
 - c. Hypoechoic or isoechoic to liver
 3. Renal medulla
 - a. Relatively hypoechoic to cortex
 - b. Hyperechoic interfaces at corticomedullary junction (CMJ)
 4. Renal sinus
 - a. Hyperechoic to renal cortex
 5. Doppler

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- a. Renal arteries
 - b. Renal veins
- 6. Contrast-enhanced ultrasound
 - a. Renal phases
 - ii) Arterial
 - iii) Cortical
 - iv) Medullary
 - b. ACR appropriateness criteria
 - i) Indeterminate renal masses
- 7. Ureters
 - a. Not routinely visualized
 - b. Anechoic tubular structure
- 8. Bladder
 - a. Anechoic lumen
 - b. Wall thickness varies with the degree of distention
 - c. Presence of ureteral jets on Doppler
- 9. Urethra
 - a. Anechoic tubular structure
- I. Pathophysiology
 - 1. Inflammatory conditions
 - a. Acute pyelonephritis (APN)
 - i) Definition
 - Acute inflammation of the tubulointerstitial renal tissue
 - ii) Clinical presentation
 - Flank pain
 - Fever
 - iii) Sonographic findings
 - Normal appearance
 - Focal or diffuse
 - Increase in size
 - Areas of increased or decreased echogenicity
 - Absence or decreased perfusion on Doppler
 - Loss of corticomedullary definition
 - Compression of renal sinus
 - Unilateral or bilateral

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- iv) Correlative and/or prior imaging
 - v) Treatment
- b. Emphysematous pyelonephritis
 - i) Definition
 - Life-threatening infection of renal parenchyma with gas formation in tissue or collecting system
 - ii) Clinical presentation
 - Fever
 - Flank pain
 - Dehydration
 - Acidosis
 - Electrolyte imbalance
 - iii) Sonographic findings
 - Gas within parenchyma
 - Presence of air within the collecting system
 - iv) Correlative and/or prior imaging
 - v) Treatment
- c. Chronic pyelonephritis
 - i) Definition
 - Interstitial nephritis resulting from ongoing or recurring urinary tract infections (UTIs)
 - ii) Clinical presentation
 - Asymptomatic
 - Renal failure
 - iii) Sonographic findings
 - Unilateral or bilateral focal areas of cortical thinning and increased echogenicity
 - iv) Correlative and/or prior imaging
 - v) Treatment
- d. Acute tubular necrosis (ATN)
 - i) Definition
 - Damage and/or necrosis to the renal tubules bilaterally
 - ii) Clinical presentation
 - Acute kidney injury
 - Oliguria
 - Uremia

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- Electrolyte imbalance
 - iii) Sonographic findings
 - Normal
 - Bilateral enlargement
 - Increased parenchymal echogenicity
 - iv) Correlative and/or prior imaging
 - v) Treatment
- e. Pyonephrosis
 - i) Definition
 - The presence of pus in the urinary collecting system
 - ii) Clinical presentation
 - Fever
 - Flank pain
 - iii) Sonographic findings
 - Hydronephrosis
 - Mobile echogenic particles in collecting system
 - iv) Correlative and/or prior imaging
 - v) Treatment
- f. Acute glomerulonephritis
 - i) Definition
 - Accumulation of inflammatory elements or necrosis of glomeruli
 - ii) Clinical presentation
 - Hematuria
 - Hypertension
 - Azotemia
 - iii) Sonographic findings
 - Normal to enlarged kidneys
 - Varying echogenicity of cortex
 - Normal medulla
 - iv) Correlative and/or prior imaging
 - v) Treatment
- g. Candidiasis
 - i) Definition
 - Systemic fungal infection, occurring in an immuno-compromised patient
 - ii) Clinical presentation

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- Worsening of existing symptoms in chronically ill patients
- iii) Sonographic findings
 - Multiple focal abscesses throughout parenchyma
 - Focal masses of varying echogenicity
 - Acoustic enhancement
 - Focal echogenic mass(es) within collecting system
- iv) Treatment
- h. Schistosomiasis
 - i) Definition
 - Parasitic infestation of *schistosoma* organism
 - ii) Clinical presentation
 - Hematuria
 - iii) Sonographic findings
 - Normal kidneys
 - Urinary bladder wall thickening
 - Focal bladder wall granuloma
 - Calcifications of bladder wall
 - Hydronephrosis
 - iv) Treatment
- i. Urinary tuberculosis
 - i) Definition
 - Infestation to the kidney of mycobacterium tuberculosis from an extraurinary source
 - ii) Clinical presentation
 - Asymptomatic
 - Frequency
 - Nocturia
 - Dysuria
 - Gross or microscopic hematuria
 - Sterile pyuria
 - iii) Sonographic findings
 - Acute
 - Focal lesions of varying echogenicity
 - Chronic
 - Varying appearances of scarring and obstruction resulting from chronic fibrotic changes

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- Decreased size
 - Increased echogenicity with shadowing (urothelial calcification)
 - May be associated with ureteral stricture or small bladder volume
 - iv) Correlative and/or prior imaging
 - v) Treatment
 - j. Abscess
 - i) Definition
 - Focal collection of inflammatory and necrotic debris
 - ii) Clinical presentation
 - Fever
 - Flank pain
 - Localized tenderness
 - iii) Sonographic findings
 - Varying echogenicity
 - Acoustic enhancement
 - Shadowing
 - Central fluid with surrounding hyperemia on Doppler
 - iv) Correlative and/or prior imaging
 - v) Treatment
2. Acute kidney injury/chronic kidney disease (formerly renal failure)
- a. Definition
 - i) Impairment of kidney function resulting in the inability of the kidney(s) to maintain normal function
 - b. Types
 - i) Prerenal
 - ii) Renal
 - iii) Postrenal
 - c. Clinical presentation
 - i) Oliguria
 - ii) Increased BUN and creatinine
 - iii) Proteinuria
 - iv) Anemia
 - v) Hypertension
 - vi) Uremia
 - d. Sonographic findings
 - i) Normal

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- ii) Hydronephrosis
 - Acute non-obstructive
 - Normal or increased size
 - Increased parenchymal echogenicity
 - Chronic
 - Normal or decreased size
 - Increased parenchymal echogenicity
 - iii) Increased size with acute
 - iv) End-stage
 - Decreased size
 - Parenchymal thinning
 - Increased parenchymal echogenicity
 - Loss of parenchymal differentiation
 - e. Treatment
3. Simple renal cysts
- a. Cortical cyst
 - i) Definition
 - Benign fluid-filled mass of unknown pathogenesis
 - ii) Complications
 - Hemorrhagic
 - Infection
 - iii) Clinical presentation
 - Asymptomatic
 - Pain
 - Palpable mass
 - Fever
 - Elevated WBC
 - iv) Sonographic findings
 - Usually cortical in location
 - Simple
 - Anechoic
 - Smooth imperceptible walls
 - Lack of wall calcifications, nodules, or septations
 - Distal acoustic enhancement
 - Complex

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- Varying echogenicity
 - Septations
 - Layering
 - Wall calcifications
 - v) Correlative and/or prior imaging
 - Contrast enhanced ultrasound
 - vi) Treatment
 - b. Parapelvic cyst
 - i) Definition
 - Fluid-filled mass of lymphatic origin located in renal hilus
 - ii) Clinical presentation
 - Asymptomatic
 - Hypertension
 - Hematuria
 - Hydronephrosis
 - iii) Sonographic findings
 - Renal sinus location
 - Anechoic
 - Well-defined walls
 - Acoustic enhancement
 - May have internal echoes
 - iv) Correlative and/or prior imaging
 - v) Treatment
4. Cystic disease
 - a. Multicystic dysplastic kidney (MCDK)
 - i) Definition
 - Developmental anomaly resulting in multiple renal cysts of varying sizes and lack of normal renal parenchyma
 - ii) Clinical presentation
 - Unilateral
 - Palpable flank mass
 - Asymptomatic
 - Rarely bilateral - incompatible with life
 - iii) Sonographic findings
 - Multiple non-communicating cysts of varying sizes, arranged randomly

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- No normal parenchyma
- Late stage
 - Usually, decreases in size
 - Lack of identifiable normal renal parenchyma
- Contralateral kidney compensatory enlargement
- iv) Correlative and/or prior imaging
- v) Treatment
- b. Autosomal recessive polycystic kidney disease (ARPKD), formerly infantile polycystic kidney disease (IPKD)
 - i) Definition
 - Autosomal recessive inherited disorder characterized by abnormal proliferation and dilatation of renal tubules resulting in multiple microscopic tubular cysts
 - ii) Clinical presentation
 - Progressive renal failure
 - May develop hepatic fibrosis, portal hypertension, and cirrhosis
 - iii) Sonographic findings
 - Bilateral enlargement
 - Increased parenchymal echogenicity
 - Loss of corticomedullary differentiation
 - Imaging with a linear high-frequency transducer can reveal radially oriented tubular cysts (dilated tubules)
- c. Autosomal dominant polycystic kidney disease (ADPKD), formerly adult polycystic kidney disease (APKD)
 - i) Definition
 - Autosomal dominant inherited disorder with bilateral development of parenchymal cysts
 - ii) Clinical presentation
 - Asymptomatic (early)
 - Usually bilateral presenting in adulthood
 - Hypertension
 - Renal failure
 - Increased incidence of renal calculi and infection
 - Obstruction
 - ~ Pain
 - Infection
 - ~ Fever

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~ Pain

- iii) Sonographic findings
 - Bilateral renal enlargement
 - Multiple cysts of variable size
 - Cysts of varying echogenicity
 - Acoustic enhancement
 - Calculi
- iv) Associated findings
 - Multiple cysts associated with other organs
 - Berry aneurysm
- d. Medullary cystic disease
 - i) Definition
 - Autosomal inherited disorder
 - Autosomal dominant: adult onset with rapid progression, uremia and death
 - Autosomal recessive: juvenile onset
 - ii) Clinical presentation
 - Salt wasting
 - Anemia
 - Azotemia
 - Polyuria
 - Polydipsia
 - iii) Sonographic findings
 - Bilateral
 - Increased medullary echogenicity
 - Medullary and subcortical cysts up to 1.5 centimeters in diameter
 - End - stage renal failure
 - Decreased renal size
 - Increase parenchymal echogenicity
 - Loss of corticomedullary differentiation
 - iv) Treatment
- e. Medullary sponge kidney
 - i) Definition
 - Bilateral, dysplastic cystic dilation of medullary and papillary portions of collecting tubules
 - ii) Clinical presentation

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- Asymptomatic
 - With complications
 - Obstruction
 - ~ Pain
 - Infection
 - ~ Fever
 - ~ Pain
 - iii) Sonographic findings
 - Increased medullary echogenicity
 - Calculi
 - Medullary nephrocalcinosis is often present
 - iv) Treatment
- f. Acquired cystic kidney disease (ACKD)
- i) Definition
 - Patients undergoing dialysis develop multiple cysts in native and allograft kidneys
 - ii) Clinical presentation
 - Asymptomatic
 - Increased risk of tumor development
 - iii) Sonographic findings
 - Multiple cysts
 - Varying sizes
 - Variable echogenicity
 - Bilateral
 - Cortical thinning
 - iv) Correlative and/or prior imaging
 - v) Treatment
5. Benign solid renal tumors
- a. Angiomyolipoma - renal hamartoma
 - i) Definition
 - Benign tumor composed of fat, blood vessels, and smooth muscle tissue
 - ii) Clinical presentation
 - Female predominance
 - Asymptomatic
 - Hematuria

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- Hypertension
- Severe flank pain
- Risk of hemorrhage > 4 cm size
- iii) Sonographic findings
 - Variable echogenicity
 - Hyperechoic lesion in renal parenchyma most common
 - Variable echogenicity if hemorrhage
 - Variable size
- iv) Correlative and/or prior imaging
- v) Treatment
- b. Adenoma
 - i) Definition
 - Benign tumor derived from glandular epithelium
 - ii) Clinical presentation
 - Asymptomatic
 - Painless hematuria
 - iii) Sonographic findings
 - Well-defined
 - Isoechoic or hypoechoic cortical mass
 - iv) Correlative and/or prior imaging
 - v) Treatment
- c. Oncocytoma
 - i) Definition
 - Epithelial cell tumor
 - ii) Clinical presentation
 - Asymptomatic
 - Male predominance in later decades of life
 - iii) Sonographic findings
 - Solid
 - Variable in size
 - Variable in echogenicity
 - Difficult to differentiate from adenocarcinoma
 - iv) Correlative and/or prior imaging
 - v) Treatment
- d. Mesoblastic nephroma

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- i) Definition
 - Mesoblastic nephroma is a rare, generally benign kidney tumor primarily affecting newborns and infants.
 - ii) Clinical presentation
 - Palpable flank mass
 - Hypertension
 - iii) Sonographic findings
 - Varying echogenicity
 - Possible areas of cystic degeneration
 - Calcifications: although rare, can be detected within the tumor
 - iv) Doppler
 - May show increased vascularity within the mass
 - v) Correlative and/or prior imaging
 - vi) Treatment
6. Malignant renal tumors
- a. Renal cell carcinoma (RCC)
 - i) Definition
 - Renal parenchymal carcinoma, consisting of tubular cells
 - ii) Clinical presentation
 - Pain
 - Hematuria
 - Palpable mass
 - iii) Sonographic findings
 - 2-D
 - Solid mass of varying echogenicity
 - Appearance is variable ranging from a solid mass to a multicystic
 - Often at least partially exophytic
 - Calcifications
 - Tumor thrombus in renal vein(s) or IVC
 - Echogenic mass(es) in renal vein, IVC, or contralateral kidney
 - iv) Doppler
 - Hypervascular, with high systolic and diastolic arterial flow
 - v) Contrast enhanced ultrasound
 - Enhancement pattern: hyperenhancement with variable washout
 - vi) Correlative and/or prior imaging

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- vii) Treatment
- b. Urothelial cell carcinoma (UCC) - the term "transitional cell" was previously used because these cells can transition in shape.
 - i) Definition
 - Primary malignant epithelial tumor originating in urinary collecting system
 - ii) Clinical presentation
 - Painless hematuria
 - Hydronephrosis
 - iii) Sonographic findings
 - “Faceless” kidney sign
 - Obliteration of the normal renal sinus appearance
 - Isoechoic or hypoechoic mass within collecting system
 - Renal pelvis
 - Ureter
 - Bladder
 - ~ Wall thickening
 - ~ Focal, irregular
 - ~ Intraluminal mass
 - Pelvicaliectasis
 - Hilar adenopathy
 - iv) Contrast Enhanced Ultrasound
 - Enhancement pattern: hypoenhancement with variable washout
 - v) Correlative and/or prior imaging
 - vi) Treatment
- c. Wilm’s tumor – nephroblastoma
 - i) Definition
 - Pediatric malignant mixed tumor composed of embryonal elements
 - ii) Clinical presentation
 - Fever
 - Hematuria
 - Hypertension
 - Palpable flank mass
 - iii) Sonographic findings
 - Most commonly is solid and heterogeneous
 - May have hypoechoic or cystic appearance

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- Large in size
 - Calcifications may be seen
 - Increased risk with horseshoe kidney
 - iv) Contrast enhanced ultrasound
 - Enhancement pattern: heterogeneous and hypervascular; well-demarcated borders; delayed washout in some cases
 - v) Correlative and/or prior imaging
 - vi) Treatment
 - d. Metastases to the kidney
 - i) Definition
 - Growth of malignant cells distant from primary tumor
 - ii) Clinical presentation
 - Asymptomatic
 - Known pathology follow-up
 - iii) Sonographic findings
 - Varies from hypoechoic to hyperechoic masses
 - Single or multiple masses
 - Diffusely hypoechoic
 - iv) Correlative and/or prior imaging
 - v) Contrast enhanced ultrasound
 - Enhancement pattern: variable intralesional enhancement
7. Renal calcification
- a. Calculi
 - i) Definition
 - Focal concentrations of calcium, uric acid, or cystine in renal parenchyma or collecting system
 - ii) Clinical presentation
 - Asymptomatic
 - Acute pain
 - Hematuria
 - iii) Sonographic findings
 - Hyperechoic foci
 - Acoustic shadowing
 - Obstructive hydronephrosis
 - Twinkle artifact
 - Echogenic focus in dilated distal ureter on bladder view

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- iv) Correlative and/or prior imaging
 - v) Treatment
 - b. Nephrocalcinosis
 - i) Medullary
 - Definition
 - Formation of aggregates of calcium in renal tubules
 - Clinical presentation
 - Asymptomatic
 - Renal failure
 - Hyperparathyroidism
 - Sonographic findings
 - Increased echogenicity of pyramids
 - Normal cortical echogenicity
 - Distal acoustic shadowing
 - Correlative and/or prior imaging
 - Treatment
 - ii) Cortical
 - Definition
 - Diffuse or focal calcium deposition in renal cortex
 - Clinical presentation
 - Asymptomatic
 - Sonographic findings
 - Focal or diffuse increase in cortical echogenicity
 - Distal acoustic shadowing
 - Decrease in size
 - Correlative and/or prior imaging
 - Treatment
- 8. Obstructive uropathy
 - a. Hydronephrosis (pelvocaliectasis)
 - i) Definition
 - Dilation of renal pelvis and calyces due to obstruction of outflow of urine from either congenital, intrinsic, or extrinsic cause.
 - ii) Etiology
 - Congenital
 - Intrinsic

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- Extrinsic
 - iii) Types/grading
 - iv) Sonographic findings
 - 2-D
 - Mild, moderate, or severe degrees of pelvocaliectasis
 - Hydroureter
 - Cortical thinning
 - Doppler
 - Ureteral jet on non-obstructed side
 - Increased resistive index (RI)
 - v) Correlative and/or prior imaging
 - vi) Treatment
9. Trauma
- a. Definition
 - i) Assault to urinary tract from blunt force, penetrating trauma, or rupture of neoplasm resulting in possible
 - Rupture of kidney and capsule
 - Subcapsular hematoma
 - Page kidney
 - ~ Extrinsic compression of the renal parenchyma
 - Parenchymal laceration
 - Urinoma
 - b. Clinical presentation
 - i) Abdominal pain
 - ii) Decreased hematocrit
 - iii) Hematuria
 - iv) Oliguria
 - v) Hypertension
 - c. Sonographic findings
 - i) 2-D
 - Sonographically occult - common
 - Diffuse heterogeneous parenchymal pattern
 - Focal mass
 - Varying echogenicity
 - Free abdominopelvic fluid
 - Loculated abdominal fluid collection

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- Anechoic
 - Septations
 - Debris
 - ii) Doppler
 - Avascular areas
 - d. Correlative and/or prior imaging
 - e. Treatment
- 10. Infarction
 - a. Definition
 - i) Necrosis of tissue due to occlusion of arterial blood supply
 - b. Clinical presentation
 - i) Asymptomatic
 - ii) Localized pain
 - c. Sonographic findings
 - i) Focal or diffuse
 - ii) Wedge-shaped
 - iii) Acute
 - Hypoechoic
 - iv) Chronic
 - Decreased size
 - Capsular retraction or focal scarring
 - Increased echogenicity
 - d. Correlative and/or prior imaging
- 11. Vascular disorders
 - a. Renal artery stenosis (RAS)
 - i) Definition
 - Luminal narrowing of renal artery
 - ii) Clinical presentation
 - Hypertension
 - iii) Sonographic findings
 - 2-D
 - Normal
 - Decrease in size of affected kidney
 - Increase in cortical echogenicity
 - Doppler

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- Direct
 - ~ Normal
 - ~ Increased renal aorta ratio (RAR)
 - ~ Increased peak systolic velocity
 - ~ Spectral broadening
 - ~ Tardus parvus waveform
 - Indirect
 - ~ Decreased diastolic systolic ratio (DSR)
 - ~ Delayed acceleration time
 - ~ Asymmetric segmental resistive index relative to other kidney
- iv) Correlative and/or prior imaging
- v) Treatment
- b. Renal artery occlusion
 - i) Definition
 - Obstruction of arterial lumen
 - ii) Clinical presentation
 - Asymptomatic
 - Flank pain
 - Hypertension
 - iii) Sonographic findings
 - 2-D
 - Decrease in renal size after acute phase
 - Increase in cortical echogenicity
 - Doppler
 - Absence of flow distal to occlusion
 - iv) Correlative and/or prior imaging
 - v) Treatment
- c. Renal vein thrombosis
 - i) Definition
 - Presence of obstructive or non-obstructive thrombus in renal vein
 - ii) Clinical presentation
 - Asymptomatic
 - Flank pain
 - iii) Sonographic findings
 - 2-D

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- Increase in renal size in acute phase
 - Decrease in size in late or chronic phase
 - Varying echogenicity
 - Echogenic material within lumen of vein
 - IVC involvement
 - Doppler
 - Absence of flow in renal vein – variable
 - Increased arterial resistance with or without diastolic reversal
 - iv) Correlative and/or prior imaging
 - v) Treatment
 - d. Other vascular disorders
 - i) Aneurysm
 - Anechoic structure with circular flow
 - May be obscured by wall calcifications
 - ii) Pseudoaneurysm
 - To-and-fro waveform
 - Circular yin-yang pattern within anechoic structure
 - iii) Arteriovenous (AV) fistula
 - Low resistance arterial flow
 - Arterialized adjacent venous flow
 - Tissue reverberation of adjacent parenchyma
12. Lower urinary tract pathology
- a. Vesicoureteral reflux
 - i) Definition
 - Abnormal reversal flow of urine from the bladder into the one or both ureters.
 - Possible kidney involvement
 - ii) Clinical presentation
 - iii) Sonographic features
 - Grading
 - 2D
 - Contrast-enhanced ultrasound
 - b. Cystitis
 - i) Definition
 - Inflammation of urinary bladder

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- ii) Clinical presentation
 - Pain
 - Frequency
 - Urgency
 - Hematuria
- iii) Sonographic findings
 - Normal
 - Focal or diffuse wall thickening
 - Luminal echoes - layering or dependent
- iv) Correlative and/or prior imaging
- v) Treatment
- c. Bladder wall thickening
 - i) Definition
 - Increase size of bladder wall
 - Causes
 - ~ Muscular hypertrophy
 - ~ Tumor
 - ~ Infection
 - ~ Under-distended bladder
 - ii) Clinical presentation
 - Asymptomatic
 - iii) Sonographic findings
 - Focal or diffuse increase in wall size
 - iv) Treatment
- d. Lower tract calculi
 - i) Definition
 - Presence of focal calcification in urinary collecting system
 - ii) Clinical presentation
 - Asymptomatic
 - If obstructing
 - Pain
 - Hematuria
 - iii) Sonographic findings
 - Focal mass of increased echogenicity
 - Distal acoustic shadowing

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- Obstructive hydronephrosis
- Mobile if in bladder
- iv) Correlative and/or prior imaging
- v) Treatment
- e. Hematoma
 - i) Definition
 - Localized collection of blood within LU tract
 - ii) Clinical presentation
 - Asymptomatic
 - iii) Sonographic findings
 - Low-level echoes
 - Focal (mass-like)
 - Layering, gravity dependent echoes
 - iv) Treatment
- f. Neoplasia
 - i) Adenoma
 - Definition
 - Benign glandular epithelial tumor
 - Clinical presentation
 - Asymptomatic
 - Painless hematuria
 - Sonographic findings
 - Focal luminal mass
 - Irregular wall thickening
 - Varying echogenicity
 - Varying size
 - Correlative and/or prior imaging
 - Treatment
 - ii) Urothelial cell carcinoma (UCC) - the term "transitional cell" was used previously because these cells can transition in shape.
 - Definition
 - Primary malignant epithelial tumor originating in urinary collecting system
 - Clinical presentation
 - Asymptomatic
 - Painless hematuria

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- Sonographic findings
 - Focal luminal bladder mass
 - Irregular bladder wall thickening
 - Echogenic ureteral mass
 - Varying echogenicity
 - Obstructive hydronephrosis
 - Correlative and/or prior imaging
 - Treatment
- iii) Metastases
- Definition
 - Growth of malignant cells distant from primary site - usually direct extension to urinary bladder
 - Clinical presentation
 - Asymptomatic
 - With obstruction
 - ~ Pain
 - ~ Oliguria
 - Sonographic findings
 - Focal luminal bladder mass
 - Irregular bladder wall thickening
 - Echogenic ureteral mass
 - Varying echogenicity
 - Obstructive hydronephrosis
 - Treatment

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Section V: Spleen

1. Describe the normal anatomy, function, sonographic technique and appearance of the spleen
 2. Correlate clinical indications and laboratory values associated with splenic disease
 3. Describe splenic pathology in terms of sonographic appearances, sequelae and associated pathologies
 4. Describe associated pathologies and sequelae relative to splenic disease
 5. Identify normal and abnormal flow characteristics and waveforms
 6. Discuss current diagnostic Doppler criteria
-

V. SPLEEN

- A. Embryology
- B. Anatomy
 1. Location
 2. Organ of the lymphatic and reticuloendothelial systems
 - a. White pulp
 - b. Red pulp
 3. Size and weight
 4. Arterial supply and venous drainage
 5. Relational anatomy
 - a. Peritoneal
- C. Variants of Normal
 1. Asplenia
 2. Polysplenia
 3. Accessory spleen (splenule)
 4. Wandering or ectopic spleen
- D. Functions
 1. Immune surveillance and response
 2. Blood filtration and maintenance
 3. Hemopoiesis (blood cell production)
 4. Platelet regulation
 5. Removal of abnormal blood cells
 6. Production of growth factors
- E. Laboratory Values
 1. White blood count (WBC)
 - a. Leukocytosis
 - b. Leukopenia
 2. Red blood count (RBC)
 - a. Decreased RBC

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- b. Increased RBC
 - 3. Hematocrit
 - a. Increase
 - b. Decrease
 - 4. Platelet count
 - a. Thrombocytosis
 - b. Thrombocytopenia
 - F. Indications
 - 1. Palpable spleen
 - 2. Abnormal laboratory tests
 - 3. LUQ pain
 - 4. Infectious diseases
 - 5. Sickle cell disease
 - G. Scanning Technique
 - 1. Patient preparation
 - 2. Transducer selection
 - 3. Patient positioning
 - 4. Image optimization
 - a. Homogeneous low to medium level echoes
 - b. Isoechoic, or slightly more echogenic than normal liver
 - c. Harmonic and compound imaging may improve quality
 - d. Spectral and color Doppler helpful in evaluating splenic and perisplenic vasculature
 - 5. Image protocol
 - H. Pathophysiology
 - 1. Congestive splenomegaly
 - a. Causes
 - i) Heart failure
 - ii) Cirrhosis
 - iii) Portal hypertension
 - iv) Portal/splenic vein thrombosis
 - v) Infiltrative disease
 - vi) HIV/AIDS
 - b. Clinical presentation
 - c. Sonographic findings
 - i) Variable echogenicity
 - ii) Increased size

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- d. Correlative and/or prior imaging
- e. Treatment
- 2. Infection/inflammation
 - a. Systemic
 - i) Types
 - Splenic granulomatous disease
 - Mononucleosis
 - Tuberculosis
 - Histoplasmosis
 - Schistosomiasis
 - Sarcoidosis
 - Candidiasis
 - b. Clinical presentation
 - i) Varies
 - c. Sonographic findings
 - i) Variable dependent on type
 - ii) Normal to increase in size
 - d. Correlative and/or prior imaging
 - e. Treatment
- 3. Focal
 - a. Types
 - i) Echinococcus
 - ii) Abscess
 - b. Clinical presentation
 - i) LUQ pain
 - ii) Fever
 - c. Sonographic findings
 - i) Focal mass of varying echogenicity
 - ii) Irregular borders
 - iii) Normal to increase size
 - iv) Ill-defined, thickened borders
 - v) Possible distal acoustic enhancement
 - vi) Shadow from presence of gas in the abscess
 - d. Correlative and/or prior imaging
 - e. Treatment

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4. Neoplasia

a. Benign

i) Hamartoma

- Definition
- Clinical presentation
- Sonographic findings
 - Focal well-defined mass
 - Variable echogenicity
- Correlative and/or prior imaging
- Treatment

ii) Hemangioma

- Definition
- Clinical presentation
- Sonographic findings
 - Typically small
 - Focal
 - Well-defined borders
 - Variable echogenicity
- Correlative and/or prior imaging
- Treatment

b. Malignant

i) Leukemia

- Definition
- Clinical presentation
- Sonographic findings
 - Marked splenomegaly
- Correlative and/or prior imaging
- Treatment

ii) Lymphoma

- Definition
- Clinical presentation
- Sonographic findings
 - Focal mass
 - ~ Typically hypoechoic mass
 - ~ Poorly defined margins

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- Diffuse splenomegaly
 - iii) Correlative and/or prior imaging
 - iv) Treatment
 - c. Hemangiosarcoma
 - i) Definition
 - ii) Clinical presentation
 - iii) Sonographic findings
 - Focal well-defined mass
 - Variable echogenicity
 - Variable size
 - iv) Correlative and/or prior imaging
 - v) Treatment
 - d. Metastasis
 - i) Definition
 - ii) Clinical presentation
 - iii) Sonographic findings
 - Multiple focal masses
 - Variable size and echogenicity
 - iv) Correlative and/or prior imaging
 - v) Treatment
5. Cysts
- a. Types
 - i) True cyst
 - Congenital
 - ii) Post-traumatic
 - iii) Infection
 - iv) Parasitic
 - v) Neoplastic
 - b. Clinical presentation
 - c. Sonographic findings
 - i) Variable, related to types and cause
 - Well-defined walls
 - Anechoic, hypoechoic
 - Posterior enhancement
 - Internal echoes

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- Fluid-fluid level
 - Wall thickening
 - Possible wall calcification
 - d. Correlative and/or prior imaging
 - e. Treatment
- 6. Blood disorders
 - a. Types
 - i) Hemolytic anemia
 - ii) Extramedullary hematopoiesis
 - Myelofibrosis
 - iii) Sickle cell anemia
 - iv) Polycythemia vera
 - b. Clinical presentation
 - c. Sonographic findings
 - d. Correlative and/or prior imaging
 - e. Treatment
- 7. Storage diseases
 - a. Types
 - i) Gaucher disease
 - ii) Diabetes mellitus
 - iii) Niemann-Pick disease
 - iv) Amyloidosis
 - v) Histiocytosis
 - vi) Hemochromatosis
 - b. Clinical presentation
 - c. Sonographic findings
 - d. Correlative and/or prior imaging
 - e. Treatment
- 8. Infarction
 - a. Definition
 - i) Occlusion of segment of splenic artery
 - Embolic source
 - b. Risk factors
 - c. Laboratory values
 - d. Clinical presentation
 - i) Usually asymptomatic

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- ii) Sudden onset of LUQ pain
 - e. Sonographic presentation
 - i) Wedge-shaped lesion
 - Well-defined borders
 - Base toward subcapsular surface of spleen
 - ii) Variable echogenicity
 - Time and age of infarction
 - iii) Possible small spleen
 - f. Correlative and/or prior imaging
 - g. Treatment
9. Splenic sequestration crisis in sickle cell disease
- a. Definition – acute trapping of large amount blood cells in the spleen leading to a severe drop in hematocrit
 - b. Clinical presentation
 - i) Fatigue
 - ii) Pallor
 - iii) Risk of cardiovascular collapse
 - c. Sonographic findings
 - i) Enlarged spleen
 - d. Correlative and/or prior imaging
 - e. Treatment

I. Trauma

- 1. Definition
- 2. Clinical presentation
- 3. Sonographic findings
 - a. Hematoma
 - i) Subcapsular or intraparenchymal
 - b. Free or focal accumulation of blood in intraperitoneal or retroperitoneal cavity
 - c. Variable echogenicity
 - i) Age and progression
 - d. Other
 - i) Splenomegaly
 - ii) Irregular borders
 - iii) Left pleural effusion
 - e. Doppler
- 4. Correlative and/or prior imaging

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5. Treatment
- J. Congenital Disorders
 1. Asplenia syndrome
 - a. Definition
 - i) Congenital absence of spleen
 - b. Associated with bilateral right-sidedness
 - i) Visceral heterotaxy
 - c. Incidence
 - i) Rare
 - ii) Occurs in females more frequently
 - d. Clinical presentation
 - i) Impaired immune response
 - e. Sonographic findings
 - i) Absent spleen
 - ii) Possible maldevelopments
 - Abnormal location of IVC
 - Horseshoe kidneys and other renal anomalies
 - Abnormal location of stomach and liver
 2. Polysplenia syndrome
 - a. Definition
 - i) Accessory splenic tissue
 - b. Associated with bilateral left-sidedness
 - i) Visceral heterotaxy - abnormal position of stomach and liver
 - ii) Associated with other congenital abdominal anomalies
 - c. Incidence
 - i) Rare
 - ii) Occurs in males more frequently
 - d. Clinical presentation
 - i) Asymptomatic
 - ii) Dependent upon the presence of other abnormalities
 - e. Sonographic findings
 - i) Biliary atresia with absent gallbladder
 - ii) Azygous/hemiazygous continuation of IVC with interruption of hepatic segment of IVC
 - iii) Genitourinary anomalies
 - iv) Abnormal location of liver

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- f. Correlative and/or prior imaging
- g. Treatment

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Section VI: Adrenal

1. Describe the normal anatomy and variants, function, sonographic technique and sonographic appearance of the adrenal glands
 2. Correlate the clinical indications and laboratory values associated with adrenal pathology
 3. Describe adrenal pathology in terms of sonographic appearances, sequelae and associated pathologies
 4. Describe associated pathologies and sequelae
-

VI. ADRENAL

- A. Embryology
- B. Anatomy
 - 1. Microanatomy
 - a. Cortex
 - i) Zona glomerulosa
 - ii) Zona fasciculata
 - iii) Zona reticularis
 - b. Medulla
 - 2. Macroanatomy
 - a. Paired organs
 - b. Retroperitoneal
 - c. Arterial supply
 - d. Venous drainage
 - 3. Relational anatomy
- C. Variants
 - 1. Agenesis – most commonly associated with unilateral renal agenesis
- D. Function
 - 1. Paired endocrine glands
 - 2. Cortex secretes steroids
 - a. Mineralocorticoids
 - b. Glucocorticoids
 - c. Gonadal hormones
 - 3. Medulla secretes
 - a. Catecholamines
 - i) Epinephrine
 - ii) Norepinephrine
 - b. Endocrine glands
 - 4. Hyperfunction
 - a. Cushing's disease/syndrome

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- b. Adrenogenital (AG) syndrome
 - c. Conn's disease
 - 5. Hypofunction
 - a. Addison's disease
- E. Laboratory values
 - 1. Aldosterone
 - 2. Cortisol
 - 3. Adrenocorticotrophic hormone (ACTH)
 - 4. Catecholamines
 - 5. Total metanephrines
 - 6. Vanillylmandelic acid (VMA) and homovanillic acid (HVA)
- F. Indications
 - 1. Decreased hematocrit – suspected hemorrhage
 - 2. Hypertension
 - 3. Virilism
 - 4. Adrenal incidentalomas - discovered incidentally during CT/MRI imaging for other reasons
- G. Sonographic technique
 - 1. Patient preparation
 - 2. Transducer selection
 - 3. Patient positioning
 - 4. Imaging optimization
 - 5. Imaging protocol
- H. Normal sonographic findings
 - 1. Pediatric
 - a. Hypoechoic cortex and a more echogenic medulla
 - 2. Adult
 - a. Not routinely visualized
- I. Pathophysiology
 - 1. Neoplasia
 - a. Adenoma
 - i) Definition
 - Benign adrenal tumor of epithelial origin
 - ii) Clinical presentation
 - Asymptomatic
 - Cushing's syndrome

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- Conn's syndrome
- iii) Sonographic findings
 - Focal mass
 - Variable size
 - Unilateral or bilateral
 - Variable echogenicity
- iv) Correlative and/or prior imaging
- v) Treatment
- b. Adenocarcinoma
 - i) Definition
 - Primary adrenal malignant tumor of epithelial origin
 - ii) Clinical presentation
 - Asymptomatic
 - Cushing's syndrome
 - Precocious puberty or virilization
 - Conn's syndrome
 - iii) Sonographic findings
 - Variable size
 - Variable echogenicity
 - Complex
 - Calcifications in some
 - iv) Correlative and/or prior imaging
 - v) Treatment
- c. Neuroblastoma
 - i) Definition
 - Pediatric malignant tumor arising in the adrenal medulla or autonomic nervous system
 - ii) Clinical presentation
 - Asymptomatic
 - Palpable mass
 - Weight loss
 - Pallor
 - Fever
 - Hypertension
 - Tachycardia

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- Diaphoresis
- iii) Laboratory values
 - Elevated catecholamines
- iv) Sonographic findings
 - Focal mass
 - Heterogeneous
 - Calcifications
 - Renal displacement
 - May metastasize to bone and regional lymph nodes
- v) Correlative and/or prior imaging
- vi) Treatment
- d. Pheochromocytoma
 - i) Definition
 - Chromaffin cell tumor originating in adrenal medulla or chromaffin tissue of sympathetic paraganglia
 - ii) Incidence
 - iii) Clinical presentation
 - Hypertension
 - Headache
 - Palpitations
 - Tachycardia
 - Diaphoresis
 - iv) Laboratory values
 - v) Sonographic findings
 - Focal mass
 - Unilateral or bilateral
 - Variable in appearance
 - Metastasizes to liver, lymph nodes, lung, and bone if malignant
 - vi) Doppler findings
 - Increased blood flow
 - Hypervascular pattern
 - vii) Correlative and/or prior imaging
 - viii) Treatment
- e. Metastases
 - i) Definition

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- Growth of malignant cells distant from primary site
 - ii) Clinical presentation
 - Asymptomatic
 - Addison's disease
 - iii) Sonographic findings
 - Focal mass
 - Unilateral or bilateral
 - Varying echogenicity
 - Varying size
 - iv) Correlative and/or prior imaging
 - v) Treatment
- 2. Inflammation/Infection
 - a. Abscess
 - i) Definition
 - Focal collection of pus from disintegration of tissue
 - ii) Clinical presentation
 - Fever
 - Pain
 - Leukocytosis
 - iii) Sonographic findings
 - Focal mass
 - Variable echogenicity
 - Acoustic enhancement
 - Fluid-fluid levels
 - Hyperechoic foci with shadowing
 - iv) Correlative and/or prior imaging
 - v) Treatment
 - b. Infectious disease
 - i) Tuberculosis
 - Chronic, granulomatous infection by *mycobacterium tuberculosis*
 - ii) Histoplasmosis
 - Infection caused by inhalation of fungal spores *histoplasma capsulatum*
 - iii) Cytomegalovirus
 - Infection by species-specific herpes-type virus
 - iv) Clinical presentation

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- Addison's disease
 - v) Sonographic findings
 - Acute
 - Bilateral enlargement
 - Inhomogeneous
 - Chronic
 - Calcification
 - vi) Correlative and/or prior imaging
 - vii) Treatment
3. Other
- a. Hemorrhage
 - i) Types
 - Spontaneous
 - Posttraumatic
 - Neonatal – often bilateral
 - ii) Clinical presentation
 - Decreased hematocrit
 - Abdominal pain
 - Asymptomatic
 - iii) Sonographic findings
 - Appearance dependent upon age of bleed
 - iv) Correlative and/or prior imaging
 - v) Treatment
 - b. Cyst
 - i) Types
 - Endothelial
 - Pseudocyst
 - Epithelial
 - Parasitic
 - ii) Clinical presentation
 - Asymptomatic
 - iii) Sonographic findings
 - Round, anechoic, thin-walled mass
 - Acoustic enhancement
 - Wall calcifications may be seen

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- iv) Correlative and/or prior imaging
- v) Treatment

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Section VII: Abdominal Vasculature

1. Describe the normal anatomy and variants, function and sonographic appearance of the major abdominal vasculature
 2. Understand the clinical indication of the study and laboratory values associated with vascular disease
 3. Recite the protocol for sonographic assessment of the abdominopelvic vasculature
 4. Describe vascular pathology in terms of sonographic appearances, sequelae and associated pathologies
 5. Identify normal and abnormal flow characteristics and waveforms
 6. Discuss current diagnostic Doppler criteria
-

VII. ABDOMINAL VASCULATURE

- A. Embryology
 - B. Anatomy
 1. Vessel wall layers
 - a. Tunica intima
 - b. Tunica media
 - c. Tunica adventitia
 2. Systemic vs. portal venous circulation
 3. Arterial anatomy
 - a. Abdominal aorta
 - i) Anterior branches
 - Celiac axis/trunk
 - Splenic artery
 - Left gastric artery (LGA)
 - Hepatic artery
 - ~ Common hepatic
 - ~ Proper hepatic
 - Right hepatic
 - Left hepatic
 - ~ Gastroduodenal
 - Superior mesenteric artery (SMA)
 - Inferior mesenteric artery (IMA)
- ii) Lateral branches
 - Right renal
 - Left renal
 - Left gonadal
 - Right gonadal
- iii) Bifurcation
 - Right common iliac

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- Right internal iliac
 - Right external iliac
 - Left common iliac
 - Left internal iliac
 - Left external iliac
- C. Arterial Variants
 1. Most common
 - a. Multiple renal arteries
 - b. Replaced right hepatic artery
 - c. Common trunk of SMA/cealic artery
- D. Functions
 1. Arteries
 2. Veins
 3. Capillaries
- E. Laboratory Values
 1. Hematocrit
 2. White blood count (WBC)
 3. Red blood count (RBC)
 4. Platelets
- F. Indications
 1. Pulsatile abdominal mass
 2. Abdominal pain
 3. Abdominal bruit
 4. Back pain
 5. Hypertension
 6. Hemodynamic compromise of lower extremities
 7. Swelling of the lower extremities
 8. Portal hypertension
 9. Pre-transplant assessment
- G. Sonographic Technique
 1. Patient preparation
 2. Transducer selection
 3. Positioning
 4. Image optimization
 5. Image protocol

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H. Normal Arterial Sonographic Findings

1. Measurements

- a. AP aorta – outer to outer wall (sagittal) and transverse (right to left) – outer to outer wall (coronal)
- b. Proximal, mid, distal aorta
- c. Proximal common iliac arteries

2. Parallel walls

3. Pulsatility

4. Anechoic lumen

5. Doppler

a. Aorta

- i) High resistance proximal to renal arteries
- ii) Triphasic distal to renal arteries

b. Celiac

- i) Low resistance

c. Splenic

- i) Low resistance
- ii) Turbulent distally

d. Hepatic

- i) Low resistance

e. SMA

- i) Pre-prandial
 - High resistance
- ii) Post-prandial
 - Low resistance

f. IMA

- i) High resistance

g. Renal arteries

- i) Low resistance

h. Common iliac arteries

- i) High resistance

i. External iliac arteries

- i) High resistance

I. Arterial Pathophysiology

1. Atherosclerosis

a. Definition

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- b. Types
- c. Complications
 - i) Thrombus
 - ii) Embolus
 - iii) Stenosis
 - iv) Occlusion
 - v) Aneurysm
- 2. Aortic ectasia/arteriomegaly
 - a. Definition
 - i) Diffuse, mild enlargement of aorta without distal tapering
 - b. Clinical presentation
 - i) Asymptomatic
 - c. Sonographic findings
 - i) Diffuse enlargement of aorta
 - d. Correlative and/or prior imaging
- 3. True aneurysm
 - a. Definition
 - i) Abnormal dilation of segment of arterial wall
 - b. Types
 - i) Fusiform
 - ii) Saccular
 - iii) Mycotic
 - c. Abdominal aortic aneurysm (AAA)
 - i) Focal or diffuse dilation of abdominal aorta
 - ii) Incidence
 - iii) Risk factors
 - iv) Clinical presentation
 - Asymptomatic
 - Palpable, pulsatile abdominal mass
 - Abdominal, back, or leg pain
 - Abdominal bruit
 - v) Sonographic findings
 - 2-D
 - Increased size of aorta (focal or diffuse)
 - Types
 - Location

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- Measurement technique
 - Irregular walls
 - Calcifications
 - Thrombus
 - Doppler
- vi) Correlative and/or prior imaging
- vii) Treatment
 - Surgical
 - Endovascular stent graft
- d. Other arterial abdominal aneurysms
 - i) Renal
 - ii) Common Iliac
 - iii) Splenic
 - iv) Hepatic
- 4. Aortic dissection
 - a. Definition
 - i) False lumen between intima and media of vessel wall
 - ii) Most common is origination in thoracic aorta
 - b. Classifications
 - i) DeBakey
 - ii) Stanford
 - c. Clinical presentation
 - i) Abdominal pain
 - ii) Back pain
 - d. Sonographic findings
 - i) Flow within true and false lumen of vessel
 - ii) Mild to no dilation of the vessel
 - iii) Thin, echogenic linear structure in true lumen (intimal flap)
 - e. Doppler findings
 - i) To and fro flow on spectral tracings in false lumen
 - ii) Opposing color in false lumen on diastole
 - f. Correlative imaging
 - g. Treatment
- 5. Aortic rupture
 - a. Definition

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- i) Disruption of all three layers of aortic wall with blood leakage into retroperitoneum, peritoneal, or thoracic cavity; typically, infrarenal and left lateral location
 - b. Clinical presentation
 - i) Abdominal pain
 - ii) Loss of consciousness
 - iii) Decreased vital signs
 - iv) Hypotensive
 - c. Sonographic findings
 - i) Para-aortic hematoma, typically left flank
 - ii) Varying echogenicity
 - iii) May displace left kidney
 - d. Treatment
 - i) Surgical emergency
 - ii) 50% mortality rate
- 6. Pseudoaneurysm
 - a. Definition
 - i) Leaking of arterial blood into the surrounding tissue creates a collection of blood that becomes self-contained and communicates with the artery via a neck
 - b. Risk factors
 - i) Iatrogenic, post procedural
 - ii) Trauma
 - c. Clinical presentation
 - i) Focal abdominal pain
 - ii) Pulsatile mass
 - iii) Bruising
 - d. Sonographic findings
 - i) Focal mass of varying echogenicity
 - ii) Identification of narrow connection (neck) between vessel and mass
 - iii) Doppler
 - Bidirectional spectral appearance in neck
 - Yin-yang color appearance in flow lumen
 - e. Treatment
 - i) Ultrasound-guided thrombin injection
 - ii) Ultrasound-guided compression
 - iii) Surgery

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7. Splanchnic artery aneurysms
 - a. Types
 - i) Splenic artery – most common type of splanchnic artery aneurysm
 - Usually multiple
 - Occur in main splenic arterial trunk
 - Female preponderance
 - Not very common but can be life threatening
 - ii) Hepatic artery – 2nd most common type of splanchnic vessel aneurysms encountered
 - 75% extrahepatic in origin
 - 25% occurs intrahepatically
 - Right hepatic arterial branch predominance
 - Rare, male preponderance
 - iii) Superior mesenteric artery
 - Rarest splanchnic artery aneurysm
 - b. Sonographic findings
 - i) 2D
 - ii) Spectral/color Doppler
8. Renal artery stenosis
 - a. Definition
 - i) Elevation in blood pressure due to decreased renal blood flow
 - b. Clinical presentation
 - i) Hypertension
 - c. Sonographic findings
 - i) Elevated velocity in the main renal artery
 - ii) Dampened (tardus et parvus) pattern in the intrarenal arteries

J. Venous Anatomy

1. Inferior vena cava (IVC)
 - a. Tributaries
 - i) Right and left common iliacs
 - ii) Ascending lumbar
 - iii) Right gonadal
 - iv) Renal veins
 - Right
 - Left
 - Left gonadal

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- v) Hepatic veins
 - Right
 - Middle
 - Left
- 2. Hepatoportal venous system
 - a. Main portal
 - i) Tributaries
 - Splenic
 - Inferior mesenteric (IMV)
 - Superior mesenteric (SMV)
 - Coronary (left gastric)
 - Pyloric (right gastric)
 - b. Branches
 - i) Right portal
 - Anterior
 - Posterior
 - ii) Left portal
 - Medial
 - Lateral
 - 3. Variants/anomalies
 - a. Accessory hepatic veins
 - b. Transposition of the IVC
 - c. Partial transposition
 - d. Situs inversus
 - e. Asplenia syndrome
 - f. Azygous continuation of the IVC
 - g. Retro-aortic left renal vein
 - 4. Indications
 - a. Known pathology
 - b. Follow up studies
 - c. IVC filter
 - d. Swelling of trunk, lower extremities
 - 5. Sonographic technique
 - a. Patient preparation
 - b. Transducer selection

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- c. Patient positioning
- d. Imaging optimization
- e. Imaging protocol
- 6. Normal sonographic findings
 - a. Cava and tributaries
 - i) Anechoic lumen
 - ii) Varying luminal size
 - b. Portal
 - i) Anechoic lumen
 - ii) Portal vein walls hyperechoic to liver parenchyma
- 7. Normal Doppler appearance
 - a. IVC
 - i) Pulsatile Doppler pattern by diaphragm and phasic Doppler pattern in distal abdomen
 - b. Hepatic veins
 - i) Pulsatile
 - c. Renal veins
 - i) Monophasic
 - d. Splenic vein
 - i) Hepatopetal
 - e. Portal vein
 - i) Hepatopetal flow
- 8. Venous pathophysiology
 - a. IVC
 - i) Intraluminal thrombus
 - Definition
 - Most common intraluminal finding in IVC
 - Extension of thrombus from tributary vein – renal, hepatic, iliac, gonadal, adrenal
 - Clinical presentation
 - Asymptomatic
 - Swelling/edema of lower extremities
 - Sonographic findings
 - 2-D
 - ~ Intraluminal mass of varying echogenicity; if malignant – lumen enlargement
 - ~ Luminal stenosis or occlusion

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- Doppler
 - Correlative and/or prior imaging
 - Treatment
- ii) Intravascular tumor
 - Definition
 - Most common - caval thrombus due to tumor; renal cell carcinoma, hepatocellular carcinoma, breast and adrenal carcinoma
 - Primary caval tumors are rare with leiomyosarcoma
 - Sonographic findings
 - 2-D
 - ~ Vessel enlargement
 - ~ Intraluminal mass of varying echogenicity
 - Doppler
 - ~ Signal from tumor mass
 - Correlative and/or prior imaging
 - Treatment
- iii) Arteriovenous (AV) shunts
 - Definition
 - Abnormal connection between artery and vein
 - Types
 - Arteriovenous malformations
 - Arteriovenous fistula
 - Indications
 - Presence of bruit or thrill associated with dilated pulsatile mass
 - Low back and abdominal pain
 - Swelling of lower trunk and extremities
 - Renal A-V fistulas
 - Hematuria
 - Hypertension
 - Cardiomegaly
 - Heart failure (rare)
 - Abdominal bruit
 - Doppler findings
 - Pulsatile, arterialized venous waveform
 - Increased systolic and diastolic arterial velocities proximal to fistula (decreased RI)

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- Reverts to normal diastolic flow distal to fistula
 - Perivascular tissue vibration
 - Correlative and/or prior imaging
 - Treatment
 - b. Portal hypertension (PH)
 - i) Definition
 - Increased resistance to flow or increased flow in portal system
 - Prehepatic
 - Intrahepatic
 - Posthepatic
 - ii) Clinical presentation
 - Asymptomatic
 - Symptomatic
 - Hematemesis, varices
 - Abdominal distention, ascites
 - Splenomegaly
 - Hepatic failure
 - Jaundice
 - iii) Sonographic findings
 - 2-D
 - Increase in portal vein diameter
 - Splenomegaly
 - Presence of portosystemic collaterals
 - Ascites
 - Variable hepatic appearance
 - Doppler
 - Hepatopetal flow
 - ~ Low velocity, reduced or minimal undulations
 - Hepatofugal flow
 - ~ Enlarged tortuous hepatic artery with high velocities
 - iv) Correlative and/or prior imaging
 - c. Portal vein thrombosis
 - i) Presence of thrombus in portal system, may be benign or malignant
 - ii) Clinical presentation
 - iii) Sonographic findings

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- 2-D
 - Intraluminal thrombus of variable echogenicity
 - Presence of collaterals (cavernous transformation)
 - Presence of flow in the thrombus (malignant)
- Doppler
 - Lack of flow in portal vein
 - Enlarged hepatic artery
- iv) Correlative and/or prior imaging
- v) Treatment
 - Transjugular intrahepatic portosystemic shunt (TIPS)
 - Pathophysiology
 - Sonographic assessment
- d. Cavernous transformation of the portal vein
 - i) Definition - sequela of portal vein obstruction
 - ii) Clinical presentation
 - Hematemesis
 - iii) Sonographic findings
 - 2-D
 - Multiple anechoic tubular channels in porta hepatis indicating presence of collaterals
 - No normal portal vein visualized
 - Doppler
 - Multiple small portal venous-like vessels in porta hepatis which may extend into the liver
 - iv) Correlative and/or prior imaging
 - v) Treatment

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Section VIII: Gastrointestinal Tract (GI)

1. Describe the normal anatomy and variants, function, sonographic technique and normal sonographic appearances of the GI tract
 2. Correlate the clinical indications and laboratory values associated with GI tract disease
 3. Describe GI tract pathology in terms of sonographic appearances
 4. Describe associated pathologies and sequelae relative to GI tract disease
-

VIII. GASTROINTESTINAL TRACT

- A. Embryology
- B. Anatomy
 1. Wall
 - a. Constant with layers; listed from the outer layer to inner layer
 - i) Serosa – outermost
 - ii) Muscularis propria
 - iii) Submucosa
 - iv) Mucosa
 - Muscularis mucosa
 - Lamina propria
 - Epithelial layer
 - b. Specific morphologic features
 - i) Stomach
 - Rugae
 - ii) Small intestine
 - Valvulae conniventes
 - iii) Large intestine
 - Haustra
 2. Macroanatomy
 - a. Esophagus
 - b. Stomach
 - i) Parts
 - Fundus
 - Body
 - Pylorus
 - ii) Openings of orifices
 - Cardiac
 - Pyloric

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- iii) Curvatures
 - Greater
 - Lesser
- iv) Surfaces
 - Anterior/superior
 - Posterior/inferior
- c. Small intestine
 - i) Duodenum
 - Superior/first part
 - Descending/second part
 - Transverse/third part
 - Ascending/fourth part
 - ii) Jejunum
 - iii) Ileum
 - Ileocecal valve
- d. Large intestine/colon
 - i) Cecum
 - ii) Appendix
 - iii) Ascending colon
 - iv) Transverse colon
 - v) Descending colon
 - vi) Sigmoid colon
 - vii) Rectum
 - viii) Anal canal
- 3. Relational anatomy
- C. Variants
 - 1. Duplication cyst
- D. Function
 - 1. Esophagus
 - 2. Stomach
 - a. Storage of food
 - b. Mixing of food with gastric secretions until chyme is formed
 - c. Permits food to empty slowly into duodenum
 - 3. Small intestine
 - a. Absorption of food

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- b. Breakdown of starch, protein and fats
 - c. Emulsifies fats
 - 4. Colon
 - a. Intestinal walls reabsorb liquid
 - b. Wastes formed into solid feces
- E. Laboratory Values
 - 1. WBC
 - 2. Hematocrit
 - 3. Hemoglobin
- F. Indications
 - 1. Pain
 - 2. Vomiting
 - 3. Bleeding
 - 4. Fever
 - 5. Leukocytosis
 - 6. Palpable mass
 - 7. Distension related to bowel obstruction
- G. Sonographic Technique
 - 1. Patient preparation
 - a. Six-hour fast is recommended
 - 2. Transducer selection
 - 3. Patient positioning
 - a. Supine
 - b. Decubitus
 - 4. Imaging optimization
 - a. High-contrast greyscale
 - b. Color Doppler
 - 5. Imaging protocol
 - a. Survey should include the entire region of the bowel with a methodical approach to avoid omission of regions.
- H. Normal Sonographic Findings
 - 1. The 'gut signature' (from lumen outward)
 - a. Hyperechoic mucosal layer
 - b. Hypoechoic intramural layer
 - c. Hyperechoic submucosa
 - d. Hypoechoic muscularis propria

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- e. Hyperechoic serosal layer
 - 2. Compressibility
 - a. Normal bowel is compressible
 - b. Thickened or infiltrated bowel is generally not compressible
 - 3. Measurements
 - a. Wall
 - b. Appendix
 - 4. Doppler
- I. Pathology
- 1. Inflammation
 - a. Crohn's disease
 - i) Definition
 - Manifestation of inflammatory bowel disease (IBD) consisting of chronic, relapsing bouts of inflammation – most commonly involving terminal portion of the ileum
 - ii) Complications
 - Fistula formation
 - Abscess
 - Perianal ulcerations/fistulae
 - Luminal narrowing
 - Stricture
 - Perforation
 - Inflammatory mass
 - iii) Clinical presentation
 - Pain
 - Fever
 - Weight loss
 - Diarrhea
 - iv) Sonographic findings
 - Related to the abnormal or involved bowel
 - Target pattern
 - Thickened bowel wall
 - Thickened bowel loops
 - Non-compressibility of bowel loop
 - Increased echogenicity of mesentery – creeping fat

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- Increased blood flow as assessed on color Doppler imaging
 - Lymphadenopathy
 - Related to complications
 - Abscess/phlegmon
 - Fistula
 - Dilated fluid filled bowel proximal to a site of stricture or luminal compromise, suggesting incomplete bowel obstruction
 - v) Correlative and/or prior imaging
 - vi) Treatment
- b. Appendicitis
 - i) Definition
 - Inflammation usually caused by obstruction
 - ii) Complications
 - Rupture
 - Abscess
 - iii) Clinical presentation
 - RLQ pain
 - Fever
 - Nausea and vomiting
 - Rebound tenderness
 - McBurney's sign
 - iv) Sonographic findings
 - RLQ target sign
 - Increased size of appendix
 - Increased size of appendiceal wall
 - Non-compressibility
 - Pericecal fluid
 - Abscess
 - Appendicolith
 - Fecalith
 - Fat stranding
 - v) Correlative and/or prior imaging
 - vi) Treatment
- c. Diverticulitis
 - i) Definition

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- Diverticular inflammation
- ii) Complications
 - Rupture
 - Abscess
- iii) Clinical presentation
 - Pain
 - Fever
- iv) Sonographic findings
 - Concentric wall thickening
 - Outpouching from gut wall
 - Non-compressibility of wall
 - Pericolonic fat changes
 - Poorly defined hyperechoic zones
 - Abscess
 - Localized fluid collections
 - Acoustic enhancement
 - Fistula
 - Linear echogenic tracts connecting bowel to other structures
 - Correlative and/or prior imaging
 - Treatment
- d. Ischemic bowel disease
 - i) Definition
 - Inadequate blood supply resulting in vascular compromise to bowel
 - ii) Clinical presentation
 - Abdominal pain
 - Weight loss
 - Post-prandial pain
 - iii) Sonographic findings
 - 2 D
 - Decreased or absent peristalsis
 - Bowel wall thickening
 - Dilated bowel loops
 - Target or double halo sign
 - Portal venous gas
 - Free intraperitoneal fluid

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- Doppler
 - Decreased or absent blood flow in the affected bowel wall
 - Increased resistive indices (RI) in mesenteric arteries
 - iv) Correlative and/or prior imaging
 - v) Treatment
2. Neoplasia
- a. Adenocarcinoma
- i) Definition
 - Malignant primary neoplasia derived from glandular tissue
 - Most common location is the colon, rectum and rectosigmoid
 - ii) Clinical presentation
 - Dependent on location
 - Asymptomatic
 - Obstruction
 - Anemia
 - Change in bowel habits
 - Weight loss
 - iii) Sonographic findings
 - Most common appearance is that of a mural mass
 - Thickened bowel wall
 - Target appearance or pseudokidney
 - Hypoechoic mass
 - Loss of continuity of wall layers
 - Metastasis to liver
 - iv) Correlative and/or prior imaging
 - v) Treatment
- b. Leiomyoma
- i) Definition
 - Benign tumor composed of smooth muscle cells – stomach is most common GI location
 - ii) Clinical presentation
 - Obstruction
 - Weight loss
 - iii) Sonographic findings
 - Thickened bowel wall

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- Target pattern
 - Variable echogenicity
- iv) Correlative and/or prior imaging
- v) Treatment
- c. Leiomyosarcoma
 - i) Definition
 - Malignant sarcoma containing smooth muscle cells
 - Most commonly referred to as gastrointestinal stromal tumor or GIST
 - ii) Clinical presentation
 - Obstruction
 - Weight loss
 - iii) Sonographic findings
 - Target pattern
 - Thickened bowel wall
 - Mural mass
 - Variable echogenicity
 - Complexity related to the tendency of necrosis
 - iv) Correlative and/or prior imaging
 - v) Treatment
- d. Lymphoma
 - i) Definition
 - Neoplastic primary of lymphoid tissue – may be primary to GI tract or metastatic
 - ii) Clinical presentation
 - Dependent on location
 - Asymptomatic
 - Obstruction
 - Weight loss
 - iii) Sonographic findings
 - Thickened bowel wall, with a strong tendency to hypoechogenicity
 - Target pattern
 - Hypoechoic mass
 - iv) Correlative and/or prior imaging
 - v) Treatment
- e. Metastases

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- i) Definition
 - Growth of malignant cells distant from primary site
 - ii) Clinical presentation
 - Dependent on location
 - Asymptomatic
 - Obstruction
 - Weight loss
 - iii) Sonographic findings
 - Thickened bowel wall
 - May produce a focal mass or a plaque like infiltration of the bowel wall
 - Target pattern
 - Varying echogenicity
 - iv) Correlative and/or prior imaging
 - v) Treatment
3. Obstruction
- a. Mechanical
 - i) Physical cause of obstruction of GI lumen
 - ii) Clinical presentation
 - Abdominal pain
 - Vomiting
 - Abdominal distention
 - iii) Sonographic findings
 - Dilated bowel loops
 - Hyperperistalsis
 - Site of obstruction is marked by a caliber alteration of the dilated bowel. A mass or bowel wall thickening may be shown at this site.
 - iv) Correlative and/or prior imaging
 - v) Treatment
 - b. Paralytic ileus
 - i) Paralysis of intestinal musculature
 - ii) Clinical presentation
 - Change in bowel habits
 - Abdominal distention
 - Abdominal pain
 - iii) Sonographic findings

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- Dilated bowel loops
 - Fluid-fluid level in dilated loop
 - Aperistaltic bowel loops
 - iv) Correlative and/or prior imaging
 - v) Treatment
- c. Intussusception
 - i) Definition
 - Invagination of segment of bowel into adjoining section
 - ii) Clinical presentation
 - Abdominal pain
 - Abdominal distension
 - Vomiting
 - Currant jelly stool
 - iii) Sonographic findings
 - Multiple concentric rings – donut sign
 - Target appearance
 - Pseudokidney appearance
 - Contains echogenic fat and lymph nodes
 - iv) Correlative and/or prior imaging
 - v) Treatment
- d. Volvulus
 - i) Definition
 - Torsion of a loop of bowel
 - ii) Clinical presentation
 - Abdominal pain
 - Vomiting
 - iii) Sonographic findings
 - Dilated bowel loops
 - Swirling/whirlpool sign of mesenteric vessels
 - iv) Correlative and/or prior imaging
 - v) Treatment
- e. Hypertrophic pyloric stenosis (HPS)
 - i) Definition
 - Congenital condition characterized by hypertrophy and hyperplasia of circular layer of muscle resulting in elongation of pylorus and constriction of canal

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- ii) Clinical presentation
 - Projectile vomiting – non-bilious, typically after feeding
 - Olive sign – enlarged pylorus felt on physical exam
 - Failure to thrive
 - Age range 2 -9 weeks
- iii) Sonographic findings
 - Target pattern
 - Elongated canal pyloric channel > 15-18 mm
 - Thick muscular wall > 3 mm
 - Non-visualization of emptying of stomach contents into duodenum
 - Protrusion of hypertrophied pyloric muscle into the antrum
- iv) Correlative and/or prior imaging
 - Upper gastrointestinal series (UGI)
- v) Treatment
 - Surgical intervention
 - Pyloromyotomy
 - ~ A surgical procedure where the hypertrophied pyloric muscle is incised to relieve the obstruction
- f. Midgut malrotation
 - i) Definition
 - Abnormal rotation and fixation of the intestines during embryonic development can lead to volvulus (twisting of the intestine) and intestinal obstruction
 - ii) Clinical presentation
 - Bilious vomiting - often a key sign, indicating possible volvulus
 - Abdominal distension - due to obstruction
 - Acute abdomen -severe abdominal pain and signs of peritonitis if volvulus occurs
 - iii) Sonographic findings
 - Abnormal position of the SMA and SMV - superior mesenteric vein (SMV) located to the left of the superior mesenteric artery (SMA), instead of the normal right-sided position
 - Whirlpool sign - twisting of the mesentery and bowel around the SMA, seen as a swirling pattern on Doppler ultrasound.
 - Duodenal obstruction - dilated proximal duodenum with tapering and obstruction distally
 - iv) Correlative and/or prior imaging
 - Upper gastrointestinal series (UGI)

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- v) Treatment
 - Surgical intervention
 - Laparotomy

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Section IX: Abdominopelvic Wall and Cavities

1. Describe the normal anatomy and variants, function, sonographic technique and appearance of the abdominopelvic wall and cavities
 2. Correlate the clinical indications and laboratory values associated with abdominopelvic wall and cavity pathology
 3. Describe abdominopelvic wall and cavity pathology in terms of sonographic appearances, sequelae and associated pathologies
-

IX. ABDOMINOPELVIC WALL AND CAVITIES

- A. Embryology
- B. Anatomy
 1. Abdominal wall layers
 - a. Skin
 - b. Superficial fascia
 - c. Subcutaneous fat
 - d. Muscles
 2. Abdominopelvic muscles
 - a. Rectus
 - b. External oblique
 - c. Internal oblique
 - d. Transversus abdominus
 - e. Psoas
 - f. Quadratus lumborum
 3. Abdominal wall fascia, tendons and ligaments
 - a. Linea alba
 - b. Linea semilunaris
 - c. Inguinal ligament
 4. Cavities
 - a. Peritoneal layers
 - i) Parietal
 - ii) Visceral
 - b. Peritoneal compartments
 - i) Lesser sac - left posterior subhepatic
 - Foramen of Winslow
 - ii) Greater sac
 - Subdiaphragmatic
 - Right

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- Left anterior – perigastric
 - Left posterior – perisplenic
 - Subhepatic
 - Right
 - ~ Hepatorenal
 - ~ Morison's pouch
 - Left anterior
 - ~ Hepatogastric recess
 - Subsplenic
 - Perinephric
 - Pelvic
 - Male
 - ~ Rectovesical
 - Female
 - ~ Vesicouterine
 - ~ Rectouterine [pouch of Douglas (POD)]
- c. Peritoneal reflections
 - i) Ligaments/mesentery
 - ii) Falciform
 - iii) Coronary
 - iv) Triangular
 - v) Hepatoduodenal
 - vi) Hepatogastric
 - vii) Gastrocolic
 - viii) Gastrosplenic
 - ix) Transverse mesocolon
 - x) Sigmoid mesocolon
 - xi) Small bowel mesentery
- d. Peritoneal omenta/compartments
 - i) Greater
 - ii) Lesser
- e. Retroperitoneal compartments
 - i) Anterior pararenal
 - ii) Perirenal
 - Anterior perirenal fascia/Gerota's fascia

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- Posterior perirenal fascia/Zuckerkandl's fascia
- iii) Posterior pararenal
- iv) Retrofascial space
 - Psoas muscle
 - Quadratus lumborum muscle
- f. Retroperitoneal organs/structures
 - i) Diaphragmatic crura
 - ii) Vessels
 - Aorta
 - Inferior vena cava (IVC)
 - Superior mesenteric
 - Hepatic
 - Splenic
 - iii) Pancreas
 - iv) Second, third, and fourth parts of the duodenum
 - v) Kidneys
 - vi) Adrenals
 - vii) Ascending, descending colon
 - viii) Distal portion of common bile duct
 - ix) Lymph nodes
- g. Extraperitoneal spaces
 - i) Space of Retzius
 - ii) Rectovesical
 - iii) Right, left paravesical
 - iv) Presacral
 - v) Right, left pararectal
- h. Extraperitoneal organs
 - i) Female
 - Urinary bladder
 - Distal ureters
 - Uterus
 - Rectum
 - ii) Male
 - Urinary bladder
 - Distal ureters

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- Prostate
 - Seminal vesicles
 - Rectum
 - iii) Posterior pararenal
 - iv) Retrofascial space
 - i. Thoracic cavity
 - i) Pleural cavities
 - Right
 - Left
 - ii) Layers
 - Parietal
 - Visceral
 - iii) Organs
 - Lungs
 - Heart
 - Thymus
 - j. Relational anatomy
- C. Variants
1. Urachal anomalies
- D. Indications
1. Fever
 2. Pain
 3. Palpable mass
 4. Bleeding
 5. Trauma
 6. Post surgery
 7. Distended abdomen
 8. Dyspnea
 9. Differentiate loculated from nonloculated intrathoracic mass
 10. Differentiate pleural from thoracic masses
 11. Delineation of opacities noted on chest x-ray
- E. Sonographic Technique
1. Patient preparation
 2. Transducer selection
 3. Patient positioning

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4. Image optimization
5. Image protocol
- F. Normal Sonographic Appearance
 1. Abdominal wall
 - a. Skin
 - i) Thin, highly echogenic
 - b. Fat
 - i) Variable echogenicity
 - ii) Usually hypoechoic to skin and muscle
 - c. Muscle
 - i) Usually hyperechoic to subcutaneous fat
 2. Peritoneal cavity
 3. Retroperitoneum
 4. Thoracic cavity
 - a. The lung-air/visceral pleura interface is echogenic
- G. Pathophysiology
 1. Abdominal wall
 - a. Hernia
 - i) Definition
 - Protrusion of bowel or fat through opening in ventral wall where no muscle is present – may be acquired or congenital
 - ii) Types/locations
 - Ventral
 - Umbilical
 - Spigelian (inferior lumbar)
 - iii) Sonographic technique
 - High resolution linear or curved linear array transducer
 - Fascial defect
 - Valsalva maneuver
 - b. Rectus sheath hematoma
 - i) Definition
 - Focal collection of extravasated blood contained within rectus sheath
 - ii) Clinical presentation
 - Pain
 - Palpable mass
 - Decreased hematocrit

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- iii) Sonographic findings may include
 - Focal mass
 - Varying echogenicity
 - Anechoic (early)
 - Echogenic (later)
- c. Abscess
 - i) Definition
 - Localized collection of pus, which consists of purulent material, within a tissue, organ, or confined space in the body, typically caused by an infection.
 - ii) Clinical presentation
 - Focal pain
 - Palpable mass
 - Fever
 - Elevated WBC
 - iii) Sonographic findings may include
 - Focal well-defined collection
 - Varying echogenicity fluid-fluid levels
 - Hyperechoic foci with shadowing
- d. Neoplasia
 - i) Desmoid
 - Definition
 - Benign, unencapsulated fibromatous tumor arising from muscle sheath
 - Invasive but does not metastasize
 - Clinical presentation
 - Palpable mass
 - Sonographic findings
 - Focal mass
 - Varying echogenicity
 - Correlative and/or prior imaging
 - Treatment
 - ii) Metastases
 - Definition
 - Growth of malignant cells from a distant primary site
 - Clinical presentation
 - Sonographic findings

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- Focal mass
 - Varying echogenicity
 - iii) Correlative and/or prior imaging
 - iv) Treatment
- 2. Abdominopelvic cavity
 - a. Adenopathy (lymphadenopathy)
 - i) Definition
 - Enlargement of lymph nodes caused by inflammatory processes, primary tumor, or metastatic spread of cancer
 - ii) Sites
 - Para-aortic chain
 - Mesenteric and celiac
 - Pelvic adenopathy
 - Iliac chain
 - Hypogastric chain
 - Intraperitoneal chain
 - Splenic hilum
 - Parapancreatic
 - Hepatic hilum
 - iii) Sonographic findings
 - Mass(es)
 - Homogeneous, low to medium level internal echoes
 - Para-aortic nodes may be individually enlarged or present as lobulated or sheet-like masses
 - Enlarged mantle of nodes can surround aorta and possibly IVC
 - Displacement of superior mesenteric and celiac vessels anteriorly
 - Anterior displacement of aorta
 - Compression of IVC
 - iv) Correlative and/or prior imaging
 - v) Treatment
 - b. Retroperitoneal fibrosis
 - i) Definition
 - Chronic inflammatory process with fibrous tissue proliferation confined to paravertebral and central region of abdomen
 - ii) Clinical presentation
 - Urinary obstruction

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- Nausea and vomiting
 - iii) Sonographic findings
 - Solid, low-level echo mass anterior and lateral to the aorta
- c. Retroperitoneal tumors
 - i) Primary malignant
 - Liposarcoma
 - Arising from fat
 - Leiomyosarcoma
 - Arising from smooth muscle
 - Rhabdomyosarcoma
 - Sarcoma with histologic features of skeletal muscle
 - Fibrosarcoma
 - Arising from connective tissue
 - ii) Benign retroperitoneal tumors
 - Lipoma
 - Arising from fat
 - Leiomyoma
 - Arising from smooth muscle
 - Fibroma
 - Arising from connective tissue
 - iii) Sonographic findings
 - Solid mass
 - Variable size and appearance
 - May invade surrounding tissues
 - Displacement of vasculature (usually anteriorly)
 - Compression of the IVC and urinary bladder
 - Obstruction of the kidneys, ureters, extrahepatic biliary ducts
 - iv) Correlative and/or prior imaging
 - v) Treatment
- 3. Retroperitoneal fluid collections
 - a. Hematoma
 - b. Lymphocele
 - c. Urinoma
 - d. Abscess
 - e. Clinical presentation

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- i) Abdominal pain
 - ii) Fever
 - iii) Palpable mass
 - f. Sonographic findings
 - i) Focal mass
 - ii) Varying appearance
 - g. Correlative and/or prior imaging
 - h. Treatment
- 4. Peritoneal fluid collections
 - a. Ascites
 - i) Excessive accumulation of serous fluid in peritoneal cavity
 - ii) Clinical presentation
 - iii) Sonographic findings
 - Transudative ascites
 - Reflection of the dynamics of the peritoneal cavity
 - Anechoic
 - Free floating bowel loops
 - Fluid conforms to surrounding structures
 - Gallbladder wall thickening
 - Changes with patient position and probe pressure
 - Exudative ascites
 - Generally a reflection of inflammation or neoplasia
 - Echogenic debris
 - Septations
 - Matted bowel loops
 - Thickened interfaces
 - Loculated
 - Does not conform to surrounding structures
 - Does not change with patient position
 - iv) Correlative and/or prior imaging
 - v) Treatment
 - b. Focal fluid collections
 - i) Types
 - Abscess
 - Lymphocele

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- Seroma
 - Biloma
 - ii) Clinical presentation
 - Abdominal pain
 - Fever
 - Palpable mass
 - iii) Sonographic findings
 - Focal mass
 - Variable echogenicity
 - Echogenic
 - Anechoic
 - Complex
 - Septations
 - Calcifications
 - Mobile debris
 - Hyperechoic foci with shadowing
 - Acoustic enhancement
 - iv) Correlative and/or prior imaging
 - v) Treatment
5. Pseudomyxoma peritonei
- a. Definition
 - i) Metastatic spread of malignant tumor filling peritoneal cavity with mucinous material and gelatinous ascites. Tumor implants on peritoneal surfaces and produces adhesions
 - Most commonly secondary to malignant tumor of the appendix.
 - ii) Clinical presentation
 - Abdominal pain
 - Abdominal distention
 - iii) Sonographic findings
 - Complex ascites
 - Non-mobile echogenic foci within ascites
 - Scalloping of the convexities of the spleen and liver
 - iv) Correlative and/or prior imaging
 - v) Treatment
6. Peritoneal carcinomatosis
- a. Definition

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- i) Metastatic spread with diffuse involvement of peritoneum
 - b. Clinical presentation
 - i) Abdominal distention
 - ii) Abdominal pain
 - c. Sonographic findings
 - i) Ascites
 - ii) Irregular masses
 - iii) Echo poor nodules
 - iv) Thickening of peritoneum
 - d. Correlative and/or prior imaging
 - e. Treatment
- 7. Thoracic cavity
 - a. Pleural effusion
 - i) Accumulation of fluid in pleural space
 - ii) Clinical presentation
 - Dyspnea
 - Chest pain
 - iii) Sonographic findings
 - Supradiaphragmatic fluid
 - Variable echogenicity
 - Anechoic
 - Echogenic
 - iv) Correlative and/or prior imaging
 - v) Treatment
- 8. Tumor
 - a. Metastases
 - i) Growth of malignant cells distant from primary site
 - ii) Sonographic findings
 - Pleural effusion
 - Pleural thickening
 - Solid nodules in pleural cavity
 - b. Mesothelioma
 - i) Rare, fatal pleural tumor
 - ii) Sonographic findings
 - Diffuse pleural thickening

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- Calcifications
 - Pleural effusion
9. Lung abscess
 - a. Localized collection of pus from disintegration of tissue
 - b. Sonographic findings
 - i) Thick, irregular walls
 - ii) Echogenic debris
 - iii) Expansion of entire mass with inspiration
 10. Mediastinal lymphadenopathy
 - a. Enlargement of mediastinal nodes
 - b. Sonographic findings
 - i) Homogeneous masses
 - ii) Calcification
 - iii) Large, homogeneous solid mass
 11. Pericardial effusion
 - a. Accumulation of fluid between pericardial layers
 - b. Sonographic findings
 - i) Fluid in pericardial sac
 - ii) Varying echogenicity
 12. Atelectasis
 - a. Absence of air in all or part of lung
 - b. Sonographic findings
 - i) Wedge-shaped, highly echogenic homogeneous mass
 - ii) Mobile, floating lung within pleural effusion
 - iii) Motion of lung with respiration
 - iv) Pleural effusion
 13. Lung consolidation
 - a. Lung filled with fluid and cells
 - b. Sonographic findings
 - i) Wedge-shaped, echo-poor mass
 - ii) Homogeneous with branching mobile air in bronchi – appearance similar to liver
 - iii) Motion with respiration

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Section X: Interventional

1. List indications for performing invasive procedures
 2. Describe the sonographic technique for interventional procedures
 3. Correlate clinical indications and laboratory values associated with interventional procedures
 4. Describe the role of sonography in interventional procedures
 5. Identify normal and abnormal flow characteristics associated with pathology
 6. List various complications associated with interventional procedures
-

X. INTERVENTIONAL

A. Clinical Indications

1. Differentiating between benign process, primary cancer, metastatic disease, or infectious process and obtaining tissue for immunohistochemistry and molecular markers
2. Obtaining tissue in order to test for specific tumor markers/receptors that may help to tailor treatment regimen
3. Progression of disease
 - a. Hepatitis
 - b. Renal failure
 - c. Cirrhosis
4. Verifying the type and presence of disease
5. Drainage of fluid or fluid collection
 - a. Therapeutic tap
 - b. Diagnostic tap
6. Distinguishing between a fluid-filled mass and a solid tumor
7. Obtain parenchymal sample to diagnose parenchymal disease
 - a. Liver
 - b. Kidney
 - c. Transplanted organ
8. Determine cause of organ dysfunction or rejection
9. Obtain fluid for cells – diagnostic tap
 - a. Ascites
 - b. Pleural
 - c. Pericardial
10. Obtain malignant tissue for clinical trials

B. Informed Consent Process

1. Risks of procedures
2. Benefits of procedure
3. Alternatives to procedure
4. How procedure is performed

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5. Witnessing a consent
6. Time out
- C. Types
 1. Biopsy
 - a. Removal and examination of living tissue from the living body
 - b. Fine needle aspiration (FNA)
 - i) Obtains cells from tissue
 - ii) Capillary or aspiration technique
 - iii) 18–27-gauge needles (most commonly 25 gauge)
 - c. Suction technique
 - i) 18–27-gauge needles (most commonly 25 gauge)
 - d. Core
 - i) Obtain core sample of tissue
 - ii) 14–20-gauge needles
 - iii) 1 or 3 cm long core samples
 - e. Needle types
 - i) Spinal
 - ii) Franseen
 - iii) Chiba
 - iv) Echogenic tips
 - v) Echogenic stylets
 - vi) One-Step catheters for aspirating large volumes of fluid
 2. Percutaneous aspiration and/or drainage
 - a. Paracentesis
 - b. Thoracentesis
 - c. Fluid collections
 - d. Indwelling catheter
 - i) Percutaneous nephrostomy
 - ii) Abscess
- D. Contraindications
 1. Bleeding disorder
 - a. Laboratory values
 - i) Prothrombin time (PT)
 - ii) Partial thromboplastin time (PTT)
 - iii) International normalized ratio (INR)
 - b. Bleeding correction methods

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- i) Platelet therapy
 - ii) Fresh frozen plasma (FFP)
 - c. Anti-coagulant therapy
 - d. Inability to give consent
 - e. Inability to cooperate
- E. Risk Factors of Procedure
 - 1. Bleeding
 - 2. Infection
 - 3. Seeding of biopsy tract with tumor
 - 4. Inconclusive results
 - 5. Inadequate sample
 - 6. Arteriovenous fistula (AVF)
 - 7. Organ damage or tissue adjacent to organ
 - 8. Collapsed lung if thoracentesis
- F. Sedation
 - 1. General anesthesia/deep sedation
 - a. Pediatric patient
 - b. Patient and performing team comfort
 - c. Patient asleep
 - d. Greatest risk to patient
 - e. Usually performed by anesthesia team
 - 2. Conscious/moderate intravenous sedation
 - a. Patient is given medication to relieve anxiety
 - b. Patient is given medication to relieve pain
 - c. Pharmacology, sedation usually performed by an IR nurse in collaboration with the proceduralist
 - d. Safer than deep sedation
 - 3. Local anesthesia
 - a. Most common for superficial procedures and paracenteses/thoracenteses
 - b. Need patient cooperation
 - c. Local skin anesthetized
 - d. Least risk to patient
- G. Sonographic Technique
 - 1. Correlative image assessment
 - a. CT, MRI, PET/CT, CEUS, prior imaging
 - 2. Patient preparation

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- a. Consent
 - b. Position
 - c. Location of lesion
- 3. Transducer selection
- 4. Sterile technique
- 5. Image optimization
 - a. 2-D
 - b. Doppler
 - i) Avoid major blood vessels
 - ii) Target areas of solid tumor with vascular blood flow; suggestive of viable tissue
 - c. Fusion technology
 - i) US/CT
 - ii) US/MRI
- 6. Guidance Approach
 - a. Transabdominal
 - b. Endovaginal
 - c. Transrectal
 - d. Transperineal
- 7. Protocol
 - a. Sonographic guidance
 - i) Transducer guide attachment
 - ii) Free hand technique
 - b. Patient care techniques
- H. Complications
 - 1. Bleeding
 - 2. Hematoma
 - 3. Vasovagal Reaction
 - 4. Arteriovenous Fistula
 - 5. Pseudoaneurysm
 - 6. Pneumothorax
 - 7. Hemoptysis
 - 8. Damage to Adjacent Organs

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Section XI: Organ Transplant

- I. List indications for organ transplant
 - II. Describe normal anatomy, organ function, sonographic technique and sonographic appearance related to organ transplant
 - III. Correlate clinical indications and laboratory values associated with organ transplant
 - IV. Describe associated pathologies and sequelae relative to organ transplants
 - V. Identify normal and abnormal flow characteristics and waveforms
 - VI. Correlate the method used to transplant the organ and expected sonographic findings
-

XI. ORGAN TRANSPLANT

A. Indications for Transplant

- 1. Renal
 - a. End-stage renal disease
 - i) Adult polycystic kidney disease
 - ii) Nephrotic syndrome
 - iii) Renal failure
 - iv) Diabetes
 - v) Systemic lupus
 - vi) Glomerulonephritis
 - vii) Renovascular disease
 - viii) Patients on renal dialysis
- 2. Liver
 - a. End-stage liver disease
 - i) Cirrhosis
 - ii) Fulminant liver failure
 - iii) Cancer
 - iv) Biliary atresia
 - v) Cholestatic liver disease
 - vi) Hepatocellular disease
 - vii) Vascular disease

B. Surgical Placement

- 1. Organ donation types
 - a. Living donor
 - b. Harvested from cadaver
- 2. Full organ transplant
 - a. Renal allograft – a type of organ transplant in which the donor and the recipient are of the same species but are genetically different individuals

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- i) Renal allograft placement
 - Transperitoneal or intraperitoneal
 - En bloc
 - ii) Liver allograft
 - Most common is from a deceased donor
 - Complex procedure
- C. Laboratory Values
 - 1. Organ and complication-specific
 - a. Kidney: Creatinine, GFR
 - b. Liver: AST/ALT, bilirubin, alkaline phosphatase
 - c. Anti-rejection medication levels
- D. Indications for Sonographic Assessment
 - 1. Baseline study
 - a. Within 24 hours post-surgery
 - b. Confirm patency of vessels, anastomoses
 - 2. Abnormal laboratory values
 - 3. Decreased urine output
 - 4. Follow progression of abnormal Doppler waveforms
 - 5. Monitor and follow complication
 - a. Fluid collection
 - i) Hematoma
 - ii) Abscess
 - iii) Lymphocele
 - iv) Urinoma
 - v) Seroma
 - b. Post-transplant lymphoproliferative disorder; long-term complications
 - c. Anastomotic leaks
 - d. Anastomotic and vascular strictures
 - 6. Vascular thrombosis
 - 7. Rejection and other complications
 - a. Organ specific
 - i) Renal
 - Acute tubular necrosis
 - More common in cadaver transplants
 - Related to length of cold ischemic time of transplant prior to transplantation

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- Acute rejection
- Chronic rejection
- Vessel thrombosis
 - Arterial
 - Venous
- Anti-rejection drug toxicity
- ii) Liver
 - Hepatic artery thrombosis
 - Hepatic artery stenosis
 - Portal vein stenosis
 - Portal vein thrombosis
 - Biliary complications
 - Reoccurrence of underlying disease
- 8. Obstruction
- 9. Biopsy guidance
- 10. Biopsy complications
- E. Sonographic Technique
 - 1. Imaging protocol for specific organ
 - a. Gray scale images
 - i) Anastomotic sites
 - ii) Thrombus
 - iii) Fluid collections
 - Hematoma
 - Abscess
 - Organ specific
 - Renal
 - ~ Urinoma
 - ~ Seroma
 - ~ Lymphocele
 - Liver
 - ~ Biloma
 - iv) Evidence of an obstruction
 - Organ specific
 - Renal
 - ~ Hydronephrosis

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- Liver
 - ~ Dilated biliary ducts
- b. Color Doppler images
 - i) Anastomotic sites
 - ii) Patency
 - iii) Stenosis or kinking of vessel
 - iv) Thrombus
 - v) Post biopsy
 - Pseudoaneurysm
 - Arteriovenous fistula (AVF)
- c. Spectral Doppler waveforms
 - i) Anastomotic sites
 - ii) Patency
 - iii) Stenosis or kinking of vessel
 - iv) Thrombus
 - Venous
 - Lack of venous signal
 - Bi-phasic or high resistive arterial signal
 - Arterial
 - Lack of arterial signal
 - Lack of venous signal
 - Evidence of collateral flow
 - v) Post biopsy
 - Pseudoaneurysm
 - Arteriovenous fistula (AVF)
 - vi) Doppler indices
 - Resistive index (RI)
 - vii) Waveform analyses
 - Velocity
 - Turbulence
 - Flow direction
 - Flow characteristics
 - Venous
 - ~ Phasicity
 - ~ Spontaneous

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- Arterial
 - ~ Amount of diastolic flow
- d. Correlative and/or prior imaging

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Section XII: Breast

1. Describe the normal breast anatomy including the sonographic appearance
 2. Describe the types of benign breast conditions, breast pathology and correlating sonographic appearances
 3. Compare the roles of mammography, sonography, computerized tomography and magnetic resonance imaging (MRI)
 4. Discuss various interventional procedures utilized in breast pathology diagnosis
-

XII. BREAST

- A. Embryology
- B. Anatomy/Normal Variants
 1. Surface of the breast
 - a. Tail of spence
 - b. Nipple
 - i) Areola
 - c. Tissues
 - i) Fat
 - ii) Ligaments
 - iii) Glandular tissue
 - iv) Ductal system
 2. Layers
 - a. Subcutaneous layer
 - i) Fat surrounded by connective tissue
 - ii) Cooper's ligaments
 - b. Mammary layer
 - i) Functional lobes
 - Acini
 - ii) Connective tissue septa
 - Cooper's ligaments
 - iii) Lobules
 - iv) Lobes
 - Lactiferous duct drains each lobe
 - Terminal ductal unit (TDLU)
 - Extralobular terminal duct
 - Intralobular terminal duct
 - Lobule (consisting of acini)
 - c. Retromammary layer

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- i) Muscles/chest wall
 - Pectoralis major
 - Pectoralis minor
 - Ribs
 - Chest wall
- 3. Lymphatics
 - a. Lymph vessels empty into lymph nodes
 - b. Axillary lymph nodes
 - i) Normal
 - ii) Abnormal
 - c. Pectoral nodes
 - d. Internal mammary nodes
 - e. Intramammary nodes
- 4. Variants
 - a. Amastia
 - b. Amazia
 - c. Athelia
 - d. Hypoplasia
 - e. Polymastia
 - f. Polythelia
- C. Physiology and Function
 - 1. Terminal ductal lobular unit (TDLU)
 - 2. Lobes (consisting of TDLUs) are drained by lactiferous ducts
 - 3. Lactiferous ducts converge to nipple and dilate to form lactiferous sinuses (ampullae)
 - 4. Lactiferous sinuses are milk reservoirs during lactation
- D. Indications
 - 1. Palpable breast and/or axillary lump
 - 2. Breast pain
 - 3. Skin redness or nipple changes
 - 4. Correlation with mammography or MRI
 - 5. Pregnant or lactating patient
 - 6. Implant rupture after breast augmentation
 - 7. Post-surgical or post-irradiated breast
 - 8. Guidance for interventional procedures
 - 9. Screening in heterogeneous or dense breasts
 - 10. Detection and biopsy of abnormal axillary nodes

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E. Sonographic Technique

1. Whole breast versus targeted area
 - a. Correlation with prior imaging
 - b. Correlation with palpable lump or pain
2. Transducer selection
3. Patient positioning
4. Image optimization
 - a. Dense breasts limitations
5. Annotation methods
 - a. Laterality (right/left)
 - b. Orientation
 - i) Radial/antiradial
 - ii) Sagittal/transverse
 - iii) Oblique
 - c. Location within breast
 - i) Clock face
 - ii) Distance from nipple
 - iii) Labeled diagram of breast
6. Tissue composition
 - a. Homogenous - fat
 - b. Homogeneous - fibroglandular tissue
 - c. Heterogeneous
7. Mass evaluation
 - a. Measurements
 - i) Three measurements in two orthogonal planes
 - Largest measurement defines longest axis (plane) of the mass
 - Next measurement is perpendicular to first measurement
 - Final measurement is from a view orthogonal to the first plane
 - b. Descriptors
 - i) Shape
 - Oval
 - Round
 - Irregular
 - ii) Orientation
 - Parallel

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- Not parallel
- iii) Margin
 - Circumscribed
 - Not circumscribed
 - Indistinct
 - Angular
 - Microlobulated
 - Spiculated
- iv) Echo pattern
 - Anechoic
 - Hyperechoic
 - Hypoechoic
 - Isoechoic
 - Heterogeneous
 - Complex
 - Cystic
 - Solid
- v) Posterior features
 - No posterior features
 - Enhancement
 - Shadowing
 - Combined pattern
- c. Calcifications
- d. Associated features
 - i) Architectural distortion
 - ii) Duct changes
 - iii) Skin changes
 - iv) Edema
 - v) Vascularity
- e. Doppler
 - i) Settings for low-flow states
 - ii) Frenitus
- f. Elastography
- g. Special cases
 - i) Simple cyst

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- ii) Clustered microcysts
 - iii) Complicated cyst
 - iv) Mass in or on skin
 - v) Foreign body including implants
 - vi) Lymph node
 - vii) Vascular abnormalities
 - AVM
 - Mondor disease
 - viii) Postsurgical fluid collection
 - ix) Fat necrosis
8. ACR BI-RADS assessment categories
- a. Category 0: incomplete
 - b. Category 1: negative
 - c. Category 2: benign
 - d. Category 3: probably benign
 - e. Category 4: suspicious
 - i) 4A = low
 - ii) 4B = moderate
 - iii) 4C = high
 - f. Category 5: highly suggestive of malignancy
 - g. Category 6: known biopsy-proven malignancy
9. Pitfalls
- a. Pseudomass (from normal fat lobules)
 - b. Large fatty breast
 - c. Shadowing from fibroglandular tissue versus very large mass
- F. Sonographic Characteristics
- 1. Benign cyst
 - a. Circumscribed, thin margins
 - b. Oval shape
 - c. Echogenicity: anechoic
 - d. Posterior enhancement
 - e. No internal vascularity (color Doppler)
 - 2. Probably benign solid
 - a. Circumscribed margins
 - b. Oval shape (includes 2-3 large lobulations)
 - c. Parallel orientation

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3. Probably benign cystic
 - a. Clustered microcysts
 - b. Complicated cyst
4. Suspicious
 - a. Irregular shape
 - b. Not circumscribed margins
 - c. Nonparallel orientation
 - d. Complex cystic and solid
 - e. Duct extension
 - f. Shadowing
 - g. Intraductal calcifications
 - h. Architectural distortion
 - i) Straightening or thickening of Cooper's ligaments
 - ii) Echogenic rim
 - iii) Obliteration of surrounding tissue planes
 - iv) Distortion of ductal pattern
 - i. Skin overlying tumor is flattened or retracted or thickened
 - j. Echogenic extensions from mass or increased echogenicity anterior to mass (desmoplasia)
- G. Pathology and Pathophysiology
 1. Cyst
 - a. Clinical signs
 - b. Sonographic findings
 - i) Circumscribed
 - ii) Anechoic
 - iii) Posterior enhancement
 2. Complicated cyst
 - a. Clinical signs
 - i) May be related to inflammation or hemorrhage within cyst
 - b. Sonographic findings
 - i) Wall thickening or irregularities
 - ii) Septations
 - iii) Internal echoes
 3. Fibrocystic changes
 - a. Clinical signs
 - b. Sonographic findings

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- i) Bilateral macrocysts; microcysts and cystic clusters are possible
 - ii) Increased fibrous stroma
 - iii) Ductal ectasia
- 4. Gynecomastia
 - a. Causes
 - i) Drugs
 - ii) Endocrine active tumors
 - iii) Reduced testosterone states
 - b. Clinical findings
 - i) Male subareolar breast lump
 - ii) Male breast tenderness
 - c. Sonographic findings
 - i) Hypoechoic tissue with ducts radiating from the nipple
 - ii) Color Doppler findings similar to female breast tissue
- 5. Solid mass – benign
 - a. Fibroadenoma
 - i) Most common breast tumor
 - ii) Primarily in young women
 - iii) Growth stimulated by estrogen
 - iv) Clinical findings
 - Firm, rubbery, freely mobile
 - Slow growing
 - v) Sonographic findings
 - Smooth, rounded margins
 - Low-level homogeneous internal echoes
 - Possible posterior acoustic enhancement
 - Typically hypoechoic
 - b. Lipoma
 - i) Fatty tissue
 - ii) Clinical findings
 - May grow large before being clinically detected
 - Usually found in middle-aged/postmenopausal women
 - Large, soft, poorly demarcated, difficult to delineate from surrounding breast tissue
 - iii) Sonographic findings
 - Typically smooth walls

Abdomen and Superficial Structures Including Introductory Pediatric and Musculoskeletal

- Hypoechoic similar to breast fat
- Posterior acoustic enhancement
- Easily compressible
- c. Fat necrosis
 - i) Causes
 - Trauma
 - Surgery
 - Radiation treatment
 - Mastitis
 - Other
 - ii) Clinical findings
 - Spherical nodule, superficial under layer of calcified necrosis
 - iii) Sonographic findings
 - Irregular
 - Complex low-level echoes
 - May mimic a malignant mass
 - Acoustic shadowing may or may not be present
- d. Abscess
 - i) Clinical findings
 - Pain
 - Swelling
 - Redness
 - Febrile
 - Enlarged axillary nodes
 - ii) Sonographic findings
 - Complex
 - Diffuse increased echogenicity of the breast (if mastitis is present)
 - Hyperemia with color and/or power Doppler
- e. Papillomas
 - i) Arise from lining of the breast ducts
 - ii) Retroareolar area most common
 - iii) Clinical findings
 - Bloody discharge from a single duct
 - iv) Sonographic findings
 - Tiny papilloma may not be detected

Abdomen and Superficial Structures Including Introductory Pediatric and Musculoskeletal

- May cause dilatation of single duct
 - Intracystic papillomas
 - Soft tissue mass growing into the lumen of cystic lesion
- f. Sebaceous cyst
 - i) Obstruction of sebaceous gland or hair follicle within the dermal layer of skin
 - ii) Sonographic findings
 - Rounded, well-defined mass with low to medium-level echogenicity
 - Wall calcification possible
- g. Phyllodes
 - i) Borderline or transitional form between benign and malignant tumor
 - ii) Clinical findings
 - Can grow quite large
 - Develop in women between ages 40-60
 - iii) Sonographic findings
 - Well-defined, lobulated solid mass with possible internal cystic spaces
- 6. Solid mass – malignant
 - a. Ductal carcinoma in situ (DCIS)
 - i) Most common non-invasive carcinoma
 - ii) Clinical findings
 - Asymptomatic
 - Palpable mass
 - Nipple discharge
 - iii) Mammography findings
 - Microcalcifications
 - iv) Sonographic findings
 - Intraductal mass
 - Microcalcifications
 - Irregular ductal dilatation
 - Architectural distortion
 - b. Lobular carcinoma in situ (LCIS)
 - i) Generally affects premenopausal women
 - ii) Distinct tumor not a feature
 - iii) Sonographic findings
 - Bilateral
 - Multicentric

Abdomen and Superficial Structures Including Introductory Pediatric and Musculoskeletal

- Mimics fibrocystic disease
- c. Invasive ductal carcinoma (IDC)
 - i) Extension past duct and into stroma
 - ii) Most common malignancy
 - iii) Clinical findings
 - Hard and fixed mass
 - Skin dimpling or skin/nipple retraction
 - iv) Mammography findings
 - Asymmetric
 - Radiopaque speculated mass
 - Microcalcifications
 - Thickened and retracted Cooper's ligaments
 - v) Sonographic findings
 - Solid mass
 - Hypoechoic
 - Heterogeneous
 - Taller-than-wide orientation
 - Distal acoustic shadowing
 - Possible
 - Microlobulation
 - Microcalcification
 - Ductal extension/branch pattern
 - Fascial plane disruption
- d. Invasive lobar carcinoma (ILC)
 - i) Bilateral
 - ii) Multicentric
 - iii) Multifocal
 - iv) Mammography
 - Can underestimate extent
 - v) Sonographic findings
 - Possible speculated mass mimicking invasive ductal carcinoma
 - Architectural distortion
- e. Medullary
 - i) Clinical findings
 - Circumscribed, non-tender, often large palpable mass

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- May be mildly compressible and movable
- Often located in the peripheral breast
- Low incidence of lymph node involvement
- Prevalence in younger females
- ii) Sonographic findings
 - Solid hypoechoic mass; round, oval or lobulated shape
 - Circumscribed margins; surface irregularities possible
 - Homogeneous/mildly heterogeneous
 - Acoustic enhancement
 - Hemorrhage or cystic degeneration may be noted
- f. Colloid/mucinous
 - i) Clinical findings
 - ii) Sonographic findings
 - Well-defined margins
 - Hypoechoic or isoechoic to fat
 - Homogeneous
 - Possible microlobulations
- g. Papillary
 - i) Clinical findings
 - Subareolar palpable mass
 - May protrude and affect the skin
 - May cause skin dimpling and retraction
 - Possible bloody nipple discharge
 - ii) Sonographic findings
 - Mimics non-invasive papillary carcinoma or papilloma
- h. Phyllodes tumor (Phylloides)
- i. Paget's disease
 - i) Clinical findings
 - Red, scaly rash involving the nipple and areolar area
 - Bloody nipple discharge
 - Flattened or inverted nipple
 - ii) Sonographic findings
 - Skin thickening at the areolar area
 - Possible mass or underlying ductal carcinoma mass

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7. Post surgical findings
 - a. Implant rupture
 - i) Stepladder sign
 - ii) Stepladder sign can be confused with normal double lumen implant
 - b. Silicone rupture
 - i) Snowstorm sign
 - ii) Silicone lymph nodes
8. Sonography-guided interventional procedures
 - a. Cyst aspiration
 - b. Fine needle aspiration cytology (FNAC)
 - c. Drainage procedure
 - d. Preoperative needle wire localization
 - e. Core needle biopsy
 - f. Vacuum assisted needle biopsy
 - g. Sentinel node biopsy
9. Related imaging
 - a. Mammography
 - b. Computed tomography
 - c. Magnetic resonance
 - d. Computer Aided Detection (CAD)
 - e. Elastography
 - f. Positron Emission Mammography (PEM)
 - g. Molecular Breast Imaging (MBI)
 - h. Doppler examination

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Section XIII: Neck

1. Describe the anatomy, physiology, pathophysiology, laboratory tests and pathology of the thyroid and parathyroid glands
 2. Recite the protocol for sonographic assessment of the neck and relational anatomy
 3. Discuss relational anatomy of the thyroid, parathyroid and other neck structures
 4. Define other neck masses evaluated with sonography
 5. Explain cervical lymph node mapping pre- and post-thyroidectomy
-

XIII. NECK

- A. Embryology
- B. Normal Thyroid Anatomy and Variants
 1. Description
 - a. Right and left lobes located anterolateral to trachea and esophagus
 2. Structure
 - a. Right and left lobe connected in midline by isthmus
 - i) Normal variant is Zuckerkandl tubercle
 - ii) Normal variant is pyramidal lobe arising from isthmus
 - iii) Four parathyroid glands
 - b. Surrounding musculature
 - i) Anterior
 - Strap muscles
 - Sternohyoid
 - Omohyoid
 - Sternothyroid
 - Sternocleidomastoid
 - ii) Posterior
 - Longus colli muscle
 - c. Vascular
 - i) Arterial
 - Superior thyroid
 - Right and left
 - Inferior thyroid
 - Right and left
 - ii) Venous
 - Superior and middle thyroid veins into the jugular vein
 - Inferior thyroid vein into the innominate vein

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- C. Function and Physiology
 - 1. Maintains body metabolism, growth, and development
 - a. Endocrine function
 - i) Secretes hormones
 - Thyroxine (T4)
 - Triiodothyronine (T3)
 - Affects metabolic rate
 - ii) Calcitonin affects calcium metabolism
 - iii) Thyroid-stimulating hormone (TSH)
 - Controls thyroid hormone secretions
 - b. Iodide ingestion
 - i) Necessary for production of thyroxine
 - c. Laboratory tests
 - i) Serum
 - Triiodothyronine (T3)
 - Thyroxine (T4)
 - Calcitonin
 - Thyroid-stimulating hormone (TSH)
 - Thyroglobulin
- D. Indications for Sonographic Examination
 - 1. Palpable enlargement
 - 2. Abnormal thyroid function tests
 - 3. Palpable mass in neck/thyroid
 - 4. Swelling of neck
 - 5. Asymmetry of neck
 - 6. Redness and/or tenderness
 - 7. Hypercalcemia
 - 8. Post thyroidectomy
- E. Sonographic Technique
 - 1. Patient preparation
 - 2. Transducer selection
 - 3. Patient positioning
 - 4. Image optimization
 - 5. Examination protocol

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F. Pathology and Pathophysiology

1. Hypothyroidism

a. Under secretion of thyroid hormones

i) Clinical signs

- Myxedema
- Weight gain
- Hair loss
- Increased tissue around eyes
- Lethargy
- Intellectual and motor slowing
- Cold intolerance
- Constipation
- Deep, husky voice

ii) Causes

- Low intake of iodine (goiter)
- Thyroid hormone failure
- Diseases of the hypothalamus or pituitary

2. Hyperthyroidism

a. Over secretion of thyroid hormones

i) Clinical signs

- Dramatic increase in metabolic rate
- Weight loss
- Increased appetite
- Nervous energy
- Tremor
- Excessive sweating
- Heat intolerance
- Cardiac palpitations
- Exophthalmos

ii) Causes

- Abnormal hormone secretion
- Localized neoplasm cause overproduction of hormone(s)
- Graves' disease

3. Thyroid nodules

a. Variable gland enlargement

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- b. Causes
 - i) Thyroiditis (ill-defined nodular areas)
 - ii) Neoplasm (benign or malignant)
 - iii) Nodular hyperplasia
 - iv) Hashimoto's thyroiditis (micronodules)
 - c. Sonographic findings
 - i) Diffuse enlargement
 - ii) Hypoechoic, heterogeneous without palpable nodules
 - iii) Markedly increased vascularity
 - Increased peak systolic velocities in the inferior thyroidal artery
4. Toxic multinodular goiter
- a. Graves' disease
 - b. Clinical signs
 - i) Hypermetabolism
 - ii) Diffuse toxic goiter
 - iii) Exophthalmos
 - iv) Cutaneous formations
 - Periorbital
 - Dorsum of feet
 - c. Cause
 - i) Autoimmune
 - d. Sonographic findings
 - i) Diffuse enlargement
 - ii) Hypoechoic, heterogeneous without palpable nodules
 - iii) Markedly increased vascularity
 - Thyroid inferno
 - Increased peak velocities in the inferior thyroidal artery
5. Thyroiditis
- a. Inflammation of the thyroid causing swelling and tenderness
 - b. Types and clinical signs
 - i) De Quervain's (subacute thyroiditis)
 - Post-viral inflammatory disorder
 - Focal or diffuse enlargement
 - Fever, neck pain, fatigue, increased sedimentation rate
 - Transient hyperthyroidism, hypothyroidism

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- Sonographic findings
 - Focal or diffuse enlargement
 - Ill-defined, hypoechoic to heterogeneous regions with decreased to absent vascularity, adenopathy
- ii) Hashimoto's
 - Most common form
 - Autoimmune - chronic inflammation
 - Diffuse enlargement/possibly asymmetric
 - Painless/may develop mild pain over time
 - Eventual hypothyroidism
 - Sonographic findings
 - Possibly hypoechoic/normal echo texture
 - Size of gland is variable
 - Microlobulations
 - Thick, fibrous strands or echogenic septa
 - Increased vascularity with color Doppler – acute phase
 - Decreased vascularity with color Doppler – chronic phase
- 6. Benign masses
 - a. Cystic nodules
 - i) Related to degeneration of an adenoma
 - ii) Sonographic findings
 - Corresponds to degenerative changes
 - Mixed solid/cystic nodule
 - b. Follicular neoplasm
 - i) Benign or malignant
 - ii) Sonographic findings
 - Isoechoic/hyperechoic
 - Thin hypoechoic peripheral halo
 - Color Doppler peripherally
 - Central cystic areas/degeneration
- 7. Malignant masses
 - a. Papillary carcinoma
 - i) Most common thyroid malignancy
 - Characterized by tiny calcifications called psammoma bodies
 - Major route of spread is through the regional lymphatic system (central and lateral neck)

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- May have macrocalcifications
- Often hypoechoic with irregular margins or heterogeneous
- ii) Clinical signs
 - Asymptomatic
 - Painless lump in neck
- iii) Sonographic findings
 - Very hypoechoic
 - Predominately solid
 - Microcalcifications, rim calcifications
 - Lobulated, contour bulge, taller than wide
 - Possible cervical lymph node metastasis
- b. Follicular carcinoma
 - i) Adenomas are more common than adenocarcinoma
 - ii) Sonographic findings
 - May be indistinguishable from adenoma
 - Tend to be hypoechoic, no halo, no cystic spaces
 - More common in older females
- c. Medullary carcinoma
 - i) Less common thyroid malignancy
 - ii) Clinical signs
 - Palpable nodule
 - Abnormal serum calcitonin levels
 - iii) Sonographic findings
 - Overlap with papillary carcinoma tends to be larger, homogeneous, greater cystic change, and may contain calcifications.
 - Hurthle cell tumors may have cystic components, which are less typical in medullary carcinoma.
 - Lymphadenopathy
- d. Anaplastic carcinoma
 - i) Rare thyroid malignancy
 - ii) Clinical signs
 - Hard, fixed mass; rapid growth
 - Pain, pressure, tenderness
 - Locally invasive
 - iii) Sonographic findings
 - Large, hypoechoic, heterogeneous mass

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- Cystic areas due to necrosis
 - Amorphous calcifications
 - Vascular, lymphatic, extracapsular invasion
 - Hypervascularity
 - Macrocalcification
 - Refractory edge shadow
 - Possible cervical lymph node metastasis (often with microcalcifications or cystic)
- e. Lymphoma
- i) Clinical signs
 - Rapidly growing mass in neck
 - Pre-existing Hashimoto's thyroiditis in more than 90% of cases
 - ii) Sonographic findings
 - Hypoechoic, heterogeneous mass/nodules
 - Echogenic septa
 - iii) May have an appearance similar to Hashimoto's thyroiditis
8. Other neck masses
- a. Thyroglossal duct cyst
- i) Congenital anomaly midline and anterior to trachea
 - ii) Clinical signs
 - Palpable midline mass
 - Pain is associated with hemorrhage or infection
 - iii) Sonographic findings
 - Cystic mass in midline anterior to the trachea
 - Internal echoes caused by hemorrhage or infection
- b. Branchial cleft cyst
- i) Remnant of embryonic development usually lateral to thyroid
 - ii) Sonographic findings
 - Primarily cystic
 - Possible low-level echogenicity, solid components
- c. Cystic hygroma
- i) Congenital lymphatic malformation, commonly posterolateral on neck
 - ii) Webbed neck
 - iii) Sonographic findings
 - Thin-walled, cystic multiloculated mass

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- d. Fibromatosis colli
 - i) Proliferative disorder of the inferior sternocleidomastoid muscle
 - ii) Often associated with neonatal torticollis
- G. Correlative and/or Prior Imaging
 - 1. Nuclear medicine
 - 2. Computed tomography
 - 3. Magnetic resonance
 - 4. Radiography
 - 5. Extracranial duplex examination

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Section XIV: Prostate

1. Describe the normal anatomy and variants, physiology and sonographic appearance of the prostate
 2. Describe the sonographic technique used to evaluate the prostate
 3. Identify the clinical indications and laboratory values associated with prostate disease
 4. Describe prostate pathology in terms of sonographic appearances, sequelae and associated pathologies
 5. Explain the sonographic technique for guided prostate biopsies
-

XIV. PROSTATE

- A. Embryology
- B. Anatomy and Normal Variants
 1. Oval-shaped, retroperitoneal structure
 2. Size
 3. Five lobes: anterior, middle, posterior, two lateral lobes
 4. Zonal anatomy
 - a. Peripheral zone (PZ)
 - b. Central zone (CZ)
 - c. Transitional zone (TZ)
 5. Seminal vesicles
 6. Relational anatomy
 - a. Prostate
 - i) Inferior to seminal vesicles and urinary bladder
 - ii) Anterior to rectum
 - iii) Posterior to space of Retzius
 - b. Seminal vesicles
 - i) Superior to prostate
 - ii) Inferior to urinary bladder
 7. Variants and congenital anomalies
 - a. Agenesis of seminal vesicle
 - i) Associated with ipsilateral renal agenesis
 - b. Cysts
 - c. Prostatic utricle cyst
 - i) Associated with unilateral renal agenesis
 - d. Ejaculatory duct cyst
 - e. Müllerian duct cyst
 - f. Agenesis of vas deferens

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- C. Function and Physiology
 1. Secretes alkaline fluid that provides a mode of fluid transport for sperm
 2. Produces majority of fluid volume of ejaculate
 3. Glandular tissue produces prostate-specific antigen (PSA)
 4. Testosterone and dihydrotestosterone regulate prostate growth and function
 5. Most accurate method to calculate prostate function is by calculating prostate-specific antigen density (PSAD)
- D. Laboratory Values
 1. Prostate-specific antigen (PSA)
 2. PSA assays
 - a. Monoclonal
 - b. Polyclonal
- E. Indications
 1. Urinary symptoms
 - a. Frequency
 - b. Nocturia
 - c. Dysuria
 - d. Decreased force of urinary stream
 2. Abnormal biochemistry
 3. Abnormal digital examination
 4. Pain
 5. Hematospermia
 6. Oligospermia
 7. Infertility
- F. Sonographic Technique
 1. Transabdominal approach
 - a. Patient preparation
 - b. Transducer selection
 - c. Patient positioning
 - d. Image optimization
 - e. Examination protocol
 2. Transrectal (TRUS)
 - a. Preferred technique
 - b. Patient preparation
 - c. Transducer selection
 - d. Transducer preparation

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- e. Patient positioning
- f. Image optimization
- g. Examination protocol
- h. Transducer cleaning and disinfectant
- 3. Measurements
 - a. Maximum transverse width
 - b. Anteroposterior (AP)
 - c. Length
 - d. Prostatic volume
- G. Pathology and Pathophysiology
 - 1. Benign prostatic hyperplasia (BPH)
 - a. Sonographic findings
 - i) Enlarged gland
 - ii) Hypoechoic inner region compared to peripheral region
 - iii) May have echogenic nodules
 - iv) Central and peripheral zones (PZ) may be compressed
 - v) Calcification and cystic change may be seen
 - vi) Thickened bladder wall
 - vii) Distended bladder with thickened walls and trabeculations
 - viii) Possible hydronephrosis, hydroureters
 - ix) Asymmetric enlargement should be evaluated for malignant change
 - 2. Prostatitis
 - a. Acute inflammation
 - i) Usually occurs in PZ
 - ii) Clinical presentation
 - Pain
 - iii) Complication
 - Abscess
 - iv) Sonographic findings
 - Most commonly normal
 - Diffuse hyperechoic appearance of PZ
 - Hypervascularity with Doppler
 - Hypoechoic mass
 - Abscess
 - b. Chronic inflammation

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- i) Recurrent episodes of acute prostatitis
 - ii) Clinical presentation varies
 - iii) Sonographic findings
 - Focal masses of varying echogenicity
 - Calcifications
 - Capsular thickening and/or irregularity
- 3. Carcinoma (CA)
 - a. The majority of prostatic carcinomas are located in PZ
 - b. 25% are located in the central gland
 - c. Sonographic findings
 - i) Small nodules are usually hypoechoic and located in PZ
 - ii) May be present in the anterior and central gland - difficult to see with ultrasound
 - iii) Isoechoic nodules (which are difficult to identify on sonography), hyperechoic or mixed
 - iv) Enlarged prostate – usually asymmetric
 - v) Distended thick bladder wall with trabeculations
 - vi) Bilateral hydroureters and hydronephrosis
 - vii) Loss of smooth contour in area of lesion indicating extracapsular spread
 - viii) Increased vascularity on color or power Doppler
- 4. Cysts
 - a. Usually asymptomatic
 - b. Sonographic findings
 - i) Smooth wall
 - ii) Anechoic, posterior enhancement
- 5. US-guided prostate biopsies
 - a. Transrectal approach
 - b. Transperineal approach
 - i) Performed in patients with absent rectum
 - c. Indications
 - i) Diagnosis of prostate cancer in patients with elevated PSA
 - ii) Diagnosis/drainage of prostate abscess

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Section XV: Scrotum

1. Describe the normal anatomy, physiology, and sonographic appearance of the scrotum
 2. Describe the sonographic technique used to evaluate the scrotum
 3. Identify the clinical indications and laboratory values associated with scrotal disease
 4. Describe scrotal pathology and pathophysiology including the sonographic appearance
 5. Identify normal and abnormal flow characteristics and waveforms
-

XV. SCROTUM

- A. Embryology
- B. Normal Anatomy and Variants
 1. Testicles
 - a. Rete testis
 - b. Mediastinum
 - i) Thickened portion of tunica albuginea
 - c. Seminiferous tubules
 - d. Layers
 - i) Tunica albuginea
 - ii) Tunica vaginalis
 2. Epididymis
 - a. Head, body, tail
 3. Vas deferens
 4. Seminal vesicles
 5. Variants
 - a. Cryptorchidism
 - i) Testicles or testis does not descend to normal position
 - b. Polyorchidism or unilateral testis
- C. Function and Physiology
 1. Testicles
 - a. Produce sperm (maturing from basal layer of spermatid tubules to inner layer and then extruded)
 2. Epididymis
 - a. Stores sperm
 3. Vas deferens
 - a. Transports sperm from epididymis to prostatic urethra
 4. Seminal vesicles
 - a. Produce fluid rich in fructose

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- D. Indications
 - 1. Pain
 - 2. Enlargement
 - 3. Palpable mass
 - 4. Search for undescended testicle
 - 5. Follow-up for patients with a previous orchiectomy for recurrent tumor
 - 6. Trauma
 - 7. Male infertility
- E. Sonographic Technique
 - 1. Patient preparation
 - 2. Transducer selection
 - 3. Patient positioning
 - 4. Image optimization
 - 5. Examination protocol
 - a. Measurements
 - b. Color and/or power Doppler
- F. Pathology and Pathophysiology
 - 1. Benign conditions
 - a. Hydrocele
 - i) Abnormal accumulation of fluid in tunica vaginalis
 - ii) Congenital or idiopathic
 - iii) Often due to epididymitis
 - iv) May be seen with orchitis, spermatic cord torsion and trauma
 - b. Hematocele
 - i) Blood in scrotal sac, usually after trauma or surgical intervention
 - c. Pyocele
 - i) Pus in scrotal sac, usually associated with epididymitis/orchitis
 - d. Epididymitis
 - i) Inflammation of epididymis
 - ii) Most common cause of acute scrotal pain
 - iii) Clinical findings
 - Fever
 - Pain
 - Dysuria
 - May have urethral discharge
 - iv) Sonographic findings

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- Enlarged epididymis, usually of head
- Thickened scrotal skin
- v) Decreased echogenicity with heterogeneous coarse echo pattern
- vi) May be associated with hydrocele
- vii) Increased Doppler flow in the affected region when compared to the contralateral side
- e. Orchitis
 - i) Inflammation of the testis
 - ii) Associated finding in 20-30% of epididymitis
 - iii) Chlamydia most common cause, mumps, viral, idiopathic
- f. Testicular spermatic cord torsion
 - i) Due to “bell clapper” deformity
 - ii) Spermatic cord becomes rotated or twisted and cuts off the blood supply
 - iii) Acute
 - Scrotal pain and swelling
 - Nausea and vomiting
 - Sonographic findings
 - Varied and non-specific
 - Enlarged testicle and epididymal head with decreased echogenicity
 - Absent flow on color Doppler
 - Twisting or looping of arteries in the spermatic cord in inguinal canal
 - iv) Chronic
 - Sonographic findings
 - Small heterogeneous testicle (infarcted)
 - Scrotal wall thickening and possible hydrocele
 - No arterial flow on Doppler study
 - Increased flow in peritesticular soft tissues
 - v) Intermittent torsion
 - Mobile testis with bell-clapper deformity with recurrent acute scrotal pain with rapid spontaneous resolution
 - Sonographic findings
 - Acute – similar to torsion
 - After the acute presentation – nonspecific, with hydrocele the most common
 - vi) Partial torsion
 - Sonographic findings

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- May show increased blood flow due to reactive hyperemia
 - Comparison must be made to the contralateral side
- g. Spermatocoele
 - i) Cystic lesion of epididymis containing sperm
- h. Varicocele
 - i) Enlargement of veins of spermatic cord
 - ii) Most common cause of infertility
 - iii) Majority occur on the left side due to venous drainage into the left renal vein
 - iv) Large, right-sided varicocele may be associated with renal or retroperitoneal tumor
 - v) Sonographic findings
 - Dilated veins
 - Valsalva maneuver or having patient stand will increase venous pressure
 - Reversal of flow occurs when intra-abdominal pressure increases
- i. Cysts
 - i) Intratesticular
 - ii) Epidermoid
- j. Abscess
 - i) Most commonly caused from untreated epididymo-orchitis
 - ii) Intratesticular or, more commonly, extratesticular
 - iii) Clinical findings
 - Fever
 - Scrotal pain
 - Swelling
 - iv) Sonographic findings
 - Anechoic or complex mass
 - Increase blood flow around periphery of the mass
 - No blood flow in mass
- k. Scrotal hernia
- l. Hematoma
 - i) Intratesticular more common than extratesticular
 - ii) Associated with trauma
- m. Extra-testicular tumors
 - i) Adenomatoid tumor
 - Most common extratesticular tumor

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ii) Rhabdomyosarcoma

G. Malignant Conditions

1. Testicular cancer

a. Clinical findings

- i) Painless
- ii) Unilateral enlargement

b. Pure tumors

i) Germ cell tumors

- Seminoma
 - Most common germ cell tumor
 - Hypoechoic lesion
- Embryonal carcinoma
 - Invasive producing ill-defined hypoechoic lesion with possible capsular distortion
- Teratoma
 - Well-defined complex mass with possible calcification, often cystic changes on US

ii) Stromal cell tumors

- Leydig cell
- Sertoli
- Granulosa cell

c. Theca cell

d. Mixed germ cell tumors

- i) Second most common tumor after seminoma

e. Metastasis

f. Lymphoma

H. Correlative and/or prior imaging

1. Nuclear medicine

2. Computed tomography (CT)

3. Magnetic resonance imaging (MRI)

Abdomen and Superficial Structures Including Introductory Pediatric and Musculoskeletal

Rationale: Sonographers must have a comprehensive knowledge of the anatomy, physiology, and pathophysiology of sonographically accessible joints, tendons, muscles, bursae, and ligaments to accurately assess and perform musculoskeletal sonograms. Understanding the sonographic appearances and dynamics of these structures is essential for performing high-quality examinations.

Section XVI: Musculoskeletal Sonography

1. Identify normal anatomic location and function of the tendons, ligaments, muscles, nerves and bursae
 2. List indications for sonographic evaluation
 3. Describe examination techniques and basic scanning protocols
 4. Summarize basic protocols for musculoskeletal examinations
 5. Describe applicable pathology
-

XVI. MUSCULOSKELETAL SONOGRAPHY

- A. Anatomy
 1. Muscles
 - a. Pennate patterns
 2. Tendons
 - a. Synovial sheath
 3. Ligaments
 4. Bursae
 5. Nerves
 - a. Lower limb
 - i) Sciatic
 - ii) Popliteal
 - b. Upper limb
 - i) Suprascapular
 - ii) Median
 - iii) Radial
 - iv) Ulnar
 6. Joints
 7. Bones
 8. Shoulder
 - a. Biceps tendon/sheath
 - b. Subscapularis tendon
 - c. Supraspinatus tendon
 - d. Infraspinatus tendon
 - e. Acromioclavicular joint
 - f. Subdeltoid bursa
 - g. Supraspinatus, infraspinatus and teres minor muscles

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9. Wrist
 - a. Carpal tunnel
 - i) Flexor retinaculum space
 - Flexus pollicis longus
 - Flexor digitorum tendons
 - ii) Ulnar artery and veins
 - iii) Scaphoid tubercle
 - iv) Trapezium ridge
 - v) Pisiform ridge
 - vi) Pisiform bone
 - vii) Hamate
 - viii) Median nerve
 - b. Wrist - Guyon's canal
 - i) Hamate and pisiform bones
 - ii) Ulnar nerve

10. Ankle/leg/foot
 - a. Achilles' tendon
 - i) Gastrocnemius muscle
 - ii) Soleus muscle
 - iii) Calcaneus
 - iv) Paratendon
 - v) Tibialis posterior
 - vi) Peroneal tendons
 - vii) Plantar fascia
 - b. Popliteal fossa
 - i) Femoral condyles and tibia
 - ii) Popliteal bursa
 - Synovial fluid
 - iii) Popliteal artery and vein

B. Indications

1. Shoulder
 - a. Shoulder pain or swelling
 - b. Weakness with arm elevation
 - c. Trauma
 - d. Decreased range of motion
 - e. Evaluation of soft tissue masses

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2. Wrist
 - a. Palpable lesion
 - b. Loss or decrease of digital flexion/extension
 - c. Pain
 - d. Swelling
 - e. Trauma
 - f. Numbness of the middle and index fingers
 - g. Weakness or clumsiness of the hand
 - h. Tingling with nerve percussion
 - i) Tinel's sign
 - ii) Phalen's sign

3. Achilles' tendon
 - a. Abnormal Thompson's test
 - b. Trauma
 - c. Displacement of Kager's fat pad on radiograph
 - d. Knob or bulge over proximal tendon
 - e. Audible pop or snap followed by a sharp pain
 - f. Inability to stand on toes
 - g. Heel pain
 - h. Decreased strength or mobility
 - i. Postoperative

4. Baker's Cyst
 - a. Swelling in the popliteal fossa
 - b. Knee pain

C. Sonographic Technique

1. Shoulder-rotator cuff
 - a. Patient position
 - b. Arm positions
 - i) Palm up, elbow flexed straight external rotation
 - ii) Dynamic internal/external
 - iii) Place palm on back pocket
 - c. Views
 - i) Longitudinal/transverse biceps/sheath
 - ii) Longitudinal/transverse subscapularis tendon
 - iii) Longitudinal/transverse supraspinatus and infraspinatus tendons
 - iv) Transverse posterior joint space/labrum

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- v) Acromioclavicular joint
 - Longitudinal/transverse supraspinatus, infraspinatus and teres minor muscles
- 2. Carpal Tunnel
 - a. Patient position
 - i) Arm resting on a stand
 - ii) Palm supinated
 - b. Views
 - i) Longitudinal and transverse of areas of interest
 - Use gel or standoff pad
- 3. Achilles' tendon
 - a. Patient position
 - i) Prone with the foot hanging over the edge of cart/table
 - b. Views
 - i) Longitudinal and transverse of areas of interest
 - ii) Dorsiflexion/plantar flexion
 - iii) Thompson's test
- 4. Popliteal fossa
 - a. Patient position
 - i) Prone with towel roll under the ankle
 - b. Views
 - i) Sagittal and transverse of areas of interest
- 5. Normal sonographic findings
 - a. Tendons
 - b. Ligaments
 - c. Muscles
 - d. Bursae
- 6. Artifacts
 - a. Anisotropy
- D. Pathology/Pathophysiology
 - 1. Shoulder
 - a. Biceps tendon
 - b. Subluxation/dislocation
 - c. Rotator cuff tear
 - d. Tendinopathy
 - e. Acromioclavicular joint arthritis

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- f. Subdeltoid effusion/bursitis
 - g. Fatty degeneration of cuff muscles
 - 2. Wrist
 - a. Carpal tunnel syndrome
 - b. Ganglion and synovial cysts
 - c. Tears of triangular fibrocartilage
 - d. Tenosynovitis
 - e. Tumor
 - f. Foreign body
 - g. Tendon tear
 - h. Inflammatory arthritis
 - i. Tendon entrapment
 - 3. Baker's cyst
 - a. Enlargement of gastrocnemius-semimembranosus bursa caused by meniscal tear or osteoarthritis, rheumatoid arthritis, joint effusion
 - i) May dissect inferiorly into calf muscles or superiorly into thigh
 - b. Sonographic findings
 - i) Anechoic fluid collection, may be complex (loose bodies, septations, internal echoes), may dissect into calf muscles
 - E. Correlative and/or Prior Imaging
 - 1. Radiography
 - 2. Arthrography
 - 3. Magnetic resonance
 - 4. Computed tomography

Abdomen and Superficial Structures Including Introductory Pediatric and Musculoskeletal

Rationale: Accurate assessment and performance of pediatric hip sonograms require sonographers to have a comprehensive knowledge of the anatomy, physiology, and pathophysiology of the pediatric hip. Understanding the sonographic appearance and dynamics of the pediatric hip is essential for performing high-quality examinations.

Section XVII: Pediatric Hip

1. Describe the anatomical structures of the hip joint and relational anatomy
 2. Describe the indications and sonographic techniques for assessment of the pediatric hip
 3. Discuss pathological conditions of the hip
-

XVII. PEDIATRIC HIP

- A. Embryology
 1. Mesoderm
 2. Osteogenesis
 3. Myoblasts and mesenchyme
 4. Medial rotation of lower limbs
- B. Anatomy
 1. Bones and joints
 - a. Pelvic girdle
 - i) Ilium
 - ii) Ischium
 - iii) Pubis
 - b. Femur
 - i) Femoral head
 - c. Fascia lata
 - d. Muscles
 - i) Anterior/extensor
 - ii) Medial/adductor
 - iii) Posterior/hamstring and gluteal
 2. Femoral triangle
 - a. Anterior of the upper thigh
 - i) Inguinal ligament
 - ii) Adductor longus muscle
 - iii) Sartorius muscle
 3. Gluteal region
 4. Hip joint
 - a. Acetabulum
 - i) Acetabular labrum
 - b. Femoral head

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- c. Iliofemoral ligament
- C. Functions
 - 1. Flexion
 - 2. Extension
 - 3. Abduction
 - 4. Adduction
 - 5. Medial rotation
 - 6. Lateral rotation
- D. Indications for Sonographic Examination
 - 1. Developmental displacement in neonate
 - a. Risk factors
 - i) First pregnancy
 - ii) Oligohydramnios during pregnancy
 - iii) Female
 - iv) Breech birth
 - v) Family history of previous displacement
 - vi) Increased birth weight
 - vii) Foot deformities
 - viii) Torticollis
 - b. Causes
 - i) Genetic
 - ii) Mechanical
 - iii) Physiologic
 - 2. Clinical hip examinations
 - a. Barlow
 - b. Ortolani
 - c. Galeazzi's or Allis test
 - 3. Response to treatment
- E. Sonographic Technique
 - 1. Patient preparation
 - 2. Transducer selection
 - 3. Patient position
 - 4. Image optimization
 - 5. Examination protocol
 - a. Coronal with neutral hip position
 - i) Push/pull movement of the hip

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- ii) Document signs of subluxation/dislocation
 - b. Coronal with hip flexion
 - i) Push/pull movement of the hip
 - ii) Barlow maneuver
 - Adduction with gentle pushing
 - iii) Document signs of subluxation
 - c. Transverse with hip flexion
 - i) Push/pull movement of the hip
 - ii) Barlow maneuver
 - iii) Ortolani test
 - iv) Document signs of subluxation
 - d. Transverse with a neutral position of the hip
 - e. Measurements using Graf's technique
 - 6. Assessment of hip during treatment
 - a. May be performed while the patient is in Pavlik harness – no maneuvers
 - b. Contraindications
- F. Pathology/Pathophysiology
- 1. Dislocation of the hip
 - a. Acquired (traumatic or non-traumatic)
 - b. Teratogenic
 - c. Developmental displacement of the hip (DDH)
 - i) Common anomaly, especially in female infants
 - ii) Dysplastic, subluxed, dislocatable or dislocated hips
 - d. Sonographic findings
 - i) Femoral head
 - Normal, subluxed, dislocated
 - ii) Stability
 - Normal, dislocatable, reducible, irreducible
 - iii) Acetabulum
 - Normal, immature, dysplastic
 - e. Treatment
 - i) Surgery
 - ii) Hip cast
 - iii) Pavlik harness
 - 2. Hip effusion – increased amount of synovial fluid within the hip joint
 - a. Widening of joint space with displacement of femur laterally

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- i) Toxic synovitis
 - ii) Septic arthritis
 - iii) Juvenile inflammatory arthritis
 - iv) Legg-Calve-Perthes disease
 - b. Scan plane is anterior and parallel to femoral neck, patient supine, hip in neutral position
 - i) Hips should be symmetrical in sonographic appearance
 - c. Sonographic findings
 - i) Both hips are examined for comparison
 - ii) Elevated joint capsule
 - iii) Joint capsule appears anterior to the echogenic femoral neck and posterior to the iliopsoas muscle. echogenicity of fluid may indicate hemorrhage, transudate, or exudate
 - iv) Hypoechoic fluid in the joint capsule
 - v) Infected fluid may appear echogenic
 - vi) Greater than 2 mm difference between hips
 - 3. Proximal femoral focal deficiency
 - a. Congenital underdevelopment of proximal femur with varying degrees of severity
- G. Correlative and/or Prior Imaging
- 1. Radiography
 - 2. Computed tomography
 - 3. Magnetic resonance

Abdomen and Superficial Structures Including Introductory Pediatric and Musculoskeletal

Rationale: Accurate assessment and performance of neonatal brain sonograms requires the sonographer to assemble a comprehensive knowledge of the anatomy, physiology and pathophysiology of the infant brain. An understanding of the embryologic development and gestational age-adjusted sonographic appearances of the premature and term infant brain are essential for performing high-quality examinations.

Section XVIII: Neonatal Brain

1. Describe the embryology, normal anatomy, and sonographic appearances of the premature and term infant brain
 2. Describe the sonographic technique, procedure and protocol used to evaluate the infant brain
 3. Describe clinical indications for sonographic examination of the infant brain in both premature and term infants
 4. Describe the major pathologies diagnosed with sonographic imaging of the neonatal brain
-

XVIII. NEONATAL BRAIN

- A. Embryology
 1. Forebrain (prosencephalon)
 - a. Telencephalon
 - b. Diencephalons
 2. Midbrain (mesencephalon)
 - a. Tectum
 - b. Tegmentum
 3. Hindbrain (rhombencephalon)
 - a. Myelencephalon
 - b. Metencephalon
- B. Anatomy
 1. Bones of the cranium, fontanelles and sutures
 2. Meninges
 - a. Dura mater
 - b. Arachnoid
 - c. Pia mater
 3. Cerebrospinal fluid (CSF)
 4. Falx cerebri
 5. Tentorium cerebelli
 6. Ventricular system
 - a. Lateral ventricles
 - i) Frontal or anterior horn
 - ii) Body
 - iii) Occipital or posterior horn
 - iv) Temporal horn or lateral horn
 - v) Trigone or atrium

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- b. Third ventricle
 - i) Single midline cavity
 - ii) Narrowest portion of the ventricular system
 - iii) Communicates with the lateral ventricles and fourth ventricle
- c. Fourth Ventricle
 - i) Foramen of Magendie on medical aperture
 - ii) Foramen of Luschka or lateral aperture
- 7. Choroid plexus
- 8. Cisterns
- 9. Cerebrum
 - a. Two hemispheres
 - i) Connected by the corpus callosum
 - b. Gray and white matter
- 10. Lobes of the brain
 - a. Frontal
 - b. Parietal
 - c. Occipital
 - d. Temporal
- 11. Gyri and sulci
- 12. Fissures
 - a. Longitudinal fissure (interhemispheric fissure)
 - b. Lateral fissure (Sylvian fissure)
 - c. Parietooccipital fissure
 - d. Transverse fissure
 - e. Central fissure or fissure of Rolando
- 13. Cerebral cortex
- 14. Corpus callosum
- 15. Cavum septum pellucidum
- 16. Basal ganglia
 - a. Caudate nucleus
 - b. Putamen
 - c. Globus pallidus
 - d. Amygdala
 - e. Claustrum
- 17. Thalamus
- 18. Germinal matrix

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- 19. Brain stem
 - a. Midbrain
 - b. Pons
 - c. Medulla oblongata
- 20. Cerebellum
 - a. Hemispheres
 - i) Vermis
 - b. Nerve tracts
 - c. White and gray matter
 - d. Coordination, balance, and posture
- 21. Cerebrovascular system
 - a. Main arteries in the neck
 - i) Common carotid arteries
 - ii) Internal carotid arteries
 - iii) Vertebral arteries
 - b. Circle of Wills
- C. Function and Physiology
 - 1. Cerebellum
 - a. Skeletal muscle movement
 - 2. Cerebral hemispheres
 - a. Frontal lobe
 - i) Speech
 - ii) Emotions
 - iii) Personality
 - iv) Morality
 - v) Intellect
 - b. Parietal lobe
 - i) Somesthetic
 - ii) Pain
 - iii) Temperature
 - iv) Spatial ability
 - c. Occipital lobe
 - i) Vision
 - d. Temporal lobe
 - i) Auditory
 - ii) Olfactory

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- e. Other
 - i) Judgment
 - ii) Memory
 - iii) Reasoning
- D. Indications
 - 1. Cranial abnormality found on prenatal sonogram
 - 2. Increasing head circumference with or without increasing intracranial pressure
 - 3. Acquired or congenital inflammatory disease
 - 4. Prematurity
 - 5. Diagnosis of hypoxia, hypertension, hypercapnia, hypernatremia, acidosis, pneumothorax, asphyxia, apnea, seizures, coagulation defects, patent ductus arteriosus
 - 6. History of birth trauma or surgery
 - 7. Genetic syndromes and malformations
- E. Sonographic Technique
 - 1. Patient preparation and care
 - a. Special considerations for premature and neonatal care
 - 2. Transducer selection
 - 3. Patient positioning
 - 4. Image optimization
 - 5. Examination protocol
 - a. Coronal scan planes
 - i) Anterior
 - Orbits, anterior horns, and lateral ventricles
 - ii) Mid
 - Lateral ventricles
 - Cavum septum pellucidum
 - Third ventricle-foramen of Monro
 - Corpus callosum
 - iii) Posterior
 - Ambient wings and cisterna magna
 - Choroids
 - Glomus of choroids
 - Occipital lobe
 - b. Sagittal and bilateral parasagittal scan planes/imaging
 - i) Midline
 - Cavum septum pellucidum

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- Corpus callosum
- Third ventricle
- Fourth ventricle
- Brain stem
- Cerebellum (tentorium)
- Cisterna magna
- ii) Thalamus and caudate
- iii) Lateral ventricle
 - Anterior horn, body, posterior horn
 - Temporal horn may be seen in cases of ventriculomegaly or hydrocephalus
 - Caudothalamic groove
- iv) Lateral
 - Lateral ventricle to show white matter and Sylvian fissure (middle cerebral artery)
- c. Special views
 - i) Axial
 - ii) Posterior fontanelle
 - iii) Mastoid
- 6. Doppler
 - a. Color and spectral Doppler may be used to demonstrate and/or evaluate intracranial blood flow
 - i) Decreased blood flow/ischemia/infarction
 - ii) Vascular abnormalities
 - iii) Cerebral edema
 - iv) Hydrocephalus
 - v) Intracranial tumors
 - vi) Near-field structures
- F. Pathology/Pathophysiology
 - 1. Chiari malformations
 - a. Caudal displacement of the cerebellar hemispheres due to small posterior fossa associated with the presence of spina bifida
 - b. Types
 - i) Chiari I: caudal displacement of the cerebellum without displacement of the fourth ventricle or medulla
 - ii) Chiari II: most common; associated with meningocele

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- iii) Chiari III: rare and severe form; cerebellum and sometimes parts of the brainstem herniate through a defect in the back of the skull into a sac-like structure (encephalocele). present at birth
- iv) Chiari IV: severe hypoplasia of cerebellum without displacement. often incompatible with life
- c. Sonographic findings
 - i) Type I
 - Caudal displacement of cerebellar hemispheres
 - Normal fourth ventricle or medulla
 - ii) Type II – Known as Arnold-Chiari malformation. typically diagnosed prenatally
 - Lemon sign: describes the frontal bone indentation depicting a lemon
 - Banana sign: describes the cerebellum wrapping around the brain stem
 - Beaking of tectum
 - Absence of the septum pellucidum with an enlarged interthalamic adhesion
 - Hydrocephalus
 - Syringomyelia
 - Agenesis or dysgenesis of the corpus callosum
 - Tethered cord syndrome
 - Myelomeningocele
 - Effacement of the cisterna magna
 - iii) Type III
 - Hydrocephalus
 - Gyral anomalies
 - Dysgenesis of the corpus callosum
 - Small posterior fossa
 - Encephalocele may contain occipital lobe tissue, cerebellum, and brainstem
 - iv) Type IV
 - Severe hypoplasia of the cerebellum hemispheres without displacement
 - Hypoplasia of the pons
 - Small posterior fossa
- 2. Holoprosencephaly
 - a. Grossly abnormal brain with common large central ventricle due to failure of cleavage of the prosencephalon into separate cerebral hemispheres
 - i) Varying degrees of severity and associated midline facial defects
 - Alobar holoprosencephaly (most severe)
 - Fused thalami anterior to a fused choroid plexus

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- Monoventricle and dorsal cyst
 - Semilobar holoprosencephaly
 - Single ventricle; brain parenchyma present with portions of falx and interhemispheric fissure in the posterior segment
 - Lobar holoprosencephaly (least severe)
 - Near complete separation of hemispheres; development of falx and interhemispheric fissure
 - ~ Only frontal lobes may be fused
 - ~ Septum pellucidum is absent
 - ~ Anterior horns of ventricles fused
- 3. Dandy-Walker complex
 - a. Congenital anomaly of the roof of the fourth ventricle with concurrent occlusion of aqueduct of Sylvius and foramina of Magendie and Luschka
 - b. Variant: enlarged cisterna magna that communicates with fourth ventricle; normal or hypoplastic cerebellar vermis
 - c. Sonographic findings
 - i) Enlarged 4th ventricle cyst occupies the area of cerebellum
 - ii) Secondary dilatation of the 3rd and lateral ventricles
 - iii) Hypoplastic vermis
 - iv) Hydrocephalus
- 4. Callosal Dysgenesis
 - a. Complete or partial absence of the connection tissue between cerebral hemispheres
 - i) May be an isolated finding or associated with other anomalies
 - b. Sonographic findings
 - i) 'Longhorn' or 'moosehead' configuration of anterior horns and third ventricle
 - ii) Lateral ventricles with parallel configuration
 - iii) Marked separation of lateral ventricles
 - iv) Widening of occipital horns and 3rd ventricle
 - v) Gyri in a straightened or 'sunray' appearance on midline sagittal view
- 5. Ventriculomegaly
 - a. Enlargement (unilateral or bilateral) of the ventricles without increased head circumference
 - b. Types
 - i) Communicating
 - ii) Non-communicating
 - iii) Result of cerebral atrophy
 - c. Sonographic findings

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- i) Ventricle(s) demonstrate(s) greater than normal size first noted in trigone and occipital horn areas
 - ii) Visualization of the third and possibly, fourth ventricle
 - iii) Choroid plexus appears to “dangle” within ventricular atrium
 - iv) Thinned brain mantle in cases of cerebral atrophy
- 6. Hydrocephalus
 - a. Enlargement (unilateral or bilateral) of the ventricle(s) with increased head circumference
 - b. Types
 - i) Communicating
 - ii) Non-communicating
 - c. Sonographic findings
 - i) Blunted lateral angles of enlarged lateral ventricles
 - ii) Possible rupture of interhemispheric fissure
 - iii) Thinned brain mantle
 - iv) Head circumference is enlarged
 - v) In cases of non-communicating hydrocephalus, point of obstruction may be seen
- 7. Aqueductal stenosis
 - a. Aqueduct of Sylvius is narrowed or is a small channel with blind end
 - b. Sonographic findings
 - i) Widening of lateral and 3rd ventricles and normal 4th ventricle
- 8. Hydranencephaly
 - a. Prenatal occlusion of internal carotid arteries resulting in necrosis of cerebral hemispheres
 - i) Absence of both cerebral hemispheres with presence of falx, thalamus, cerebellum, brain stem, and portions of occipital and/or temporal lobes
 - b. Sonographic findings
 - i) Large fluid-filled cranial vault with identifiable falx
 - ii) Intact cerebellum and midbrain
 - iii) May mimic holoprosencephaly
- 9. Cephalocele
 - a. Herniation of a portion of the neural tube through a defect in skull
 - i) Occipital defect most common
 - ii) May contain variable amounts of brain tissue
 - If cephalocele is large, head circumference may be decreased
 - b. Sonographic findings

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- i) Sac/pouch containing cerebral spinal fluid (CSF) or meninges and brain tissue (encephalocele), or meninges, brain tissue, and ventricles (encephalocystomenocele)
 - ii) Lateral ventricle enlargement
- 10. Hemorrhagic pathology
 - a. Subependymal - intraventricular hemorrhage (SEH –IVH)
 - i) Pre-term infants are at risk
 - ii) Grades
 - Grade I - SEH without ventricular enlargement
 - Grade II - IVH without ventricular enlargement
 - Grade III - IVH with ventricular enlargement
 - Grade IV - parenchymal hemorrhage
 - b. Sonographic findings
 - i) Appearance/location depends on grade
 - ii) Echogenicity depends on the age of hemorrhage/clot
- 11. Intraparenchymal hemorrhage
 - a. Sonographic findings
 - i) Zones of increased echogenicity in white matter
- 12. Intracerebellar hemorrhage
 - a. Types
 - i) Primary
 - ii) Venous infarction
 - iii) Traumatic laceration
 - iv) Extension SEH-IVH
 - b. Sonographic findings
 - i) Areas of increased echogenicity within echogenic cerebellar parenchyma
- 13. Ischemic - hypoxic lesions
 - a. Types
 - i) Selective neuronal necrosis
 - ii) Status marmoratus
 - iii) Parasagittal cerebral injury
 - iv) Periventricular leukomalacia (PVL) or periventricular white matter injury
 - v) Focal brain lesions
 - b. Sonographic findings
 - i) Variable
 - Areas of increased echogenicity in periventricular white matter – more echogenic than choroid

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- Areas of increased echogenicity in subcortical and deep white matter in basal ganglia
 - Necrosis
 - Cysts

14. Ventriculitis

a. Sonographic findings

- i) Thin septations extending from walls of lateral ventricles
- ii) Echogenic ventricular walls

15. Ependymitis

a. Sonographic findings

- i) Thickened, hyperechoic ependyma

16. Cerebral edema

a. Swelling of the brain associated with hypoxic events or metabolic abnormalities in full-term infants

- i) May be related to metabolic disorders, birth asphyxia, infection, and congenital malformation
- ii) May lead to infarction and subsequent porencephaly or encephalomalacia

b. Sonographic findings (initial)

- i) Diffusely echogenic brain with loss of visualization of normal landmarks
- ii) Slit-like ventricles
- iii) Speckling of parenchyma and poorly defined sulci

c. Sonographic findings (resolved)

- i) Patchy increased periventricular echogenicity
- ii) Development of cystic areas
 - Also known as periventricular leukomalacia (PVL), cystic encephalomalacia or white matter necrosis (WMN)

G. Miscellaneous

1. Lissencephaly
2. Lipoma of the corpus callosum
3. Papilloma of the corpus callosum
4. Schizencephaly
5. Septo-optic dysplasia
6. Arachnoid cyst
7. Sub-dural hemorrhage
8. Vein of Galen aneurysmal malformation
9. Calcifications

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- H. Correlative and/or Prior Imaging
 - 1. Computed tomography
 - 2. Magnetic resonance
 - 3. Angiography
 - 4. Radiography

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Rationale: Accurate assessment and performance of neonatal spine sonograms require the sonographer to have a comprehensive knowledge of the anatomy, physiology, and pathophysiology of the infant spine. An understanding of embryologic development and sonographic appearances is essential for performing high-quality examinations.

Section XIX: Neonatal Spine

1. Describe the anatomy of the neonatal spine
 2. List the common pathologic conditions of the neonatal spine that relate to sonographic diagnosis
 3. Describe the indication and sonographic techniques for neonatal spine imaging
 4. Describe the major pathologies diagnosed with sonographic imaging of the neonatal spine
-

XIX. NEONATAL SPINE

A. Embryology

1. Neural plate
2. Neurulation
3. Caudal cell mass development
4. Neural tube and canal
5. Spinal meninges
6. Paraxial mesoderm
 - a. Vertebrae

B. Anatomy

1. Vertebrae
2. Sacrum
3. Intervertebral discs
4. Ligaments and nerves
5. Spinal cord
 - a. Conus medullaris
 - b. Filum terminale
 - c. Anterior median fissure
 - d. Posterior media fissure
 - e. Roots of spinal nerves
 - i) Cauda equina
6. Meninges of spinal cord
 - a. Dura mater
 - b. Arachnoid mater
 - c. Pia mater

C. Function and Physiology

1. Spinal cord carries nerve impulses to and from the brain and to the rest of the body
2. Bony spine encloses and protects the spinal cord

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D. Indications

1. Midline cutaneous abnormalities
2. Sacral dimple(s)
3. Hemangioma
4. Raised midline
5. Hairy patch
6. Tail-like projection of lower spine
7. Diagnosis of myelomeningocele or myeloschisis
8. Lower extremity deformity

E. Sonographic Technique

1. Patient positions
 - a. Prone
 - b. Lateral decubitus
 - c. Upright
 - d. Spine flexed
 - e. Head should be more elevated than caudal end of the spinal canal, gravity may pull fluid into sacs or cystic spaces that may not be seen otherwise
2. Transducer selection
3. Scan considerations
 - a. Stand-off pad may be utilized
 - b. Determine level of the conus medullaris
 - i) Begin at sacrum which is ossified at birth; coccygeal ossification centers are rounded - possible to have 6 lumbar vertebrae
 - ii) Counting from lowest rib bearing vertebra – possible to have hypoplastic 12th ribs that mimic transverse processes
4. Sonographic findings
 - a. Vertebral bodies
 - b. Spinous processes
 - c. Dura mater
 - d. Coccyx
 - e. Spinal cord
 - i) Central echo complex
 - f. Nerve roots
 - g. Filum terminale

F. Pathology/Pathophysiology

1. Tethered cord
 - a. Fixation of cord at a more caudal location below bottom of L2

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- b. Diminished cord movement with stretching and ischemia of cord
 - c. Sonographic findings
 - i) Visualization of cord caudal to normal termination
 - ii) Diminished CSF cord pulsations of the nerve roots may be noted
 - iii) Eccentric cord location within the canal
 - iv) Displacement of nerve roots posteriorly while in prone position
- 2. Lipoma
 - a. Mass of filum terminale
 - b. Frequently associated with tethered cord
 - c. Sonographic findings
 - i) Echogenic mass
- 3. Hydromyelia
 - a. Dilatation of the central canal which may be diffuse or focal
 - b. Associated with myelomeningocele and diastematomyelia, may mimic or co-exist with syringomyelia
 - c. Sonographic findings
 - i) Separation of echogenic linear structures of central canal
- 4. Diastematomyelia
 - a. Cord is split at one or more sites by septum
 - b. Associated with meningocele or myelomeningocele
 - c. Sonographic findings
 - i) Split segments best seen on transverse views
- 5. Cysts of the spinal cord
 - a. May be noted in cauda equina or filum terminale, possible arachnoid cyst, thought to be normal variant
 - b. Related to tethered cord
- 6. Myelomeningocele
 - a. Spina bifida with low termination of spinal cord and a sac/pouch containing cerebral spinal fluid and nerves
 - b. Sonographic findings
 - i) Pre-operative sonographic examination can differentiate between a myelomeningocele and a meningocele (sac/pouch containing only cerebral spinal fluid)
 - ii) Detection of associated anomalies
 - Hydromelia, diastematomyelia, lipoma or thickened filum terminale
- G. Correlative and/or Prior Imaging
 - 1. Radiography

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2. Computed tomography
3. Magnetic resonance

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Abbreviations

A

AAA	Abdominal Aortic Aneurysm
ACTH	Adrenocorticotrophic Hormone
ADPKD	Autosomal Dominant Polycystic Kidney Disease
AFP	Alpha-Fetoprotein
AG	Adrenogenital Syndrome
AI	Acceleration-Index
AIDS	Acquired Immune Deficiency Syndrome
ALP	Alkaline Phosphatase
ALT	Alanine Aminotransferase
AP	Anterior-Posterior
APCKD	Adult Polycystic Kidney Disease
APN	Acute Pyelonephritis
ARDS	Acute Respiratory Distress Syndrome
ARPKD	Autosomal Recessive Polycystic Kidney Disease
AST	Aspartate Aminotransferase
AT	Acceleration Time
ATN	Acute Tubular Necrosis
AV	Arteriovenous Fistula

B

BPH	Benign Prostatic Hyperplasia
BUN	Blood Urea Nitrogen

C

CA	Carcinoma
CBD	Common Bile Duct
CCA	Common Carotid Artery
CHA	Common Hepatic Artery
CHD	Common Hepatic Duct
CHF	Congestive Heart Failure
CMJ	Corticomedullary Junction
C/RL	Caudate to Right Lobe Ratio Technique
CSF	Cerebral Spinal Fluid

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CT	Computed Tomography
CEUS	Contrast Enhanced Ultrasound
CZ	Central Zone

D

DCIS	Ductal Carcinoma In-Situ/Intraductal Carcinoma
DDH	Developmental Dysplasia of the Hip
DSR	Diastolic Systolic Ratio

E

ERCP	Endoscopic Retrograde Cholangiopancreatography
ECA	External Carotid Artery

F

FFP	Fresh Frozen Plasma
FNAC	Fine Needle Aspiration Cytology
FNH	Focal Nodular Hyperplasia

G

GDA	Gastroduodenal Artery
GI	Gastrointestinal
GU	Genitourinary

H

HIV	Human Immunodeficiency Virus
HPS	Hypertrophic Pyloric Stenosis

I

IBD	Inflammatory Bowel Disease
IDC	Invasive Ductal Carcinoma
IMA	Inferior Mesenteric Artery
IMV	Inferior Mesenteric Vein
INR	International Normalized Ratio
IPCKD	Infantile Polycystic Kidney Disease
ICA	Internal Carotid Artery
IVC	Inferior Vena Cava

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IVH Intraventricular Hemorrhage

IVP Intravenous Pyelogram

J

JPD Junctional Parenchymal Defect

L

LCIS Lobular Carcinoma In-Situ

LDH Lactic Dehydrogenase

LFT Liver Function Test

LHV Left Hepatic Vein

LLQ Left Lower Quadrant

LPV Left Portal Vein

LU Lower Urinary

LUQ Left Upper Quadrant

M

MHV Middle Hepatic Vein

MPV Main Portal Vein

MRI Magnetic Resonance Imaging

P

PFL Persistent Fetal Lobulation

PH Portal Hypertension

PSA Prostate Specific Antigen

PT Prothrombin Time

PTT Partial Prothrombin Time

PUV Posterior Urethral Valves

PV Portal Vein

PVL Periventricular Leukomalacia

PZ Peripheral Zone

R

RAR Renal Aortic Ratio

RBC Red Blood Count

RCC Renal Cell Carcinoma

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RHV	Right Hepatic Vein
RI	Resistive Index
RLD	Right Lateral Decubitus
RLQ	Right Lower Quadrant
RPV	Right Portal Vein
RUQ	Right Upper Quadrant

S

SA	Splenic Artery
SEH	Subependymal Hemorrhage
SGOT	Serum Glutamic-Oxaloacetic Transaminase
SGPT	Serum Glutamic-Pyruvic Transaminase
SMA	Superior Mesenteric Artery
SMV	Superior Mesenteric Vein
SPSA	Serum Prostate Specific Antigen

T

T3	Triiodothyronine
T4	Thyroxine
TDLU	Terminal Ductal Lobular Unit
TIPS	Transjugular Intrahepatic Portosystemic Shunt
TRUS	Transrectal Ultrasound
TSH	Thyroid Stimulating Hormone
TZ	Transitional Zone

V

VMA	Vanillylmandelic Acid
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W

WBC	White Blood Count
WMN	White Matter Necrosis

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