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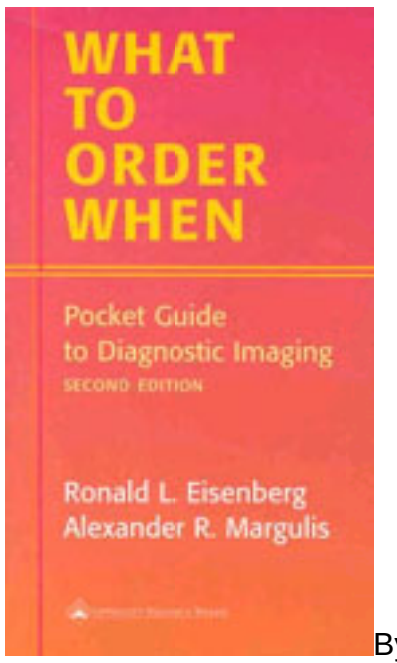

By OkDoKeY

What to Order When: Pocket Guide to Diagnostic Imaging

Contents

Contributing Authors

Peter W. Callen, M.D.
Professor of Radiology, Obstetrics, Gynecology and Reproductive Science
University of California School of Medicine
San Francisco, California

William Dillon, M.D.
Professor of Radiology, Neurology and Neurosurgery
University of California School of Medicine
San Francisco, California

Burton P. Drayer, M.D.
Chairman, Department of Radiological Sciences
Director of Magnetic Resonance Imaging
St. Joseph's Hospital and Medical Center
Barrow Neurological Institute
Phoenix, Arizona

N. Reed Dunnick, M.D.
Professor and Chair
Department of Radiology
University of Michigan
Ann Arbor, Michigan

Ronald L. Eisenberg, M.D., J.D.
Clinical Professor of Radiology
University of California School of Medicine
San Francisco, California
University of California School of Medicine
Davis, California
Chairman of Radiology
Alameda County Medical Center
Oakland, California

Brian Funaki, M.D.
Assistant Professor of Radiology
University of Chicago
Chicago, Illinois

Richard M. Gore, M.D.
Professor of Radiology
Northwestern University Medical School
Chicago, Illinois
Chief, Section of Gastrointestinal Radiology
Evanston Hospital-McGaw Medical Center of Northwestern University
Evanston, Illinois

Hedvig Hricak, M.D.
Professor of Radiology, Urology and Radiation Oncology
Chief, Abdominal Imaging Section
University of California School of Medicine
San Francisco, California

Martin J. Lipton, M.D.
Professor and Chairman
Department of Radiology
The University of Chicago
The University of Chicago Hospitals
Chicago, Illinois

Alexander R. Margulis, M.D., D.Sc. (hon.)
Professor of Radiology
University of California School of Medicine
San Francisco, California

Charles E. Putman, M.D.
James B. Duke Professor of Radiology
Professor of Medicine
Duke University Medical Center
Executive Vice President for Administration
Duke University
Durham, North Carolina

Donald Resnick, M.D.
Professor of Radiology
University of California, San Diego
La Jolla, California
Chief, Osteoradiology Section
Veterans Administration Medical Center
San Diego, California

Edward A. Sickles, M.D.
Professor of Radiology
Chief, Breast Imaging Section
University of California School of Medicine
San Francisco, California

Nina S. Vincoff, M.D.
Resident
Department of Radiology
University of California School of Medicine
San Francisco, California

Dedication

To Zina, Avlana, and Cherina and To Hedi

Preface

The format and approach of the first edition of this handbook has met our goal of providing a user-friendly guide to the most efficient and cost-effective imaging strategies for 300 clinical problems. Since its publication, managed care has become more prevalent and cost controls on medical care more stringent. With this in mind, the second edition offers updated imaging approaches (and some additional clinical situations) that reflect the continued technological advances in diagnostic imaging. For example, conventional radiography has become increasingly digital, with PACS making retrieval of images virtually instantaneous. In ultrasound, contrast media are now available, and harmonic imaging can diminish noise. Helical and multi-detector CT have greatly improved patient throughput, and the reduction in price of nonionic contrast media has made their widespread use more feasible. Automation of reformatting has increased specificity and improved treatment planning. Single-shot sequencing has made MRI applicable in imaging the acute abdomen, while diffusion MR imaging is now available for diagnosing stroke at an early stage. Proton MR spectroscopy shows promise in the staging and treatment follow-up of prostate cancer and in evaluating brain tumors.

One further important change in the second edition is the new title, *What to Order When: Pocket Guide to Diagnostic Imaging*. This change recognizes that a major audience for this book consists of residents-in-training and practicing physicians in internal medicine, general practice, emergency medicine, and surgery, and others who are on the firing lines and actually order imaging studies. It is essential that these physicians have a clear understanding of the advantages and limitations of both newer and traditional imaging procedures, as well as their relative costs, so that they can make informed decisions regarding the appropriate imaging strategies for their patients.

Medical imaging is rapidly advancing, and this pocket guide is designed to update physicians on the critical decision of *What to Order When*. In this way, physicians can ensure that their patients have the most appropriate imaging procedures that will lead to prompt diagnosis and timely treatment.

Ronald L. Eisenberg, M.D., J.D.
Alexander R. Margulis, M.D.

Preface to the First Edition

Medical imaging has made spectacular advances in the past fifteen years, reflecting the explosive developments in computers, electronics, and television. New cross-sectional imaging modalities are now widely used for diagnosing a broad spectrum of clinical disorders. Ultrasound is the most available and least expensive of these new techniques, but it is highly operator-dependent and requires rigorous training of technologists and physicians. Computed tomography is extremely versatile and has better signal-to-noise ratios than ultrasound. However, it is more expensive, uses ionizing radiation, and often requires the use of iodinated contrast media. Magnetic resonance imaging is the most sophisticated of these cross-sectional techniques, offering the best soft-tissue contrast resolution and the ability to image directly in multiple planes with a variety of pulse sequences. However, it is the most expensive and time-consuming of these imaging modalities. Nuclear medicine procedures now provide metabolic as well as morphological information, especially when using highly sophisticated tomographic procedures (SPECT, PET). The major disadvantage of nuclear procedures is the need for the handling and disposal, the administration to patients, and in the case of PET, the very high cost of radioactive materials.

The availability of a wide variety of alternative imaging approaches comes at a time when the medical profession is facing severe financial constraints. Thus, it is essential that the practicing physician and resident-in-training have an understanding of the advantages and limitations of the newer (and the traditional) imaging procedures and a conception of their relative costs.

To meet this critical need, we have developed the *Radiology Pocket Reference* to recommend the most efficient and cost-effective imaging strategies for 300 clinical problems. The book is organized to reflect the two basic situations that the clinician faces when ordering an image study. The first part of each section deals with those symptoms and signs that do not permit a single working diagnosis. The second part provides coherent strategies that can be used when there is a working clinical diagnosis to be confirmed, refined, or rejected by imaging procedures. For every symptom or sign, a list of differential diagnoses is offered; for each clinical diagnosis, there is a brief outline of typical signs and symptoms as well as predisposing factors.

Our guiding principle in selecting the order of imaging examinations has been the need to combine cost effectiveness and noninvasiveness with high diagnostic accuracy. However, the reader must always take into consideration such local conditions as the availability and adequacy of equipment and the expertise of the radiologists performing the recommended studies. Therefore, we often suggest alternative approaches to be taken when modern equipment and adequate expertise are not available.

To fit the goal of a pocket-sized book that would receive frequent use, we have used a terse outline approach, choosing to include more clinical scenarios at the expense of long explanations. We intentionally did not burden the reader with detailed statistical information on sensitivity, specificity, accuracy, and positive and negative predictive values, because these figures vary greatly, are often in dispute, and are constantly changing. Similarly, we chose not to include specific references that would have made the book substantially longer without providing any additional practical information. Nevertheless, we have taken a wealth of experimental data into account in selecting those procedures that provide the highest likelihood of leading to the diagnosis.

To ensure that the information provided to the reader is up to date, each chapter has been edited by a prominent radiologist subspecializing in that area (in most instances the author of a highly regarded textbook in the field). Rather than repeat the same information throughout the book, we have included an appendix that describes the basics of each of the newer sophisticated imaging modalities as well as the relative costs of individual procedures in multiples of the basic chest radiograph.

We sincerely hope that the pocket-sized format of the book will make it readily available when it is needed most—in the many clinical situations in which there is not enough time to go to the medical library and consult larger, more encyclopedic texts. We intend to keep this reference book current by adding or deleting information as it becomes available in the literature. To meet our overall goal, we would appreciate receiving suggestions from readers concerning ways in which we could make this pocket-sized reference book even more user-friendly.

Ronald L. Eisenberg, M.D.
Alexander R. Margulis, M.D.

CHAPTER 1. CHEST

Charles E. Putman

SIGNS AND SYMPTOMS

Cough

Common Causes

- Inflammatory (laryngitis, tracheitis, bronchitis, bronchiolitis, pneumonia, lung abscess)
- Mechanical (compression of airway due to neoplasm, foreign body, granulomas, bronchospasm)
- Inhalation of particulate material (pneumoconioses)
- Chemical (inhalation of irritant fumes, including cigarette smoke)
- Thermal (inhalation of cold or very hot air)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred imaging technique to demonstrate infection, neoplasm, or diffuse pulmonary parenchymal disease

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Notes: Additional imaging studies are rarely needed, except for appropriate follow-up radiographs, because the overwhelming majority of patients with clinically significant new cough will have pneumonia, bronchitis, or some other acute infectious disease of the respiratory tract.

Because a negative chest radiograph does not exclude pneumonia (or cancer), especially in immunocompromised patients, if an antibiotic-sensitive infection is suspected clinically, a sputum specimen should be obtained and the patient treated despite the unrevealing film.

Cyanosis

Presenting Signs and Symptoms

- Bluish discoloration of the skin or mucous membranes (due to excess of reduced hemoglobin in the blood)

Common Causes

- Impaired pulmonary function (pneumonia, pulmonary edema, chronic obstructive pulmonary disease)
- Anatomic vascular shunting (congenital heart disease, pulmonary arteriovenous fistula)
- Decreased oxygen in inspired air (high altitude)
- Abnormal hemoglobin

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred imaging technique to demonstrate underlying pulmonary or cardiac abnormality

Dyspnea

Presenting Signs and Symptoms

- Shortness of breath
- Difficulty breathing on exertion
- Uncomfortable awareness of breathing (increased muscular effort required)

Common Causes

- Physical exertion
- Hypoxia (high altitude)
- Restrictive lung disease (pulmonary fibrosis, chest wall deformity)
- Obstructive lung disease (emphysema, asthma)
- Congestive heart failure
- Pulmonary embolism

Approach to Diagnostic Imaging

1. **Plain chest radiograph**

- Best imaging technique for identifying an underlying pulmonary or cardiac cause, as well as any need for appropriate additional imaging studies

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Note: Soft-tissue views of the neck (or fiberoptic examination) may be helpful in patients with suspected acute upper airway obstruction.

Pleurisy

Presenting Signs and Symptoms

- Pain that is aggravated by breathing or coughing (may be of sudden onset, chronic, or recurring)
- Rapid and shallow respiration
- Limited motion of the affected side
- Decreased breath sounds on the affected side
- Pleural friction rub (characteristic finding that is often absent and is frequently heard only 24 to 48 hours after the onset of pain)

Common Causes

- Pneumonia
- Tuberculosis
- Pulmonary embolism
- Trauma
- Neoplasm
- Occult rib fracture
- Congestive heart failure
- Mixed connective tissue disease
- Pancreatitis

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred imaging technique that may demonstrate the underlying pulmonary, rib, or chest wall abnormality, as well as a confirming pleural effusion

Hemoptysis

Presenting Signs and Symptoms

- Coughing up blood (resulting from bleeding from the respiratory tract)

Common Causes

- Infection (pneumonia, tuberculosis, fungal infection, lung abscess)
- Bronchogenic carcinoma
- Bronchiectasis
- Bronchitis
- Pulmonary infarction (secondary to embolism)
- Congestive heart failure

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Initial imaging procedure
   - Normal study does not exclude neoplasm or bronchiectasis as the cause of the bleeding
2. **Fiberoptic bronchoscopy**
   - Indicated in a patient for whom there is a high clinical suspicion of malignancy and who has a relevant abnormality on the plain chest radiograph
   - Relatively invasive procedure with potential complications (e.g., hemorrhage, pneumothorax, hypoxemia)
3. **Computed tomography**
   - Indicated in a patient with a normal chest radiograph in whom the clinical suspicion of malignancy is relatively low
   - Indicated if a neoplasm is not detected by fiberoptic bronchoscopy (which is unreliable in locating peripheral tumors demonstrable by CT)
   - Indicated in any patient with recurrent symptoms of bronchitis or bronchiectasis

> **Caveat: Despite a systematic and intensive search, the cause of hemoptysis will not be found in 30% to 40% of patients.**

Stridor/Upper Airway Obstruction

Presenting Signs and Symptoms

- Musical sound that is predominantly inspiratory and is loud enough to be heard without a stethoscope at some distance from the patient (heard better over the neck than over the chest)

Common Causes

- Epiglottitis
- Croup
- Inhaled foreign body
- Pharyngeal tumor
- Glottic edema
- Retropharyngeal abscess

Approach to Diagnostic Imaging

1. **Plain radiograph of the neck (soft-tissue technique)**
   - Preferred imaging technique to demonstrate narrowing or luminal obstruction of the upper airway (lateral projection is often more valuable than the frontal view)

Note: Laryngoscopy or CT of the neck may be required, especially in older patients in whom malignancy is more common and infection is a less likely cause.

Wheezing

Presenting Signs and Symptoms

- Wheezing or whistling noise associated with breathing (implies obstruction to the flow of air at some level in the respiratory tract)
- Most commonly heard on expiration

Common Causes

- Asthma
- Congestive heart failure
- Pneumonia
- Bronchogenic tumor
- Pulmonary embolus
- Foreign body

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred imaging study to exclude a tumor or a foreign body

DISORDERS

Abscess (Lung)

Presenting Signs and Symptoms

- Cough productive of moderate-to-large amounts of purulent, often foul-smelling sputum that may be tinged with blood
- Fever and sweats
- Chest pain and dyspnea
- Anorexia and weight loss
- Leukocytosis

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred initial imaging technique to demonstrate an area of consolidation that may develop into a cavity with an air–fluid level after rupture of the abscess into the bronchial tree
   - May permit differentiation of a peripheral lung abscess (round; formation of an acute angle with the chest wall) from an empyema (lenticular shape; formation of an obtuse angle with the chest wall)
2. **Computed tomography**
   - Best modality for differentiating peripheral lung abscess from empyema

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Note: Most lung abscesses can be treated with antibiotic therapy and postural drainage; empyemas require a drainage procedure.

3. **Fiberoptic bronchoscopy**
    - May allow the removal of an underlying foreign body or excessive mucus and permit material to be obtained for culture

Adult Respiratory Distress Syndrome (ARDS)

Presenting Signs and Symptoms

- Tachypnea, then dyspnea (24 to 48 hours after initial illness/injury)
- Noncardiogenic pulmonary edema
- Hypoxemia and cyanosis

Common Causes

- Diffuse pulmonary infection (bacterial or viral)
- Aspiration of gastric contents
- Direct chest trauma
- Prolonged or profound shock
- Inhalation of toxins and irritants
- Systemic reaction to nonpulmonary processes (e.g., gram-negative septicemia, hemorrhagic pancreatitis, fat embolism)
- Massive blood transfusion
- Cardiopulmonary bypass (“pump lung”)
- Narcotic overdose pulmonary edema
- Burns
- Near-drowning

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
    - Nonspecific diffuse bilateral opacities similar to pulmonary edema (but cardiac silhouette within normal size and no pleural effusion)
    - Findings may lag many hours behind functional changes and appear much less severe than the clinical degree of hypoxemia
    - Required during mechanical ventilation to detect evidence of barotrauma (pneumothorax, pneumomediastinum) and to evaluate tube placements (endotracheal, chest, and nasogastric tubes; Swan-Ganz catheter; central venous line)

Asbestosis

Presenting Signs and Symptoms

- Insidious onset of exertional dyspnea and reduced exercise tolerance
- Symptoms of airways disease (cough, sputum, wheezing) occurring primarily in heavy smokers

Common Causes

- Occupational exposure

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
    - Preferred initial imaging technique to demonstrate irregular or linear small opacities (usually most prominent in the lower zones), characteristic diffuse or localized pleural thickening (pleural plaques), and calcification of the parietal pleura
    - Relatively low specificity because of frequent difficulty in differentiating pleural thickening from normal intercostal muscles and extrapleural fat companion shadows of the chest wall (more likely asbestos-related if bilateral, symmetric, and along the midlateral chest wall)
2. **High-resolution computed tomography**
    - Superior to chest radiography for detecting pleural plaques
    - Not recommended as a screening examination because of its high cost (good-quality chest radiographs interpreted by an informed reader have a high sensitivity and negative predictive value in the diagnosis of pleural plaques)
    - Valuable for eliminating false-positive diagnoses of noncalcified plaques caused by muscle or fat and for distinguishing pleural plaques from lung

Asthma

Presenting Signs and Symptoms

- Episodic respiratory distress, often with tachypnea, tachycardia, and audible wheezes
- Anxiety and struggling for air
- Use of accessory muscles of respiration

- Hyperexpansion of the lung (due to air trapping)
- Prolonged expiratory phase

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Findings varying from entirely normal to hyperinflation, increased lung opacities, bronchial wall thickening, and regions of atelectasis

     Caveat: Once the diagnosis of asthma is established, chest radiographs are only required during recurrent episodes when there is clinical suspicion of complications (e.g., pneumothorax, atelectasis, secondary infection).
2. **Fiberoptic bronchoscopy**
   - Indicated in a patient who has the potential for aspiration of a foreign body or is unresponsive to medical management
3. **Computed tomography**
   - Indicated in a patient with chronic bronchospasm when chest radiography is normal
   - May reveal focal opacities of increased attenuation with air trapping (mosaic perfusion). This heterogeneous pattern could reflect bronchiolitis obliterans, hypersensitivity pneumonitis, or allergic alveolitis

Atelectasis

Presenting Signs and Symptoms

- Depend on the speed of the bronchial occlusion, the extent of lung affected, and the presence of infection

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Note: Hypoxemia may cause decreased perfusion and produce a ventilation–perfusion (V/Q) mismatch.

Common Causes

- Mucous plugs (tenacious bronchial exudate)
- Endobronchial tumor
- Granuloma
- Foreign body
- Extrinsic compression of a bronchus (enlarged lymph nodes, tumor, aneurysm)
- External compression of the lung (pleural effusion, pneumothorax)
- Neonatal respiratory distress syndrome (decreased or abnormal surfactant)
- Infection (resorptive atelectasis)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred imaging technique to demonstrate characteristic linear streaks (plate-like atelectasis) or a segment of shrunken, airless lung
   - If atelectasis involves a substantial amount of the lung, the chest radiograph may show secondary elevation of the ipsilateral hemidiaphragm; shift of the trachea, heart, and mediastinum toward the affected area; and modification of the normal pulmonary vascular pattern
   - May show the underlying cause of atelectasis (extrinsic mass, pleural effusion, pneumothorax)
2. **Fiberoptic bronchoscopy or computed tomography**
   - Indicated to search for a cause of obstruction if there is no other obvious source for a collapsed segment or lobe

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Note: Fiberoptic bronchoscopy may be therapeutic as well as diagnostic (e.g., removal of mucous plugs, obtaining material for culture or cytology).

Bronchiectasis

Presenting Signs and Symptoms

- Chronic cough with sputum production (often after severe pneumonia with incomplete clearing of symptoms)
- Hemoptysis
- Recurrent pneumonia
- Chronic atelectasis

Common Causes

- Recurrent or chronic pneumonia
- Chronic aspiration
- Cystic fibrosis
- Allergic bronchopulmonary aspergillosis
- Interstitial pulmonary fibrosis
- Tuberculous scarring (upper lobes)

- Intrinsic bronchial disease (stenosis, extrinsic compression, endobronchial mass)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Abnormal in most patients, but the specific diagnosis can be suggested less than one-half the time
   - Demonstrates increased interstitial opacities from recurrent inflammatory or infectious responses or changes consistent with subsegmental atelectasis
   - Often “tram tracking” (parallel linear shadows representing the walls of cylindrically dilated bronchi) and areas of multiple thin-walled cysts, with or without air–fluid levels, which tend to be peripheral and cluster together in the distribution of a bronchovascular bundle
2. **High-resolution computed tomography**
   - High accuracy for demonstrating characteristic multiple, dilated, thin-walled circular lucencies (on cross-section) and parallel linear opacities (bronchial walls sectioned lengthwise)
   - Mucoid impactions may simulate lung nodules or branching, finger-like opacities
   - Cystic bronchiectasis produces a “cluster of grapes” appearance
   - May show evidence of inhomogeneous lung attenuation (mosaic perfusion), reflecting abnormal lung ventilation and resultant reduced perfusion

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Note: CT has all but eliminated the need for contrast bronchography, except for those few patients considered for curative resection who appear to have localized disease according to CT.

3. **Fiberoptic bronchoscopy**

Bronchogenic Carcinoma

Presenting Signs and Symptoms

- Cough (with or without hemoptysis)
- Dyspnea, wheezing, pneumonia
- Weight loss
- History of smoking
- Pleural effusion
- Recurrent Horner's syndrome
- Superior vena cava syndrome
- Symptoms relating to distal metastases (e.g., occult fracture, seizure)

Note: The lesion may be an asymptomatic pulmonary nodule discovered incidentally on a routine chest radiograph.

Risk Factors

- Cigarette smoking
- Occupational exposure (e. g., asbestos, radiation, arsenic, chromates, nickel, mustard gas)
- Pulmonary scars (e.g., old inflammatory disease such as tuberculosis)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred initial imaging technique to demonstrate a solitary pulmonary nodule, atelectasis, pulmonary opacity, bronchial narrowing, hilar or mediastinal lymphadenopathy, or pleural effusion
2. **Computed tomography**
   - Permits percutaneous fine-needle biopsy of peripheral lesions to obtain material for cytologic studies

Staging

1. **Computed tomography (chest/upper abdomen)**
   - Definitive noninvasive study
   - Detects hilar and mediastinal lymphadenopathy and bronchial narrowing
   - May show metastases in the liver and adrenal glands

Note: MRI may be valuable for detecting vascular invasion and mediastinal spread of tumor, as well as for clarifying whether adrenal enlargement is due to metastases or a benign cause.

Bronchopleural Fistula

Presenting Signs and Symptoms

- Fever, cough, dyspnea, pleurisy
- Intractable pneumothorax

- Large air leak in a person with a pleural drain

Common Causes

- Dehiscence of bronchial stump after lobectomy or pneumonectomy
- Necrotizing pulmonary infection
- Carcinoma of the lung with pleural invasion

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Demonstrates a loculated intrapleural collection of air and fluid (with an air–fluid level on upright films)

Note: In bronchopleural fistula, the air–fluid level has equal dimensions in both frontal and lateral radiographs; this is in contrast to lung abscess, in which the dimension of the air–fluid level varies between frontal and lateral projections.

2. **Computed tomography**
   - Can often distinguish a bronchopleural fistula from a peripheral lung abscess
   - Occasionally may demonstrate the actual fistulous communication
3. **Sinogram**
   - Injection of contrast material into a chest tube draining the pleural space may demonstrate the site of bronchial communication

Chronic Bronchitis

Presenting Signs and Symptoms

- Chronic productive cough (excessive tracheobronchial mucus secretion sufficient to cause cough with expectoration of sputum that occurs on most days for at least 3 consecutive months in at least 2 consecutive years)

Common Causes

- Cigarette smoking
- Occupational exposure
- Air pollution and other types of bronchial irritation
- Chronic pneumonia
- Superimposed emphysema

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Normal examination in about one-half of patients
   - May demonstrate nonspecific appearance with prominence of interstitial markings and thickened bronchial walls

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Note: Chronic bronchitis is a clinical and not a radiographic diagnosis. Once the diagnosis of chronic bronchitis is established, chest radiographs are only required if there is clinical suspicion of a supervening acute pneumonia or a developing malignancy.

Emphysema

Presenting Signs and Symptoms

- Exertional dyspnea (gradually progressive)
- Productive cough
- Abnormal pulmonary function tests

Common Causes

- Cigarette smoking
- Occupational exposure
- a_1-antitrypsin deficiency
- Congenital

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Lungs often appear normal in early stages of the disease
   - Eventually demonstrates hyperexpansion of the lungs (depressed diaphragm, generalized radiolucency of the lungs, enlarged retrosternal air space, ability to see diaphragmatic insertions on the ribs) and focal

opacifications due to atelectasis or scarring
   - Bullous changes (especially in the apices and subpleural regions)
   - Marked attenuation and stretching (even virtual absence) of pulmonary vessels
   - Often evidence of pulmonary hypertension (enlargement of central pulmonary arteries with rapid peripheral tapering)
   - In a_1-antitrypsin deficiency, emphysematous changes predominantly involve the lower lobes

> **Caveat: Once the diagnosis of emphysema is established, repeated chest radiographs are only indicated if there is clinical indication of supervening disease (e.g., infection, congestive heart failure).**

2. **High-resolution computed tomography**
   - More sensitive than conventional radiography for detecting emphysematous changes in the lungs, but rarely necessary. (The extent of clinical derangement is generally determined by pulmonary function tests.)
   - Of special value in detecting otherwise unsuspected blebs and bullae in select high-risk populations, such as those with suspected a_1-antitrypsin deficiency or with recurrent pneumothoraces

Empyema

Presenting Signs and Symptoms

- Chest pain (varies from vague discomfort to stabbing pain and is often worse with coughing or breathing)
- Rapid, shallow breathing
- Fever, chills, night sweats
- Cough
- Weight loss

> **Note:** If an empyema develops during the course of antibiotic treatment for bacterial pneumonia, the symptoms may be mild and the condition may go unrecognized.

Common Causes

- Acute pneumonia
- Lung abscess
- Thoracic surgery or trauma
- Spread from extrapulmonary sites (osteomyelitis of spine, subphrenic abscess)
- Sepsis
- Tuberculosis

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred initial imaging technique
   - May permit differentiation of empyema (lenticular shape; formation of an obtuse angle with the chest wall) from lung abscess (round; formation of an acute angle with the chest wall)
2. **Computed tomography**
   - Best modality for differentiating empyema from peripheral lung abscess

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> **Note:** Empyema requires a drainage procedure; most lung abscesses can be treated with antibiotic therapy and postural drainage.

   - May show contrast enhancement of the parietal and visceral pleura, thickening of the extrapleural subcostal tissues, and increased attenuation of the extrapleural fat, which are rarely seen with transudative effusions
3. **Thoracentesis**
   - Required to confirm suspected empyema to avoid a delay in diagnosis, which may have serious consequences
4. **Ultrasound**
   - Can serve as a valuable guide for obtaining fluid from a loculated empyema

Hypersensitivity Lung Disease

Presenting Signs and Symptoms

- Range from mild respiratory symptoms and low fever (and prompt recovery) to severe pulmonary symptoms in a life-threatening condition
- Striking blood eosinophilia (20% to 40% or more)
- Coexistent bronchial asthma

Common Causes

- Drug-induced eosinophilic lung disease (penicillin, aminosalicylic acid, hydralazine, chlorpropamide, sulfonamides)
- Hypersensitivity pneumonitis (extrinsic allergic alveolitis)
- Asthmatic pulmonary eosinophilia (hypersensitivity bronchopulmonary aspergillosis)
- Tropical eosinophilia (parasites such as roundworm, filaria)

- Pulmonary eosinophilia (Löffler's syndrome)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred imaging technique for detecting the broad spectrum of pulmonary abnormalities seen in these disorders
2. **Computed tomography**
   - Infrequently required in a symptomatic patient with normal chest radiographs as a “road map” prior to biopsy and as an aid to following the response to treatment

Infectious Granulomatous Disease

Presenting Signs and Symptoms

- Varies from asymptomatic exposure to fever, productive cough, and night sweats

Common Causes

- Tuberculosis (especially in HIV-positive patients and in immigrants from Asia and Central America)
- Histoplasmosis (central and eastern United States)
- Coccidioidomycosis (southwestern United States and Mexico)
- Blastomycosis (south-central and midwestern United States)
- Cryptococcosis
- Actinomycosis
- Nocardiosis

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred imaging technique to show the various patterns of opacifications within the lung (lobar consolidation, nodular opacities ranging from miliary to more discrete nodules, masses suggesting neoplasm, and diffuse disease with or without pleural effusion)
   - Best imaging modality for identifying potential complications (empyema, extensive atelectasis, and focal or diffuse dissemination of the primary disease)

Mediastinal Mass (Anterior)

Presenting Signs and Symptoms

- Asymptomatic and incidental finding on plain chest radiograph
- Myasthenia gravis (in up to 30–50% of patients with thymoma)

Common Causes

- Thymoma
- Teratoma
- Lymphoma
- Parathyroid tumor (ectopic)
- Aortic aneurysm (ascending portion)
- Morgagni hernia

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Detects and determines precise compartment of a mediastinal mass but otherwise does little to characterize the mass (can demonstrate erosion of the sternum in Hodgkin's disease and gas within a Morgagni hernia)
2. **Computed tomography**
   - Definitive imaging study for defining the origin and extent of a mass and determines its underlying characteristics
   - With contrast enhancement, highly accurate in differentiating among fatty, cystic, and soft-tissue masses and aneurysms
3. **Magnetic resonance imaging**
   - Equivalent to CT in confirming the presence and location of a mediastinal mass
   - Less effective than CT for assessing tracheal involvement and demonstrating calcification
   - Superior to CT for distinguishing tumor from fibrosis and in patients in whom the use of iodinated contrast material is contraindicated

Mediastinal Mass (Middle)

Presenting Signs and Symptoms

- Asymptomatic and incidental finding on plain chest radiograph
- Compression of trachea or esophagus (dysphagia, stridor, cough, wheezing, or localized or diffuse chest

pain–depends more on size of mass than on its identity)

Common Causes

- Lymph node enlargement (metastases, lymphoma, tuberculosis, histoplasmosis, sarcoidosis, pneumoconiosis)
- Aortic aneurysm
- Dilated venous structures (azygos, hemiazygos, superior vena cava)
- Bronchogenic carcinoma
- Bronchogenic cyst
- Pericardial cyst
- Mediastinal hemorrhage/inflammation/lipomatosis

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Detects and determines precise compartment of a mediastinal mass but does little to characterize it
2. **Computed tomography**
   - Definitive imaging study for determining the origin and extent of a mass and its underlying characteristics
   - With contrast enhancement, highly accurate in differentiating among fatty, cystic, and soft-tissue masses and aneurysms
3. **Magnetic resonance imaging**
   - Equivalent to CT in confirming the presence and location of a mediastinal mass
   - Less effective than CT for assessing tracheal involvement by a mass or for demonstrating calcification
   - Superior to CT for distinguishing tumor from fibrosis and in patients in whom the use of iodinated contrast material is contraindicated
   - Able to image directly in the coronal or sagittal plane, which is an advantage in mediastinal regions that are parallel to the axial plane (sub-carinal space, aortopulmonary window) and thus suffer from partial volume averaging effects on CT

> **Caveat: False-positive results may occur because of the relatively low spatial resolution of MRI, which may result in an inability to distinguish between a group of normal-sized nodes and a single enlarged node.**

Mediastinal Mass (Posterior)

Presenting Signs and Symptoms

- Asymptomatic and incidental finding on plain chest radiograph

Common Causes

- Neurogenic tumor
- Vertebral lesion (trauma, infection, tumor)
- Esophageal lesion (dilatation, neoplasm, diverticulum, duplication cyst)
- Hiatal hernia
- Lymphoma
- Aortic aneurysm (descending portion)
- Bochdalek hernia

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Detects and determines precise compartment of a mediastinal mass but otherwise does little to characterize the mass (can show bone erosion in neurogenic tumor or air in a hiatal or Bochdalek hernia)
2. **Barium swallow**
   - Indicated if there is clinical suspicion of an esophageal lesion
3. **Computed tomography**
   - Definitive imaging study for defining the origin and extent of the mass and for determining its underlying characteristics
   - With contrast enhancement, highly accurate in differentiating among fatty, cystic, and soft-tissue masses and aneurysms
4. **Magnetic resonance imaging**
   - Equivalent to CT in confirming the presence and location of a mediastinal mass
   - Less effective than CT for showing calcification
   - Superior to CT for showing the spinal cord and in patients in whom the use of iodinated contrast material is contraindicated

Mediastinal Mass (Superior)

Presenting Signs and Symptoms

- Asymptomatic and incidental finding on plain chest radiograph
- Displacement, deviation, or compression of the trachea (upper thoracic portion)

Common Causes

- Substernal thyroid
- Lymph node enlargement
- Parathyroid mass
- Other causes of anterior, middle, or posterior mediastinal masses

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Detects a mass displacing, deviating, or compressing the trachea but otherwise does little to characterize the mass
2. **Radionuclide thyroid scan**
   - Most accurate method for diagnosing the presence of abnormal thyroid tissue in the neck or superior mediastinum
3. **Computed tomography**
   - Definitive imaging study for defining the origin and extent of the mass and for determining its underlying characteristics
4. **Magnetic resonance imaging**
   - Equivalent to CT in confirming the presence and location of a mediastinal mass
   - Less effective than CT for assessing tracheal involvement and for demonstrating calcification
   - Superior to CT for distinguishing tumor from fibrosis and in patients in whom the use of iodinated contrast material is contraindicated

Metastases (Pulmonary)

Presenting Signs and Symptoms

- Most are asymptomatic and only detected incidentally during staging or follow-up of patients with a known malignancy
- Develop in up to one-third of patients with cancer
- Only demonstrable metastatic site in about one-half of patients with metastatic spread of tumor

Common Primary Sites of Tumor

- Breast
- Lung
- Kidney
- Thyroid
- Head and neck
- Melanoma

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred screening technique (detects almost all metastases greater than 15 mm in diameter)
   - May fail to detect smaller nodules (because of overlying ribs or blood vessels) and nodules in specific areas (lung apices, inferior recesses just above dome of diaphragm, subpleural region)
2. **Computed tomography**
   - Often detects small (3–10 mm), otherwise occult metastases (especially those located peripherally and in the subpleural region)
   - Unfortunately, high sensitivity of CT leads to potential problem of false-positive examinations (granulomas, intrapulmonary lymph nodes, or even pulmonary vessels on end are sometimes erroneously interpreted as metastases)
   - Best imaging modality for following the response of metastases to chemotherapy

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Note: Although resolution of nodules indicates a positive response, persistent nodular opacities representing sterilized tumor deposits may be seen after successful treatment of metastatic seminoma, choriocarcinoma, or hypernephroma.

3. **Radionuclide thyroid scan (total body)**
   - Highly specific and more sensitive than plain chest radiographs for detecting thyroid carcinoma metastatic to the lung

Indications for CT If Plain Chest Radiograph Is Normal

1. High propensity of tumor spread to lung (melanoma, testicular carcinoma, choriocarcinoma, head and neck tumors)

   Caveat: Common primary tumors of the lung, breast, colon, prostate, and cervix have a low propensity of spread to the lungs.
2. Presence of metastases would alter treatment (usually by cancellation of planned extensive surgery)
   - Radical amputation for osteosarcoma

    - Extensive lymph node dissection for melanoma
    - Lobectomy for presumed solitary metastasis or several nodules localized to one lobe
3. Effective therapy available for metastases (osteogenic sarcoma, choriocarcinoma, nonseminomatous testicular tumors, renal cell carcinoma, certain functioning thyroid carcinomas)

> **Caveat: The detection of pulmonary metastases is of no clinical significance if there is no effective treatment for metastases or if there already are obvious extrathoracic metastases.**

Pleural Effusion

Presenting Signs and Symptoms

- Pleuritic pain
- Dyspnea
- Often asymptomatic and discovered as incidental finding on chest radiograph
- Decreased or absent breath sounds, percussion dullness, and decreased motion of hemithorax

Common Causes

- Congestive heart failure (usually bilateral but larger on the right)
- Neoplasm (primary or metastatic lung cancer, lymphoma)
- Pneumonia
- Ascites
- Pancreatitis (usually left-sided)
- Tuberculosis
- Pulmonary embolism (small)
- Mixed connective tissue disease (lupus, rheumatoid arthritis)
- Trauma (hemothorax)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
    - Preferred initial imaging technique that can show classic blunting or meniscus appearance at the lateral and posterior costophrenic angles, apical cap, or increased opacity of the hemithorax without obscuring of vascular markings
    - Large effusions may opacify an entire hemithorax and shift the mediastinum to the opposite side
    - Subpulmonic effusions may be detected by an unusually lateral position of the top of the diaphragmatic contour on supine films
    - Lateral decubitus projection (affected side down), can determine whether pleural fluid is free or loculated and estimate the amount of the effusion
2. **Computed tomography**
    - Procedure of choice for determining the status of the underlying lung parenchyma in a patient with extensive pleural effusion (e.g., may detect lung abscess, pneumonia, or bronchogenic carcinoma that is hidden from view on plain radiograph)
    - Limited value in differentiating transudates from exudates or chylous effusions
3. **Ultrasound**
    - Readily available for bedside imaging in severely ill patients in whom a lateral decubitus projection cannot be obtained
    - Best technique for identifying and localizing a loculated effusion as an echo-free or hypoechoic fluid collection separate from the lung and chest wall that may mimic a mass on plain radiographs
    - May permit demonstration of an exudate as a complex, septated pattern or a homogeneously echogenic appearance
    - Permits marking of the chest wall for thoracentesis (may be performed under ultrasound guidance in difficult cases)

Pneumoconioses

Presenting Signs and Symptoms

- Insidious onset of decreased pulmonary function (related to occupational exposure to inorganic dusts)

Common Types

- Silicosis
- Asbestosis
- Coal worker's pneumoconiosis
- Talcosis

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
    - Preferred initial imaging technique that may demonstrate a broad spectrum of chronic changes in the lung parenchyma and pleura

Note: There may be poor correlation between the extent of radiographic findings and the degree of alteration in pulmonary function.

2. **Computed tomography**
   - More sensitive than plain chest radiography for detecting subtle changes, but not usually necessary for clinical evaluation

Pneumomediastinum

Presenting Signs and Symptoms

- Chest pain
- May be asymptomatic

Common Causes

- Spontaneous
- Trauma (injury to chest wall, bronchus, trachea, lung)
- Iatrogenic (surgery or instrumentation of the esophagus, trachea, bronchi, or neck; overinflation during anesthesia and respiratory therapy)
- Extension of gas from the neck or abdomen
- Asthma (primarily in children)
- Rupture of the esophagus (e.g., Boerhaave's syndrome)
- Hyaline membrane disease (extension of pulmonary interstitial emphysema)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred imaging technique for detecting gas separating the medial margin of the pleura from the mediastinal contents or interposed between the heart and diaphragm
   - Can show any associated pneumoperitoneum or gas within the soft tissues of the neck

Note: The clinical concern in patients with pneumomediastinum is the possible development of a pneumothorax, which can have dire consequences in patients whose respiratory status is already compromised.

Pneumonia

Presenting Signs and Symptoms

- Cough with sputum production
- Fever and chills
- Chest pain and dyspnea

Predisposing Factors

- Viral respiratory infection
- Cigarette smoking
- Chronic obstructive pulmonary disease
- Alcoholism
- Unconsciousness
- Dysphagia with regurgitation
- Hospitalization or institutionalization
- Surgery/trauma
- Heart failure
- Immunosuppressive disorders and therapy

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred initial imaging technique to show the various patterns of opacifications within the lung
   - Best imaging modality for identifying potential complications (empyema, extensive atelectasis, and focal or diffuse dissemination of the primary infection)

Notes: The mere presence of an opacity in a patient with fever or chest pain does not necessarily indicate the presence of an infectious process. Atelectasis, neoplasm, pulmonary embolism or infarction, and atypical pulmonary edema can all mimic pneumonia both clinically and radiographically.

Pneumonia may exist in the presence of a normal radiograph (especially with atypical organisms and those pneumonias that develop in immunocompromised hosts).

Frequent radiographs after acute pneumonia should not be obtained in the normal population (unnecessary cost and radiation exposure), unless there is some clinical reason to warrant serial studies. Symptoms usually resolve, even though the radiographic opacity may be unchanged and persistent. However, in an immunocompromised patient in whom clinical manifestations may be depressed, serial chest radiographs are justified, as they may be the only means of following the results of a course of therapy.

2. **Computed tomography**
   - May be indicated if there is incomplete clearing of an opacity or clinical suspicion of either postobstructive pneumonia distal to an endobronchial lesion or a secondary lung abscess

Pneumonia in AIDS Patients

Presenting Signs and Symptoms

- Cough with sputum production
- Fever and chills
- Chest pain and dyspnea

Predominant Organisms

- *Pneumocystis carinii*
- *Histoplasma*
- Cytomegalovirus
- *Cryptococcus*
- *Aspergillus*
- *Toxoplasma*
- Varicella

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred imaging technique to show the various patterns of opacifications within the lung
   - Best imaging modality for identifying potential complications (empyema, extensive atelectasis, focal or diffuse dissemination of the primary infection)

Notes: The mere presence of an opacity in a patient with fever or chest pain does not necessarily indicate the presence of an infectious process. Atelectasis, neoplasm, pulmonary embolism or infarction, and atypical pulmonary edema can all mimic pneumonia both clinically and radiographically.

The radiograph may be normal, even though there is clinical evidence of pneumonia. Conversely, in immunocompromised patients, there may be extensive radiographic findings with minimal clinical manifestations. Therefore, in this population, serial chest radiographs are justified because they may be the only means of following a course of therapy (as opposed to the normal population, in which frequent radiographs after acute pneumonia should not be obtained).

Pneumothorax

Presenting Signs and Symptoms

- Range from asymptomatic to sudden, sharp chest pain, severe dyspnea, shock, and life-threatening respiratory failure
- Pain may be referred to corresponding shoulder, across the chest, or over the abdomen (simulating acute coronary occlusion or acute abdomen)
- Markedly depressed or absent bowel sounds
- Shift of mediastinum to opposite side (with large or tension pneumothorax)

Common Causes

- Spontaneous (rupture of small, usually apical bleb)
- Trauma (penetrating, blunt, rib fracture)
- Complication of mechanical ventilation (barotrauma)
- Chronic obstructive pulmonary disease

- Chronic pulmonary disease (e.g., sarcoidosis, eosinophilic granuloma)
- *Pneumocystis carinii* pneumonia
- Lung abscess with bronchopleural fistula
- Rupture of the esophagus
- Extension from pneumomediastinum
- Iatrogenic (surgery, lung or pleural biopsy, thoracentesis, central line placement)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred initial imaging technique that shows apical and lateral air without peripheral lung markings and separated from normal lung by a sharp pleural margin
   - May show underlying bullous or interstitial changes consistent with chronic obstructive pulmonary disease or any chronic interstitial lung disorder

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Notes: Pneumothorax is best seen on an expiration film obtained with low penetration (light film).

In patients on mechanical ventilation for ARDS, a small pneumothorax on a supine film may present subtly as a loculated collection in a subpulmonic or paracardiac location and be associated with a pneumomediastinum.

   Caveat: The visceral pleural line of a pneumothorax may be mimicked by skin folds (resulting from compression of redundant skin by the radiographic cassette). The key is to identify normal vascular markings that extend peripherally beyond the skin fold interface. The visceral pleural line may also be mimicked by bullae (it is necessary to detect the thin curvilinear walls that are concave rather than convex to the chest wall).
2. **Computed tomography**
   - More sensitive than plain chest radiographs for detecting a pneumothorax, but rarely necessary
   - May be required to differentiate pneumothorax from bullous disease and in patients in whom an anterior pneumothorax is suspected on a supine radiograph but who cannot undergo upright or lateral decubitus films
   - In a patient undergoing CT for abdominal trauma, routine sections through the chest may be obtained to detect a subtle pneumothorax that might not be evident on conventional supine radiographs

Proper Tube Placement

Indication for Study

- Determination of the tip of a radiopaque tube placed within the thorax

Common Types of Tubes

- Endotracheal tube
- Central venous pressure (CVP) catheter
- Swan-Ganz catheter
- Nasogastric tube

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Demonstrates whether the tip of the tube is in the proper position
   - **Endotracheal tube:** With the head in a neutral position, the tip should be 5 to 7 cm above the carina

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Note: With flexion and extension of the neck, the tip of the tube will move about 2 cm caudally and cranially, respectively.

   - **CVP catheter:** Within the superior vena cava (above the level of the right atrium), preferably at the level of the carina

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Note: Up to one-third of CVP catheters are incorrectly placed at the time of initial insertion.

   - **Swan-Ganz catheter:** Within the right or left main pulmonary arteries

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Note: Too peripheral a position of the tip may lead to occlusion of the pulmonary artery and resulting distal pulmonary infarction.

   - **Nasogastric tube:** Stomach

Note: The tip of the tube may remain in the esophagus above the esophagogastric junction or be misplaced in the bronchial tree.

Pulmonary Edema: Cardiac versus Noncardiac (Permeability)

Types of Edema

1. **Cardiac**
   - Low-protein transudate due to increased hydro-static pressure generated across the capillary membrane that initially accumulates in the connective tissues surrounding the blood vessels
2. **Noncardiac**
   - Protein-rich exudate that accumulates in the extravascular space as a consequence of increased microvascular permeability. Because of the high protein osmotic pressure of the extravasated proteins, water may not flow from the extravasation toward the loose connective tissue but may flood the alveolar space.

Note: Clearance of the protein-rich exudate is slower than that of the nonproteinaceous transudate.

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Can distinguish between cardiac and noncardiac (permeability) edema in about 80% of patients using the following criteria:

	Cardiac	***Noncardiac***
Major Signs		
Kerley lines	Present	Unusual
Pleural effusions	Present	Unusual
Cardiomegaly	Present	Unusual
Opacities in lung	Diffuse	Patchy and peripheral
Minor Signs		
Air bronchograms	Rare	Often present
Hilar haze	Present	Infrequent
Peribronchial cuffs	Present	Unusual

Pulmonary Fibrosis

Presenting Signs and Symptoms

- Often asymptomatic except for insidious onset of exertional dyspnea
- Cough (if secondary bronchial infection)
- Anorexia, weight loss, fatigue, weakness, vague chest pains
- Cyanosis, cor pulmonale, clubbing (severe disease)

Common Causes

- Idiopathic (Hamman-Rich syndrome, UIP)
- Collagen vascular diseases (scleroderma, rheumatoid arthritis)
- Sarcoidosis
- Eosinophilic granuloma
- Occupational exposure
- Immunosuppressive and antineoplastic drugs (busulfan, bleomycin, methotrexate, cyclophosphamide)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred initial imaging technique to show characteristic pattern of prominent linear markings, rounded opacities, and small cystic lesions (honeycombing), as well as evidence of pulmonary hypertension and cor pulmonale

     Caveat: Chest films may be normal even in the presence of significant symptoms or functional abnormalities.
2. **High-resolution computed tomography**
   - More sensitive than plain chest radiographs for detecting pulmonary fibrosis and suggesting the correct histologic diagnosis, but not usually required in clinical practice

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Note: Lung biopsy may be needed if the imaging findings and clinical course do not indicate the precise diagnosis.

Pulmonary Nodule (Solitary)

Presenting Signs and Symptoms

- Asymptomatic
- Incidental finding on a chest radiograph

Common Causes

- Benign nonneoplastic process (granuloma, arteriovenous malformation)
- Benign neoplastic process (hamartoma, bronchial adenoma)
- Primary bronchogenic carcinoma
- Solitary metastasis

Age Effect on Malignancy in Benign-Appearing Nodule (Small, Round, Sharply Defined)

- Younger than age 30: Cancer risk is less than 1%
- Ages 30 to 45: Cancer risk is about 15%
- Older than age 50: Cancer risk is 50%

Radiographic Criteria for Benignity

- Central dense or popcorn calcification
- No growth demonstrated on serial chest films over 2 years (comparison films must be eagerly sought)

Approach to Diagnostic Imaging

1. **Chest fluoroscopy (low kVp technique)**
   - May detect characteristic benign calcification and thus obviate any further investigation
   - May show that apparent nodule actually represents only a healing rib fracture or pleural changes
2. **Computed tomography**
   - May show additional nodules not visible on plain chest radiograph (suggesting metastases)
   - Detects any hilar or mediastinal metastases
   - Permits percutaneous fine-needle aspiration biopsy of peripheral lesions as an alternative to thoracotomy for establishing a definite diagnosis (25% pneumothorax rate, although chest tube required in only 5%; false-negative rate of about 10% in patients with carcinoma)

Pulmonary Embolism

Presenting Signs and Symptoms

- Nonspecific tachypnea, dyspnea, and hemoptysis

Major Risk Factors

- Prolonged bed rest
- Recent surgical procedure
- Recent myocardial infarction or chronic congestive heart failure
- Deep venous thrombosis in the veins of the pelvis or proximal lower extremities
- Indwelling venous catheter

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Usually normal (may be nonspecific opacity, pleural effusion, atelectasis, or elevation of the hemidiaphragm consistent with other pulmonary or pleural processes)
   - Classic pleural-based, wedge-shaped opacity (Hampton's hump) is seen in a minority of cases with pulmonary infarction
   - Uncommon findings of focal oligemia (Westermark's sign) and enlargement of the ipsilateral pulmonary artery (Fleischner's sign)
   - Essential for accurate interpretation of radionuclide lung scan
2. **Radionuclide ventilation–perfusion (V/Q) lung scan**
   - Most frequently performed noninvasive imaging study for detecting clinically significant pulmonary emboli
   - If the perfusion study is *normal*, significant embolization is excluded and no further studies are needed
   - If segmental or larger perfusion defects are present with normal ventilation in these areas (V/Q mismatch), there is a high likelihood of pulmonary embolism

     Caveat: There may be a relatively large number of indeterminate examinations in patients with chronic pulmonary disease or parenchymal abnormalities on plain chest radiograph.
3. **Contrast-enhanced computed tomography**
   - Has replaced V/Q lung scanning in some institutions as the preferred imaging modality for detecting and excluding pulmonary emboli
   - Shows a pulmonary embolus as a filling defect within the pulmonary artery or as an abrupt cutoff (complete

obstruction) of a pulmonary vessel

Note: Limitations of CT include a relatively high false-positive rate and difficulty in detecting lesions in the periphery of the lung.

4. **Pulmonary arteriography**
   - Most definitive study ("gold standard") that shows pulmonary emboli as intraarterial filling defects or abrupt cutoff (complete obstruction) of pulmonary vessels
   - Although invasive, it is indicated if the radionuclide scan is indeterminate or of intermediate probability and there is a clinical need for a definitive diagnosis
   - Indicated to confirm a high-probability radionuclide scan *only* if the patient is either a surgical candidate (for venous occlusion or embolectomy) or at extremely high risk for anticoagulation

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Note: Doppler ultrasound or magnetic resonance angiography of the lower extremity may be employed as noninvasive procedures to search for venous clots if the diagnosis of pulmonary embolus is equivocal in a patient for whom pulmonary arteriography is contraindicated due to an allergy to iodinated contrast material.

Sarcoidosis

Presenting Signs and Symptoms

- Asymptomatic (hilar and mediastinal lymphadenopathy discovered incidentally on a routine chest radiograph)
- Constitutional symptoms (fever, weight loss, anorexia, fatigue)
- Erythema nodosum and other skin lesions
- Uveitis
- Hypercalcemia/hypercalciuria
- Variety of symptoms involving the cardiac, respiratory, musculoskeletal, and central nervous systems

Common Causes

- Unknown

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred initial imaging technique that may demonstrate characteristic bilateral hilar and right paratracheal lymphadenopathy and a diffuse reticular pulmonary infiltration that may accompany or follow the lymphadenopathy
2. **High-resolution computed tomography**
   - More sensitive than plain chest radiographs for detecting parenchymal pulmonary changes and enlarged lymph nodes in regions that are invisible on plain radiographs

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Note: Although good correlation has been shown between the CT findings and pulmonary function, clinically this imaging modality is not as important as the response to therapy and pulmonary function tests.

Trauma (Blunt Chest)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred initial imaging study that can confirm suspected clinical diagnoses (tension pneumothorax, hemothorax, pulmonary contusion)
   - Can diagnose or suggest other injuries that may be difficult to detect by clinical examination (mediastinal and pericardial hemorrhage, diaphragmatic rupture, and bronchial, esophageal, or pulmonary parenchymal laceration)
   - May be obtained during acute resuscitation efforts
2. **Computed tomography**
   - Far more sensitive than plain chest radiograph for detecting pneumothorax, ruptured diaphragm or esophagus, pleural or pericardial hemorrhage, and pulmonary contusion and laceration
   - Effective in demonstrating mediastinal hemorrhage and determining the need for aortography to exclude aortic rupture in a patient who has a limited indication for aortography (based on the reported mechanism of injury) or whose plain chest radiographs are equivocal or of suboptimal quality

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Note: An unequivocally normal CT scan of the mediastinum may indicate that the aorta is intact, and thus preclude the need for aortography.

3. **Aortography**
   - Immediately required in patients with history of blunt, decelerating thoracic injury and radiologic evidence of

mediastinal hemorrhage
- Only imaging modality that allows complete evaluation of the thoracic aorta from the aortic root to the diaphragmatic hiatus and the brachiocephalic arteries and their branches

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Note: Transesophageal echocardiography with color flow imaging may be performed to show small aortic intimal tears, some of which are not evident at aortography.

Wegener's Granulomatosis

Presenting Signs and Symptoms

- Paranasal sinus congestion and pain
- Nasal mucosal ulcerations (with consequent secondary bacterial infection)
- Serous or purulent otitis media with hearing loss
- Cough, hemoptysis, dyspnea, pleuritis
- Glomerulonephritis (renal failure is major cause of death)

Common Causes

- Unknown

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Preferred initial imaging technique to demonstrate the characteristic multiple and bilateral thick-walled cavitating lung lesions (50% of patients), as well as a pattern of diffuse or nodular opacities that may simulate metastases
2. **Computed tomography**
   - Best imaging technique for detecting mucosal and submucosal lesions in the tracheobronchial tree (seen almost exclusively in women) that produce irregular narrowing of the airway lumen

CHAPTER 2. CARDIOVASCULAR

Martin J. Lipton and Brian Funaki

SIGNS AND SYMPTOMS

Angina Pectoris

Presenting Signs and Symptoms

- Episodes of precordial discomfort or pressure, typically precipitated by exertion and relieved by rest or sublingual nitroglycerin

Common Cause

- Atherosclerotic coronary artery disease

Risk Factors

- Elevated serum cholesterol
- High cholesterol intake
- Tobacco smoking (primarily cigarettes)
- Diabetes mellitus
- Hypertension
- Strong family history

Approach to Diagnostic Imaging

1. **Radionuclide myocardial perfusion scan**
   - SPECT scanning has a specificity and sensitivity approaching 95% for detecting areas of myocardial ischemia as perfusion defects on stress testing that fill in during an examination performed with the patient at rest

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Note: Perfusion defects that are stable during both stress and rest examinations usually represent areas of infarction.

2. **Coronary arteriography**
   - Indicated when angioplasty or bypass surgery is being considered
   - Evaluates the extent and severity of disease (percentage of stenosis involving one, two, or three vessels)
   - Left ventricular angiogram can be obtained to evaluate wall motion (if not contraindicated by potential adverse effects of additional volume of contrast material on renal or ventricular function)

Note: Wall motion can also be assessed by radionuclide techniques or echocardiography.

3. **Radionuclide gated blood pool studies**
   - To evaluate the ejection fraction because of the important relationship between ventricular function and prognosis
4. **Angioplasty**
   - Interventional technique in which inflation of a balloon-tipped catheter at the site of a stenotic atherosclerotic lesion can rupture the intima and media and dramatically dilate the obstruction

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Note: This is an alternative to bypass grafting in patients with suitable anatomic lesions (risk is comparable to surgery).

Evaluating Postsurgical Patency of Bypass Grafts

1. **Ultrafast computed tomography or magnetic resonance imaging**
   - Accuracy of more than 90% for establishing patency of coronary artery bypass grafts

Claudication

Presenting Signs and Symptoms

- Deficient blood supply to muscles during exercise (initially intermittent, may proceed to continuous pain at rest)

Common Cause

- Atherosclerotic vascular disease

Approach to Diagnostic Imaging

1. **Ultrasound with color Doppler**
   - Preferred noninvasive imaging technique to demonstrate the presence of atherosclerotic plaques and assess the degree of luminal stenosis
2. **Ankle-brachial index (ABI)**
   - A blood pressure cuff is inflated at the ankle, and a systolic measurement (A) is taken by Doppler at the posterior tibial and dorsalis pedis arteries. An arm pressure (B) is also recorded, and the ratio (ABI) is computed:

Normal	1.0
Claudication	0.5 to 1.0
Rest pain/ulceration	<0.5

Note: Diabetics usually have an artificially elevated ABI due to calcified tibial vessels.

3. **Arteriography**
   - Indicated if surgery or angioplasty is contemplated to more precisely define the location and extent of a lesion and assess the status of the peripheral runoff vessels

Note: Magnetic resonance angiography (MRA) is rapidly evolving and continues to improve. Currently, two-dimensional time-of-flight is the preferred method for evaluating arteries below the knee, and contrast-enhanced MRA provides excellent images of the pelvis and thighs. In the near future, contrast-enhanced MRA may become the standard for imaging the entire legs and feet.

4. **Interventional radiology (percutaneous transluminal angioplasty)**
   - PTA, with or without stenting, is generally considered the treatment of choice for focal iliac lesions
   - Nearly as durable as aorto-bifemoral bypass grafting with much lower morbidity
   - Excellent technical success with PTA below the pelvis, but not as durable as surgical bypass procedures

Congestive Heart Failure

Common Causes

- Left ventricular failure
- Valvular heart disease (stenosis or regurgitation)
- Pulmonary venoocclusive disease
- Congenital heart disease

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Demonstrates the classic findings of indistinct vascular markings, progressive redistribution of venous blood flow to the lungs (cephalization), and Kerley B lines (edematous thickening of the interlobular septa at the periphery of the lungs)
2. **Echocardiography**
   - Indicated to evaluate the dimensions of the left ventricle and other cardiac chambers, ejection fraction, wall-motion dysfunction, and the presence and severity of incompetence or stenosis of the heart valves
   - Echo and color Doppler studies can accurately detect the presence of pericardial effusion, intracardiac thrombi, and cardiac tumors

Peripheral Ischemia (Acute)

Presenting Signs and Symptoms

- Sudden onset of severe pain, coldness, numbness, and pallor of a portion of an extremity
- Absent pulses distal to the obstruction

Common Causes

- Embolization (from the heart, a proximal atherosclerotic plaque, or an aneurysm)
- Acute thrombosis on preexisting atherosclerotic disease

Approach to Diagnostic Imaging

1. **Arteriography**
   - Demonstrates the precise site of obstruction and permits therapeutic thrombolysis of the clot

> **Caveat: Lytic therapy is contraindicated in patients with active bleeding; recent gastrointestinal bleeding, central nervous system surgery, or stroke; intracranial tumor; or nonviable extremity. Complications include bleeding, puncture site hematoma, pericatheter thrombus formation, and distal embolization.**

DISORDERS

Heart

Cardiac Tumors

Presenting Signs and Symptoms

- Protean findings of fever, elevated erythrocyte sedimentation rate, anemia, weight loss, syncope, and embolic symptoms
- Left atrial lesions may mimic rheumatic valvular disease

Common Causes

- Myxoma
- Rhabdomyoma, lipoma, fibroma
- Sarcoma
- Metastases (breast, lung, lymphoma, melanoma)

Approach to Diagnostic Imaging

1. **Echocardiography (especially transesophageal)**
   - In left atrial myxoma, confirms the presence of a filling defect that often prolapses into the left ventricle during diastole
2. **Magnetic resonance imaging**
   - Excellent for detecting direct extension of a lesion, intracardiac metastases, and pericardial involvement in suspected malignant cardiac tumor
3. **Computed tomography**
   - Demonstrates invasion of the heart by noncardiac tumors of the lung or mediastinum
   - Electron-beam CT is diagnostic of most intracardiac masses (including blood clots)

Cardiomyopathy (Restrictive)

Presenting Signs and Symptoms

- Congestive heart failure
- Arrhythmias
- Heart block

Common Causes

- Infiltrative disorders (amyloid, glycogen storage disease, mucopolysaccharidoses, hemochromatosis, sarcoidosis, tumor infiltration of the myocardium)
- Endomyocardial fibrosis (highly prevalent in the tropics)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Typically shows a normal-sized (or even small) heart with pulmonary venous congestion
2. **Echocardiography or magnetic resonance imaging**
   - Shows normal systolic and diastolic function, myocardial hypertrophy, and often dilatation of the atria
   - Demonstrates a normal pericardium, thus permitting differentiation from constrictive pericarditis (in which the pericardium is thickened)
   - T2-weighted MR images show high signal in the myocardium in patients with amyloidosis or sarcoidosis
3. **Electron-beam computed tomography**
   - Highly accurate in differentiating restrictive cardiomyopathy from constrictive pericarditis

> **Caveat: CT has limited use in patients with severe congestive heart failure, in whom contrast material is best avoided.**

Cardiomyopathy (Congestive)

Presenting Signs and Symptoms

- Congestive heart failure (may be right-sided or left-sided dominance or biventricular involvement)

Common Causes

- Chronic diffuse myocardial ischemia (coronary artery disease)
- Infection (especially coxsackievirus, Chagas disease)
- Toxins or drugs (ethanol, doxorubicin, cocaine, psychotherapeutic drugs)
- Granulomatous disease (sarcoidosis, giant cell myocarditis, Wegener's granulomatosis)
- Metabolic disease (endocrinopathies, lipid or glycogen storage diseases, uremia)
- Nutritional deficiencies (beriberi, selenium deficiency, kwashiorkor)
- Connective tissue disorders

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Demonstrates global cardiomegaly and evidence of congestive failure

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Note: Detection of coronary artery calcification may be a clue to an underlying ischemic cause.

2. **Echocardiography, radionuclide scan, magnetic resonance imaging, or electron-beam computed tomography**
   - Echocardiography shows dilated, hypokinetic cardiac chambers with reduced fractional shortening, while excluding primary valvular disease or segmental wall-motion abnormalities (seen in discrete myocardial infarcts)
   - Gated myocardial scintigraphy demonstrates abnormal ejection fractions and times; gallium scanning can detect acute myocarditis
   - MRI shows dilatation of specific cardiac chambers, abnormal ejection fractions and stroke volumes, and an abnormal texture of the myocardial tissue. If available, MRI is excellent for assessing all types of cardiomyopathy (including asymmetric septal hypertrophy, which can be difficult to define completely using echocardiography)

Cardiomyopathy (Hypertrophic)

Presenting Signs and Symptoms

- Chest pain
- Syncope
- Palpitations
- Exertional dyspnea
- Congestive heart failure

Note: Sudden death occurs in about 50% of patients (overall mortality rate about 2-3% per year).

Common Causes

- Familial (autosomal dominance with variable penetration)
- Obstructive (subaortic or midventricular)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Deceptively normal-looking in about 50% of patients (because hypertrophy occurs at the expense of the ventricular cavities)
   - May demonstrate left atrial enlargement (commonly due to mitral regurgitation)
   - May show right ventricular enlargement or an unusual shape of the cardiac silhouette that is not diagnostic of any specific disorder (e.g., neither a valvular lesion nor pericardial effusion)
2. **Echocardiography**
   - Preferred noninvasive modality that permits measurement of the thickened ventricular walls and allows differentiation among the different subgroups
   - Often permits quantitation of the degree of obstruction of the outflow tract (an important determinant of the effectiveness of treatment)
3. **Electron-beam computed tomography**
   - If available, permits diagnosis and quantitation of the severity of hypertrophic cardiomyopathy (allows assessment of all areas of the myocardium and is not subject to the imaging limitations of echocardiography)
   - May evaluate left ventricular mass and provide indices of left ventricular function, as well as exclude other cardiac and noncardiac abnormalities

Congenital Heart Disease

- Presenting Signs and Symptoms
- Broad spectrum of murmurs, shunts, alterations in systemic and pulmonary blood flow, and altered workloads of specific cardiac chambers
- Cyanosis (in right-to-left shunts)

Risk Factors

- Chromosomal defects (trisomy 13, 18, 21; Turner's syndrome; Holt-Oram syndrome)
- Maternal illness (diabetes mellitus, systemic lupus erythematosus)
- Environmental exposure (e.g., thalidomide)
- History of congenital heart disease in a first-degree relative

Common Types

- Atrial septal defect
- Ventricular septal defect
- Patent ductus arteriosus
- Total anomalous venous return
- Persistent truncus arteriosus
- Transposition
- Endocardial cushion defect
- Tetralogy of Fallot
- Hypoplastic right heart syndrome
- Coarctation of the aorta

Approach to Diagnostic Imaging

BEFORE BIRTH

1. **Prenatal ultrasound**
   - May permit the diagnosis of some serious defects during pregnancy (thus offering the parents the option of discontinuing the pregnancy or permitting the physician and parents to make realistic plans for the labor, delivery, and care of the child)

AFTER BIRTH

1. **Plain chest radiograph**
   - Initial imaging study for assessing the pulmonary vasculature, size of the main pulmonary artery, size and position of the aorta (especially whether it is right-sided), and size and contour of the cardiac silhouette
2. **Echocardiography**
   - Plays a prominent role in the initial imaging evaluation of congenital heart disease
3. **Magnetic resonance imaging**
   - Cine studies have become the primary modality for imaging most congenital heart disease because of the ability to show directly both morphologic and functional anomalies in multiple planes

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Note: Electron-beam CT can provide similar information, but it currently is less available.

4. **Angiocardiography**
   - Definitive (but invasive) study

Note: Some authors recommend angiocardiography only if surgery is contemplated.

Cor Pulmonale

Presenting Signs and Symptoms

- Exertional dyspnea
- Angina pectoris
- Syncope

Common Causes

- Chronic obstructive pulmonary disease
- Pulmonary fibrosis
- Acute or chronic pulmonary embolism
- Primary pulmonary hypertension
- Pulmonary venoocclusive disease

- Extrapulmonary diseases affecting pulmonary mechanics (morbid obesity, chest wall deformities, neuromuscular disease)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Usually shows a normal-sized heart or only mild cardiomegaly, but there may be enlargement of the right ventricle and right atrium

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Note: Plain films may be relatively insensitive indicators of right ventricular enlargement because hyperinflation of the lungs and bullae may distort the position of the heart in these patients.

   - Characteristic prominence of the main and central pulmonary arteries with rapid tapering (pruning) so that the lung periphery appears oligemic

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Note: The lungs usually will show evidence of chronic obstructive pulmonary disease or interstitial fibrosis (i.e., right ventricular failure secondary to pulmonary arterial or parenchymal disease).

2. **Echocardiography or radionuclide studies**
   - Indicated to evaluate the degree of function of the left ventricle (as well as the degree of enlargement of the right atrium and right ventricle)

Endocarditis (Infective)

Presenting Signs and Symptoms

- Insidious onset of low-grade fever, night sweats, fatigue, malaise, weight loss
- New regurgitant murmur and signs of valvular insufficiency
- Chills and arthralgia
- Emboli may produce stroke, myocardial infarction, flank pain and hematuria, abdominal pain, or acute arterial insufficiency in an extremity
- Petechial hemorrhages and Osler's nodes

Predisposing Factors

- Rheumatic heart disease
- Congenital heart disease (ventricular septal defect, tetralogy of Fallot)
- Prosthetic heart valve
- Intravenous drug abuse
- Central venous line

Approach to Diagnostic Imaging

1. **Echocardiography**
   - Procedure of choice for demonstrating the characteristic vegetations on affected heart valves

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Note: Transesophageal studies can increase the specificity and sensitivity of echocardiography from about 60% to 90% and are indicated if the diagnosis remains in question after conventional echocardiography.

Echocardiography should be repeated after 6 weeks of intravenous antibiotic therapy for infective endocarditis.

2. **Electron-beam computed tomography**
   - Demonstrates not only the vegetations but also valvular calcification, distorted orifices, and aneurysms of the sinus of Valsalva
   - Complementary to echocardiography, especially in seriously ill patients who cannot lie flat (i.e., the table can be tilted)

Note: Infections of prosthetic valves can result in perivalvular or perisutural leaks that may be detected by cine MRI.

Myocardial Infarction

- Presenting Signs and Symptoms
- Deep substernal chest pain (described as an aching or pressure) that often radiates to the back, jaw, or left arm

- Pain similar to that of angina pectoris but usually more severe, long lasting, and relieved only a little or briefly by rest or nitroglycerin
- Symptoms of left ventricular failure, pulmonary edema, shock, or significant arrhythmia may dominate the clinical appearance
- About 20% of acute myocardial infarctions are silent (or not recognized as an illness by the patient)
- Elevation of myocardial enzymes in the serum

Caveat: In some cases, acute chest pain may suggest possible aortic dissection.

Common Cause

- Atherosclerotic coronary artery disease

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Useful as a baseline for assessing pulmonary venous congestion

Direct Infarct Imaging

Caveat: The diagnosis of myocardial infarction is usually evident from the patient's history and confirmed by electrcardiogram and enzyme studies. Infarct imaging is indicated if the clinical, laboratory, and electrocardiographic findings are equivocal; if there has been recent cardiac surgery or trauma; or if there is a suspicion of right ventricular infarction.

1. **Radionuclide imaging, electron-beam computed tomography, or magnetic resonance imaging**
   - Can demonstrate areas of myocardial infarction and usually can determine whether they are acute or remote

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Note: Echocardiography is often performed to assess the function of the right and left ventricles, as well as to detect the 10-20% incidence of cardiac-wall clots that alter clinical management.

Valvular Heart Disease

Presenting Signs and Symptoms

- Murmur and clinical symptoms vary, depending on the precise valve involved and whether there is predominant stenosis or regurgitation

Common Causes

- Rheumatic fever
- Congenital heart disease
- Infectious endocarditis

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Inexpensive imaging technique to show enlargement of the entire heart or specific chambers, valvular calcification, and any evidence of pulmonary vascular congestion
2. **Echocardiography**
   - More precisely demonstrates any chamber enlargement or wall thickening and the precise size of the orifices of affected valves
   - Doppler flow studies can assess the degree of regurgitation

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Note: Although not yet widely used, cine MRI shows promise for demonstrating and quantitating the regurgitation of blood across any incompetent valve (without the need for contrast material).

Pericardium

Cardiac Tamponade

Presenting Signs and Symptoms

- Cardiogenic shock (low cardiac output and low systemic arterial pressure)
- Tachycardia
- Dyspnea and orthopnea
- Usually elevated systemic venous pressure (prominent neck veins) and pulmonary venous pressure

- Distant heart sounds
- Pericardial rub
- Pulsus paradoxus (accentuation of the normal inspiratory decline in systemic systolic blood pressure greater than 10 mm Hg)

Mechanism

- Pericardial effusion under tension causing compression of the cardiac chambers and compromising diastolic filling

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Demonstrates rapid enlargement of the cardiac silhouette with relatively normal-appearing vasculature
2. **Echocardiography**
   - Modality of choice not only to demonstrate the accumulation of a large amount of pericardial fluid but also to show septal shift, paradoxic septal motion, diastolic collapse of the right ventricle, and cyclic collapse of the atria

Constrictive Pericarditis

Presenting Signs and Symptoms

- Elevation of ventricular diastolic, atrial, pulmonary, and systemic venous pressures (unlike tamponade, the ventricular venous pressure, or ejection fraction, is usually preserved)
- Dyspnea and orthopnea (prolonged elevation of pulmonary venous pressure)
- Hypervolemia, engorgement of neck veins, pleural effusion, hepatomegaly, ascites, peripheral edema (elevated systemic venous pressure)
- Kussmaul's sign (inspiratory swelling of neck veins), which is absent in tamponade

Common Causes

- Postpericardiotomy (although the pericardium is usually partly resected after coronary artery bypass grafting)
- Viral infection (especially coxsackievirus B)
- Tuberculosis
- Uremia
- Radiation
- Neoplastic involvement
- Rheumatoid arthritis
- Idiopathic

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Demonstrates characteristic pericardial calcification in 50% of patients (as well as pleural effusions, small atria, a flat or straightened right heart border, and dilated superior and inferior vena cava and azygos vein)
2. **Magnetic resonance imaging or computed tomography**
   - Preferred imaging techniques to show the abnormally thick pericardium (which permits the distinction of constrictive pericarditis from restrictive cardiomyopathy)

Notes: MRI is more specific in that it can show that the pericardial thickening represents fibrosis.

Although echocardiography can show the thickened pericardial wall, the findings are not as specific as in the case of pericardial fluid.

Pericardial Effusion

Presenting Signs and Symptoms

- Severity of symptoms varies greatly depending on the underlying cause, the rate at which the pericardial fluid accumulates, and the total amount present
- Milder symptoms include chest pain and a friction rub; large effusions may lead to congestive heart failure and shock
- Faint, distant heart sounds on auscultation

Common Causes

- Idiopathic
- Infection
- Autoimmune (systemic lupus erythematosus, rheumatoid arthritis, scleroderma)
- Dressler's and postpericardiotomy syndromes
- Neoplasm (lymphoma, lung or breast metastases)
- Drug-induced (procainamide, hydralazine, phenytoin)

- Uremia
- Myxedema
- Congestive heart failure
- Trauma

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Suggests the diagnosis if there is a rapid increase in the size of the cardiac silhouette on serial chest films (especially when the lungs remain clear)

Note: A rapid increase in heart size related to congestive heart failure is generally associated with pulmonary venous congestion.

2. **Echocardiography**
   - Procedure of choice for demonstrating as little as 50 mL of pericardial fluid (normal, 20 mL) as a posterior sonolucent collection

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Note: CT is valuable for detecting loculated pericardial effusions, whereas MRI may be able to characterize the fluid as serous or hemorrhagic (because of characteristic changes in signal intensity).

Vascular

Aneurysm (Abdominal Aorta)

Presenting Signs and Symptoms

- Most are asymptomatic and discovered incidentally on routine physical examination or plain abdominal radiograph
- Pulsatile mass
- Severe abdominal pain and hypotension (if rupture)

Common Causes

- Atherosclerosis
- Trauma
- Arteritis syndromes
- Connective tissue disorders (Marfan's syndrome, cystic medial necrosis)
- Syphilis

Approach to Diagnostic Imaging

Caveat: Any patient with a pulsatile abdominal mass and hypotension should proceed directly to surgery without any intervening imaging study.

1. **Ultrasound**
   - Most cost-effective initial imaging technique to show dilatation of the aorta to greater than 3 cm and the presence of intraluminal clot
   - Serial examinations can be easily performed to follow aneurysm size in patients who are not considered surgical candidates at the time

   Caveat: Ultrasound has limited ability to consistently show the proximal and distal extent of an aneurysm and its relationship to the surrounding retroperitoneal structures (required prior to elective surgical repair).
2. **Computed tomography**
   - Indicated if there is suspicion of retroperitoneal hematoma secondary to leaking or acute rupture
   - More accurate than ultrasound for determining the true diameter of an aneurysm and its longitudinal extent, but more expensive and requires contrast material

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Note: Helical CT with three-dimensional reformatting permits demonstration of the abdominal aorta in multiple planes, improves the visualization of the relationship of an aneurysm to the origins of the renal arteries, and ensures a constant bolus of contrast material throughout the aorta.

3. **Magnetic resonance imaging**
   - Alternative to ultrasound or CT
   - Especially useful in patients with depressed renal function (because MR contrast is not nephrotoxic)
   - MRA may eventually supplant catheter angiography in the preoperative assessment of abdominal aortic

aneurysms

4. **Aortography**
   - Traditionally, the preoperative procedure of choice for determining the number of renal arteries and their relationship to the aneurysm, as well as the patency of the visceral, renal, external iliac, and femoral arteries (factors that may modify the surgical approach and define additional procedures required to decrease postoperative morbidity)
   - Because aortography outlines only the aortic lumen, it underestimates the true size of an aneurysm if its wall is lined with thrombus.

Note: The ability of newer, less invasive techniques such as CT and MRA to demonstrate the extent of an aneurysm and the patency of other vessels has substantially reduced the need for preoperative aortography, which now is rarely required for this purpose.

Caveat: There is no indication for plain lateral radiographs of the abdomen to detect calcification in the wall of an aneurysm (very low sensitivity).

Aneurysm (Peripheral)

Presenting Signs and Symptoms

- Limb ischemia (due to thrombus within the aneurysm)
- Signs of distal embolization
- Gangrene

Common Causes

- Atherosclerosis
- Trauma
- Mycosis
- Complication of vascular surgery

Approach to Diagnostic Imaging

1. **Ultrasound with color Doppler**
   - Preferred initial imaging procedure to detect a peripheral aneurysm (most commonly involving the popliteal artery) and assesses its size

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Note: CT angiography or MRA may be employed to evaluate a suspected aneurysm.

2. **Arteriography**
   - Usually required prior to surgery (bypass grafting and aneurysm repair) to evaluate the status of the peripheral vessels
   - Covered stents inserted via the femoral artery may be used instead of bypass grafting to repair aneurysms

Aneurysm (Thoracic Aorta)

Presenting Signs and Symptoms

- Asymptomatic
- Symptoms related to secondary compression
  - Stridor, wheezing (trachea and bronchi)
  - Dysphagia (esophagus)
  - Venous obstruction of the upper extremities, head, and neck (superior vena cava)
  - Hoarseness (recurrent laryngeal nerve)
- Substernal or back pain

Common Causes

- Atherosclerosis
- Syphilis
- Mycosis
- Connective tissue disorders (Marfan's and Ehlers-Danlos syndromes)

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Demonstrates contour abnormalities and tortuosity of the thoracic aorta, as well as calcification within its wall

Caveat: It may be difficult to distinguish a thoracic aneurysm from other mediastinal masses.

2. **Computed tomography or magnetic resonance imaging**
   - Preferred methods for initial evaluation and follow-up

- Accurately demonstrates vessel diameter, mural thrombus, calcifications, degree of luminal patency, mass effects on adjacent mediastinal structures, and evidence of leakage or rupture
- CT is superior to MRI for showing calcifications within the wall of an aneurysm
- MRI is superior to CT for demonstrating the relationship of an aneurysm to the arch vessels (because of its ability to directly image in the sagittal plane) and requires no contrast material

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Note: Transesophageal ultrasound is increasingly being used for accurately determining the size of thoracic aortic aneurysms, especially in unstable patients, since it can be rapidly performed at the bedside.

3. **Aortography**
   - Indicated only for preoperative planning when it is vital to know the relationship between the aneurysm and the great vessels and coronary arteries, as well as the vascular supply to the spinal cord

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Note: Aortography is unreliable for assessing the size of an aneurysm, as it only visualizes the patent portion of the lumen and cannot show the extent of mural thrombus.

Aortic Dissection

Presenting Signs and Symptoms

- Sudden, severe, tearing substernal chest pain with radiation to the back
- Frequent migration of pain from the original site as the dissection extends along the aorta
- Aortic insufficiency murmur
- Absent or asymmetric major arterial pulses
- Neurologic complications (stroke, paraparesis, or paraplegia from spinal cord ischemia; ischemic peripheral neuropathy from abrupt occlusion of an artery supplying a limb)

Predisposing Factors

- Hypertension
- Connective tissue disorders (Marfan's and Ehlers-Danlos syndromes)
- Bicuspid aortic valve
- Coarctation of the aorta
- Trauma
- Granulomatous arteritis
- Pregnancy (cause of 50% of dissections in women younger than age 40)
- Previous aortic surgery or arterial catheterization

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Demonstrates mediastinal widening in up to 90% of patients and frequently a left pleural effusion
   - Localized bulging of the aortic contour indicates the likely site of origin of a dissection
2. **Computed tomography**
   - Preferred initial imaging study in acutely ill patients
   - Shows the classic double-barrel aorta (opacification of both the true and false lumens) and intimal flap (linear filling defect within the aortic lumen)

Note: If available, transesophageal ultrasound is also an extremely sensitive screening technique for diagnosing aortic dissection.

3. **Magnetic resonance imaging**
   - Probably the best noninvasive technique for imaging the aorta, but often difficult to obtain in severely ill patients who require life-support systems and close monitoring

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Note: MRI is the procedure of choice for the detection of chronic aortic dissection.

4. **Aortography**
   - This most definitive study is required if surgical therapy is contemplated to identify the precise origin and extent of the dissection, the severity of any aortic insufficiency, and the extent of involvement of major arterial trunks arising from the aorta (including the coronary arteries)

Peripheral Occlusive Vascular Disease

Presenting Signs and Symptoms

- Intermittent claudication that progresses to pain at rest
- Coolness and numbness of the affected extremity
- Nonhealing ulcers
- Gangrene
- Diminished pulses distal to the area of narrowing

Vessels Primarily Involved

- Superficial femoral artery
- Aortoiliac system
- Trifurcation vessels
- Popliteal artery

Approach to Diagnostic Imaging

1. **Ultrasound with color Doppler**
   - Preferred noninvasive imaging technique to demonstrate the presence of atherosclerotic plaques and assesses the degree of luminal stenosis
2. **Ankle-brachial index (ABI)**
   - A blood pressure cuff is inflated at the ankle, and a systolic measurement (A) is taken by Doppler at the posterior tibial and dorsalis pedis arteries. An arm pressure (B) is also recorded, and the ratio (ABI) is computed.

Normal	1.0
Claudication	0.5 to 1.0
Rest pain/ulceration	<0.5

Note: Diabetics usually have an artificially elevated ABI due to calcified tibial vessels.

3. **Arteriography**
   - Indicated if surgery or angioplasty is contemplated
   - More precisely defines the location and extent of a lesion and assesses the status of the peripheral runoff vessels

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Note: MRA is rapidly improving and may eventually replace contrast arteriography for evaluating the peripheral vascular system.

4. **Interventional radiology (percutaneous transluminal angioplasty)**
   - Excellent alternative to surgery for dilating localized stenotic lesions (especially in the iliac arteries where the success rate approaches 95%)

Note: The success rate in arteries of the thigh and calf is about 50-60%.

Deep Venous Thrombosis

Presenting Signs and Symptoms

- Asymptomatic (one-third of patients with symptomatic pulmonary emboli but no clinical signs of DVT will nevertheless have a lower extremity venous thrombus)
- Variable combination of pain, edema, warmth, skin discoloration, and prominent superficial veins over the involved area
- Delayed complications of dermatitis, ulceration, and varicosities

Common Causes

- Stasis (postoperative, postpartum states; chronic illness)
- Pregnancy or the use of oral contraception
- Obesity
- Hypercoagulability (malignant tumor, blood dyscrasia)
- Endothelial injury (indwelling catheter, injection of irritating substance, septic phlebitis, thromboangiitis obliterans)
- Prolonged immobilization with the legs dependent while traveling (especially on prolonged airplane flights)

Approach to Diagnostic Imaging

1. **Color Doppler ultrasound**

- Preferred initial imaging modality (>95% accuracy) that can demonstrate lack of compressibility of the vein (indicating the presence of thrombus within it)
- Visualizes intraluminal thrombus itself and characteristic alterations in spontaneous flow that occur because of obstruction of the proximal veins

2. **Venography**
   - Traditional “gold standard” that can demonstrate the conclusive finding of a persistent filling defect within the lumen of a vein.
   - Other findings that are highly suggestive of DVT include abrupt termination of the contrast column within a vein, inability to opacify a major vein, and the formation of extensive collateral venous circulation

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Note: See “ Pulmonary Embolism”.

Superior Vena Cava Syndrome

Presenting Signs and Symptoms

- Progressive dilatation of the veins of the head and upper extremities
- Edema and plethora of the face, neck, and upper torso
- Cyanosis and conjunctival edema
- Dizziness, syncope, headache
- Respiratory distress (due to airway edema)

Note: If the obstruction occurs slowly, the formation of a compensatory collateral venous network may prevent the development of clinical symptoms.

Common Causes

- Malignant neoplasm (primary bronchogenic carcinoma, lymphoma, metastases from breast carcinoma)
- Mediastinal granulomatous or fibrosing disease
- Long-term indwelling central venous catheter
- Aortic aneurysm

Approach to Diagnostic Imaging

1. **Computed tomography or magnetic resonance imaging**
   - Preferred noninvasive methods to show both the proximal dilatation of the superior vena cava and its branches and the underlying cause of the obstruction
2. **Venography**
   - Allows better definition of the superior vena cava and collateral vessels
   - Metallic stents are generally the preferred treatment for malignant obstruction of the SVC. These can be placed via a femoral vein puncture and usually provide relief of symptoms within several hours.

Thoracic Outlet Syndrome

Presenting Signs and Symptoms

- Numbness, paresthesias, pain, and sensory and motor deficits in the hand, neck, shoulder, or arm (secondary to arterial, venous, or nerve compression)
- Obliteration of the radial pulse on the involved side with 90° elevation and external rotation of the arm or with simultaneous hyperextension of the neck and turning of the head toward the affected side (if the artery is involved)
- Intermittent cyanosis, edema, and thrombotic symptoms (if the vein is involved)

Common Causes

- Congenital anatomic anomaly (cervical rib, abnormal insertion of the anterior scalene muscle on the first rib)
- Aberrant healing of rib or clavicle fracture
- Neoplasm

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Imaging study of choice to demonstrate a cervical rib or a tumor in the apex of the lung
2. **Arteriography or venography**
   - Studies performed in both the neutral position (arms at the sides) and in the position that reproduces the patient's symptoms may demonstrate kinking or partial obstruction of the subclavian artery or vein

CHAPTER 3. GASTROINTESTINAL

Richard M. Gore

SIGNS AND SYMPTOMS

Ascites

- Presenting Signs and Symptoms
- Small amounts may be asymptomatic
- Abdominal distension and discomfort
- Anorexia, nausea, and early satiety
- Respiratory distress (due to reduced lung volume)
- Bulging flanks, fluid wave, shifting dullness

Common Causes

- Cirrhosis
- Neoplasm (hepatic cancer or peritoneal carcinomatosis)
- Congestive heart failure
- Tuberculosis (and other infections)
- Hypoalbuminemia (nephrotic syndrome, protein-losing enteropathy, malnutrition)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Mobile, echo-free fluid regions shaped by adjacent structures
   - Smallest amounts (as little as 100 mL) in a supine patient appear first around the inferior tip of the right lobe of the liver, the superior right flank, the cul-de-sac of the pelvis, and the hepatorenal area (Morison's pouch)
2. **Computed tomography**
   - More expensive, but may demonstrate the underlying abdominal disease process (if US fails to do so)
   - May be able to distinguish ascites (water attenuation) from blood (higher attenuation) or chyle (lower attenuation)

> **Caveat: Plain abdominal radiographs are not indicated because a large amount of fluid (800 to 1000 mL) must be present to be detected and the underlying cause is infrequently shown.**

Constipation

Presenting Signs and Symptoms

- Decrease in frequency of stools or difficulty in defecation

Common Causes

ACUTE

- Bowel obstruction or adynamic ileus

CHRONIC

- Neurologic dysfunction (diabetes, spinal cord disorder, parkinsonism, idiopathic megacolon)
- Scleroderma
- Drugs (anticholinergic agents, opiates, aluminum-based antacids)
- Hypothyroidism
- Cushing's syndrome
- Hypercalcemia
- Debilitating infection
- Anorectal pain (fissures, hemorrhoids, abscess, proctitis)

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - Detects mechanical bowel obstruction
2. **Barium enema**
   - For better characterization of the site and cause of narrowing or obstruction of the bowel
3. **Radiopaque marker study**
   - A plain abdominal radiograph 5 days after ingestion of the tablets can indicate whether there is a significant

delay in clearing the radiopaque material from the bowel

4. **Defecography (evacuation proctography)**
    - Dynamic study that can demonstrate mechanical abnormalities such as rectal intussusception, anterior wall prolapse, or rectocele

Diarrhea

Presenting Signs and Symptoms

- Increased volume, fluidity, or frequency of fecal discharges

Common Causes

- Osmotic (lactase deficiency, polyvalent laxative abuse)
- Secretory (viral or protozoal infection, bacterial toxins, castor oil, Zollinger-Ellison syndrome, prostaglandin therapy, vasoactive intestinal peptide)
- Exudative (mucosal inflammation, necrosis, neoplasm)
- Malabsorption (sprue, pancreatic insufficiency, bowel resection, Whipple's disease)
- Altered intestinal motility (diabetes, hyperthyroidism, magnesium-containing laxatives, irritable bowel syndrome)

Approach to Diagnostic Imaging

1. **Small bowel study**
    - May suggest underlying causes such as sprue or scleroderma (dilated small bowel), hypoproteinemia (regularly thickened folds), Whipple's disease (irregularly thickened folds), inflammatory bowel disease (ileitis or colitis), tuberculosis (ileocecal inflammation), intestinal fistula, or motility disorders

        Caveat: Plain abdominal radiographs are *not* indicated.

Dysphagia

Presenting Signs and Symptoms

- Difficulty initiating swallowing
- Food sticking in the upper or middle esophageal region
- Odynophagia (pain on swallowing)
- Regurgitation
- Aspiration

Common Causes

- Carcinoma
- Peptic or lye stricture
- Achalasia
- Scleroderma
- Diffuse esophageal spasm
- Cervical esophageal web
- Lower esophageal (Schatzki's) ring
- Neuromuscular disorder

Approach to Diagnostic Imaging

1. **Barium swallow**
    - Imaged on video fast-sequence radiographs or digitally

        Caveat: Hyperosmolar water-soluble contrast should not be used because aspiration of this material causes increased fluid to enter the tracheobronchial tree and may lead to the development of pulmonary edema.

Gastrointestinal Bleeding (Chronic, Obscure Origin)

Presenting Signs and Symptoms

- Anemia (iron deficiency)
- Fecal occult blood/guaiac positive stools

Common Causes

- Neoplasm (benign or malignant anywhere in alimentary tube)
- Peptic ulcer
- Gastritis
- Meckel's diverticulum

- Angiodysplasia

Approach to Diagnostic Imaging

1. **Barium enema (double contrast)**
   - If *negative,* proceed to
2. **Upper gastrointestinal series (biphasic)**
   - If *negative,* proceed to
3. **Enterolysis (not a “small bowel follow-through”)**
   - If *negative,* proceed to
4. **Arteriography (celiac, superior mesenteric artery, inferior mesenteric artery)**
   - May detect a vascular malformation (angiodysplasia) or an occult neoplasm that is the underlying source of the bleeding
   - If *negative* (especially in young patients), consider
5. **Radionuclide scan for Meckel's diverticulum**
   - Isotope may collect in ectopic gastric mucosa

Note: Endoscopy and colonoscopy can also be used to detect a source of chronic gastrointestinal bleeding, depending on the availability of physicians skilled in performing these techniques.

Gastrointestinal Bleeding (Acute Lower)

Presenting Sign and Symptom

- Brisk rectal bleeding without blood in gastric aspirate

Common Causes

- Diverticulosis
- Angiodysplasia
- Ischemic colitis
- Hemorrhoids (diagnosed by proctoscopy)
- Polyps/carcinoma (more frequently associated with chronic bleeding)

Approach to Diagnostic Imaging

1. **Radionuclide scan**
   - Most sensitive diagnostic study that can document active bleeding of as little as 0.05–0.1 mL/min as a focal area of increased radionuclide activity corresponding to extravasation of blood in the gastrointestinal tract
   - Movement of the radionuclide proximally or distally indicates active bleeding. Lack of movement suggests an angiodysplasia, arteriovenous malformation, or vascular tumor

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Note: If the radionuclide scan shows no evidence of an active bleeding site, there is *no* indication for arteriography.

2. **Arteriography**
   - If bleeding continues to be rapid (>0.5–1 mL/min), may show the precise bleeding site by demonstrating extravasation of contrast material into the lumen of the bowel or the tangled blood vessels of an angiodysplasia
   - Offers therapeutic options through transcatheter measures (embolization or vasoconstrictive agents) and may preclude the need for surgery (especially in diverticular hemorrhage)

Note: Many patients have a positive radionuclide scan and a bleeding site demonstrated surgically but a negative arteriogram.

3. **Barium enema or colonoscopy**
   - Indicated only if bleeding is minimal or has stopped, to search for underlying colonic pathology that *may* represent the bleeding site

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Note: Introduction of barium into the colon prevents the performance of arteriography until the barium has cleared from the region of interest.

Colonoscopy, although valuable for assessing chronic and subacute bleeding, is not the examination of choice for acute rapid bleeding because the presence of fresh blood and clots prevents an adequate view of the mucosa.

Caveat: Unstable patients with massive hemorrhage should have emergency surgery without any diagnostic studies.

Gastrointestinal Bleeding (Acute Upper)

Presenting Signs and Symptoms

- Hematemesis, melena, hematochezia
- Blood in nasogastric aspirate

Common Causes

- Peptic ulceration (duodenum, stomach, esophagus)
- Gastric mucosal lesion (superficial erosions, stress ulcers)
- Esophageal varices
- Neoplasm
- Mallory-Weiss tear

Approach to Diagnostic Imaging

1. **Endoscopy**
   - Procedure of choice that can permit precise visual identification of a lesion that is actively bleeding
   - Offers therapeutic options (electrocautery or laser cautery, mechanical clips, tissue adhesives, or injection of sclerosing agents for varices)
   - May be falsely negative if there is rapid bleeding, because large amounts of fresh blood and clots may obscure the underlying bleeding lesion
2. **Arteriography**
   - Indicated for patients with rapid bleeding (0.5 to 1 mL/min, but not if massive hemorrhage) in whom endoscopy is technically difficult
   - Demonstrates extravasation of contrast material or an angiodysplasia
   - Offers therapeutic options through transcatheter measures (embolization or infusion of vasoconstrictive agents); even if hemostasis fails or is only temporary, generally allows time for vascular volume replacement to stabilize the patient before surgery
3. **Upper gastrointestinal series**
   - If bleeding is minimal or has stopped, this readily available, safe, and relatively inexpensive procedure is a good screening study for demonstrating an ulcer, neoplasm, or varices that *may* represent the bleeding site

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Note: Introduction of barium into the gastrointestinal tract prevents the performance of endoscopy or arteriography until the barium has cleared from the region of interest.

Caveat: Patients with massive hemorrhage whose condition is unstable should have emergency surgery without any diagnostic studies.

Jaundice: Differentiation of Medical (Hepatocellular) from Surgical (Biliary Obstruction) Causes

Presenting Signs and Symptoms

- Yellowing of skin and sclera
- Abnormal liver enzymes
- Dark urine and pale stools

Common Causes

- Common duct stone
- Pancreatic carcinoma
- Cholangiocarcinoma
- Primary hepatocellular dysfunction (alcoholism, hepatitis)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred initial imaging technique for demonstrating dilated bile ducts (indicating biliary obstruction)
   - May be equivocal or incomplete in obese patients or those with large amounts of intestinal gas
2. **Computed tomography**
   - Highly accurate for showing dilated bile ducts, as well as disease in adjacent structures (liver, porta hepatis, pancreas, adrenals, retroperitoneum)
   - Not adversely affected by obesity or large amounts of intestinal gas
3. **Magnetic resonance cholangiopancreatography (MRCP)**
   - Preferred diagnostic approach if ERCP is likely to be unsuccessful, as in patients with surgical bypass procedures (Billroth II anastomosis, hepatojejunostomy) or those with acute pancreatitis (increased risk of complications from ERCP)
4. **Percutaneous transhepatic cholangiography (PTHC)**
   - Invasive procedure of choice for defining the precise site of obstruction in a dilated biliary system
   - Superior to ERCP for diagnostic and therapeutic maneuvers (e.g., balloon dilatation of strictures, brush biopsy, stone removal, insertion of an endoprosthesis) that involve lesions above the porta hepatis (intrahepatic)

- Generally safe, but complications include sepsis, bile leakage with peritonitis, and bleeding

5. **Endoscopic retrograde cholangiopancreatography (ERCP)**
   - Invasive procedure of choice if the bile ducts are not dilated (e.g., sclerosing cholangitis) and if the patient has abnormal bleeding parameters
   - Permits therapeutic procedures such as sphincterotomy, stone extraction, brush biopsy of strictures, and insertion of an endoprosthesis

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Note: Local experience often dictates the choice between PTHC and ERCP.

Caveat: Although dilated bile ducts are virtually pathognomonic of extrahepatic biliary obstruction, normal bile ducts do not absolutely exclude this diagnosis because of the underlying disease process (e.g., sclerosing cholangitis) or because the obstruction may be recent or intermittent.

Nausea and Vomiting

Common Causes

- Drug reaction (chemotherapeutic agents, central nervous system [CNS]-active drugs, analgesics, cardiovascular drugs, hormones, antibiotics, diuretics, antiasthmatics)
- Gastrointestinal disorders
  - Gastric outlet obstruction (peptic ulcer disease, gastric malignancy, extrinsic compression)
  - Small bowel obstruction (adhesions, inflammatory bowel disease, neoplasm)
  - Inflammatory conditions (gastroenteritis, peptic ulcer disease, cholecystitis, pancreatitis, Crohn's disease)
  - Motility disorders (gastroparesis, irritable bowel syndrome, chronic intestinal pseudoobstruction, scleroderma)
- CNS disorders (stroke, neoplasm, labyrinthine disease, motion sickness, psychiatric disorders)
- Metabolic conditions (pregnancy, uremia, hyperglycemia, hyperparathyroidism, metabolic acidosis, adrenal insufficiency)
- Infectious disorders (hepatitis, meningitis, labyrinthitis)

Approach to Diagnostic Imaging

Caveat: Initially, a detailed history, physical examination, and laboratory workup should be performed. Appropriate imaging studies can then be ordered, based on the probable clinical diagnosis.

SUSPECTED *GASTROINTESTINAL* CAUSE

1. **Plain abdominal radiograph**
   - Inexpensive initial imaging procedure for detecting a suspected gastric outlet or small bowel obstruction
2. **Computed tomography**
   - Best study for detecting a suspected intraabdominal inflammatory process (and for further evaluation of small bowel obstruction demonstrated on plain films)

DISORDERS

Abscess

Peritonitis

Presenting Signs and Symptoms

- Generalized abdominal tenderness with rigidity
- Absence of bowel sounds
- Fever
- Vomiting

Common Causes

- Perforation of a viscus
- Trauma
- Strangulating intestinal obstruction
- Pancreatitis
- Pelvic inflammatory disease
- Vascular catastrophe (mesenteric thrombosis or embolus)
- Ascites (spontaneous infection or peritoneosystemic shunt)

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - *Upright* films to demonstrate free air beneath the diaphragm, indicating perforation of a viscus
   - If the patient cannot stand or sit, a *lateral decubitus* film (using a horizontal x-ray beam) with the patient's *left* side down may be used (any free air can be more easily detected over the soft-tissue-density liver on the right

than when it is overlying luminal air in the stomach, small bowel, or splenic flexure on the left)
    - On *supine* films, look for the *double-wall sign* (air outlining both the inner and outer walls of bowel loops), as well as free air outlining the normally invisible falciform and various pelvic ligaments

Caveat: *NEVER* use barium in the presence of free air in the peritoneal cavity.

2. **Computed tomography**
    - Procedure of choice for detecting loculated fluid collections, abscesses, and strangulating obstruction

Suspected Abdominal Abscess (No Localized Findings)

Presenting Signs and Symptoms

- Spiking fever, chills
- Leukocytosis
- Indolent course in immunosuppressed patients

Common Causes

- Recent surgery or trauma
- Alcoholism
- Parenteral drug use
- Chronic illness
- Steroids, chemotherapy, immunosuppressive therapy

Approach to Diagnostic Imaging

1. **Computed tomography**
    - Preferred initial imaging procedure for detecting, characterizing, and determining the extent of an abdominal abscess
    - Does not have the disadvantage of the substantial delay required with radionuclide scanning
    - Limited value in patients with abrupt and extreme changes in density (metallic clips, residual barium) because of “streak” artifacts
2. **Radionuclide scan (indium)**
    - Can examine the entire abdomen simultaneously and detect multiple or extraabdominal sites of infection
    - Indium is superior to gallium because normal accumulation of gallium in the liver, spleen, and colon can obscure an abscess; also, gallium (but not indium) can accumulate in lymphoma and other neoplasms

Caveat: There is a substantial delay before diagnostic results can be obtained (at least 18 to 24 hours after radionuclide injection).

3. **Ultrasound**
    - Alternative to CT in very sick patients (who can suspend respiration only briefly)
        - Multiplicity of scanning planes may be of value in assessing the precise anatomic relationships of a lesion
    - Procedure of choice for children (uses no ionizing radiation)
    - Because the examination requires close contact between the transducer and the skin, it may be difficult to perform on postsurgical patients with recent incisions, wound dressings, drains, superficial infections, or stomas

Hepatic Abscess

Presenting Signs and Symptoms

- Subacute onset of fever, chills, nausea, anorexia, weight loss
- Right upper quadrant pain
- Hepatomegaly (acute onset suggests multiple abscesses from systemic bacteremia or biliary tract infection)

Common Causes

- Ascending cholangitis in a partially or completely obstructed biliary tract
- Portal bacteremia from an intraabdominal site (e.g., appendicitis, diverticulitis)
- Systemic bacteremia (organisms reach liver through the hepatic artery)
- Direct extension from adjacent extrabiliary site
- Trauma

Approach to Diagnostic Imaging

1. **Computed tomography**
    - Preferred study for detecting and characterizing a hepatic abscess
2. **Ultrasound**
    - Alternative imaging technique

Left Subphrenic Space Abscess

Presenting Signs and Symptoms

- Left upper quadrant pain and tenderness

- Fever
- Leukocytosis
- History of surgery 3 to 6 weeks before onset

Common Causes

- Surgery or trauma
- Peritonitis (e.g., perforated viscus)
- Spread from distant abdominal abscess

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred initial imaging study (negative CT scan excludes a left subphrenic abscess)
   - US is usually less effective because of gas in the stomach, small bowel, or colon
2. **Radionuclide scan (indium or gallium)**
   - Indicated if CT is equivocal (not uncommon if there has been recent surgery or trauma) and if it is impossible to differentiate an infected from a sterile collection (e.g., perisplenic hematoma)

> **Caveat: Barium enema is contraindicated because retained barium within the bowel significantly delays the performance of more sensitive and specific studies such as CT and radionuclide scans.**

Pancreas/Lesser Sac Abscess

Presenting Signs and Symptoms

- Fever and abdominal pain arising 10 to 21 days after acute pancreatitis
- Nausea and vomiting
- Abdominal mass
- Leukocytosis
- Increased serum amylase

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred imaging technique
   - US is generally ineffective because of the large amounts of intestinal gas related to the usually associated adynamic ileus

Perihepatic Abscess

Presenting Signs and Symptoms

- Right upper quadrant pain and tenderness
- Fever
- Leukocytosis

Common Causes

- Prior surgery or trauma

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - Can detect subtle perihepatic gas collections
   - Localized ileus of the hepatic flexure and right pleural effusion are both suggestive but not diagnostic signs, since they may merely reflect nonspecific postoperative or post-traumatic changes
2. **Computed tomography**
   - Preferred imaging technique
3. **Ultrasound**
   - Alternative imaging technique
4. **Radionuclide scan (indium or gallium)**
   - Examination of the entire abdomen and pelvis is indicated if an occult abscess is still suspected clinically despite negative US and CT studies
   - Negative indium or gallium radionuclide scan effectively excludes an abscess

Pelvic Abscess

Presenting Signs and Symptoms

- Lower abdominal pain and tenderness
- Palpable mass on vaginal or rectal examination

- Fever and leukocytosis

Common Causes

- Acute appendicitis
- Pelvic inflammatory disease
- Colon diverticulitis

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred imaging technique for pelvic inflammatory disease
   - Fluid-filled urinary bladder provides an excellent acoustic window for examining the supravesical and paravesical spaces
2. **Computed tomography**
   - Preferred initial imaging procedure for men and for women following total abdominal hysterectomy and bilateral salpingo-oophorectomy, as well as for diagnosing perirectal abscesses
3. **Magnetic resonance imaging**
   - Can often best define perirectal abscesses and fistulas
4. **Radionuclide scan**
   - May be necessary to confirm the inflammatory nature of the lesion because the differential diagnosis of cystic masses is large

Caveat: Indium is the preferred radionuclide because gallium normally accumulates in the sigmoid and rectum.

Renal/Perirenal Abscess

Presenting Signs and Symptoms

- Acute onset of unilateral flank or abdominal pain and tenderness
- Dysuria
- Fever, chills
- Leukocytosis

Common Cause

- Pyelonephritis (often associated with renal calculous disease, recent urologic surgery, or obstruction by malignancy)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred initial imaging technique for detecting inflammatory and infectious renal disease
   - May demonstrate thickening of Gerota's fascia, a subtle change that may be the first sign of a perirenal infection
2. **Magnetic resonance imaging**
   - Alternate imaging technique in patients who cannot receive iodinated contrast material
3. **Ultrasound**
   - Alternative imaging technique that demonstrates a fluid-filled intrarenal or perirenal collection

Splenic Abscess

Presenting Signs and Symptoms

- Subacute onset of left-sided pain (often pleuritic) in the flank, upper abdomen, or lower chest that may radiate to the left shoulder
- Left upper quadrant tenderness
- Splenomegaly
- Fever
- Leukocytosis

Common Causes

- Systemic bacteremia (e.g., endocarditis, salmonellosis)
- Trauma (superinfection of hematoma)
- Extension from contiguous infection (e.g., subphrenic abscess)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred imaging technique
   - US is of less value because most of the spleen lies between the ribs and is largely hidden from the US beam
2. **Radionuclide scan (indium or gallium)**

- Can specifically identify an intrasplenic mass as an abscess

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Mass

Abdominal Mass in a Neonate

Organ of Origin

- Kidney
- Gastrointestinal tract

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - To exclude obstruction of the gastrointestinal tract
2. **Ultrasound**
   - Can detect intrinsic renal masses and hydronephrosis
   - If US is normal, no further imaging is required
   - If US detects a mass, further imaging depends on the anatomic location and sonographic characteristics of the lesion

Abdominal Mass in a Child

Organ of Origin

- Kidney
- Adrenal glands
- Pelvic structure

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - Can detect characteristic calcification associated with neuroblastoma (and its metastases)
2. **Ultrasound**
   - Best initial imaging modality for detecting masses in the kidney, adrenal gland, or genital organs in a child (uses no ionizing radiation)
   - Can detect appendiceal abscesses or hepatobiliary lesions, the most common causes of gastrointestinal masses that develop after the neonatal period
3. **Excretory urography and voiding cystourethrography**
   - If US shows a cystic renal mass or severe hydronephrosis, these studies can evaluate kidney function, define the bladder anatomy, and confirm or exclude vesicoureteral reflux
4. **Computed tomography**
   - Indicated if US shows a solid mass suggestive of malignancy (to better define the anatomy and any local or metastatic spread)

Diffusely Enlarged Abdomen (No Discrete Mass)

Common Causes

- Ascites
- Lipodystrophy
- Massive peritoneal/retroperitoneal tumor

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Best modality for defining the organ of origin of any mass in the peritoneal or retroperitoneal compartments
   - In patients with massive ascites, can suggest the origin of the peritoneal fluid by detecting masses, metastases, loculation, and the relative distribution of fluid in the lesser and greater sacs
   - Adequate US examination is often prevented by gas contained within the stomach, small bowel, and colon

Epigastric Mass

Organ of Origin

- Liver
- Spleen
- Stomach
- Duodenum
- Pancreas

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Directly images the liver, spleen, gastric wall, and pancreas
   - Adequate US examination is often prevented by gas contained within the stomach, small bowel, and colon
2. **Upper gastrointestinal series**
   - If there is evidence of gastric outlet obstruction, can evaluate for peptic ulcer or gastric malignancy

Hypogastric Mass

Organ of Origin

- Bladder
- Colon
- Uterus
- Ovary

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred initial imaging technique because most masses in this region are related to the pelvic organs
2. **Computed tomography**
   - Indicated to better define the extent of a lesion if a solid mass is detected by US
3. **Barium enema**
   - Indicated if the clinical examination suggests a gastrointestinal tumor as the underlying cause

Left Lower Quadrant Mass

Organ of Origin

- Colon

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - Can demonstrate large bowel obstruction or fecal impaction
2. **Computed tomography**
   - Preferred initial imaging technique for detecting and defining the origin of a palpable mass or the extent of diverticulitis
3. **Barium enema**
   - Can detect free or walled-off perforation or eccentric narrowing of the colonic lumen related to diverticulitis (the most likely clinical diagnosis)

     Caveat: If free perforation into the peritoneal cavity is suspected, *water-soluble* contrast must be used.

Left Upper Quadrant Mass

Organ of Origin

- Spleen
- Left lobe of the liver
- Stomach (gastric outlet obstruction or tumor)
- Splenic flexure of the colon
- Pancreas
- Left kidney
- Left adrenal gland

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Directly images the spleen, liver, gastric wall, pancreas, left kidney, and left adrenal gland
   - Adequate US examination is often precluded by gas contained within the stomach, small bowel, and colon
2. **Upper gastrointestinal series**
   - If there is evidence of gastric outlet obstruction, can evaluate for peptic ulcer or gastric malignancy

Midabdominal Mass

Organ of Origin

- Superficial structures
- Peritoneal structures
- Retroperitoneal structures

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Directly images the organs within all three compartments
   - Adequate US examination is often prevented by gas contained within the stomach, small bowel, and colon
2. **Ultrasound**
   - Initial modality of choice in an asthenic patient with a pulsating mass suggesting aortic aneurysm

Right Lower Quadrant Mass

Organ of Origin

- Gastrointestinal tract
- Abscess
- Enlarged lymph nodes

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - Can exclude or confirm bowel obstruction, appendicolith, or fecal impaction
2. **Computed tomography**
   - Can differentiate among such entities as inflammatory bowel disease, abscess, and enlarged lymph nodes

Right Upper Quadrant Mass

Organ of Origin

- Right lobe of the liver
- Gallbladder
- Bile ducts
- Right kidney
- Right adrenal gland
- Hepatic flexure of the colon
- Duodenum

Approach to Diagnostic Imaging

1. **Ultrasound**
   - High accuracy for detecting masses involving the gallbladder (acute cholecystitis, hydrops, carcinoma, Courvoisier gallbladder) and bile ducts, as well as diffuse and focal hepatic abnormalities
   - Good imaging test for detecting renal lesions and differentiating renal cysts from solid tumors or abscesses
2. **Computed tomography**
   - Indicated if there is bile duct dilatation and US fails to show an obstructing mass
   - Indicated for confirmation and staging if US shows a solid renal mass
   - Best modality for detecting adrenal masses (metastases, adenoma, carcinoma)
3. **Barium enema or upper gastrointestinal series**
   - Highest accuracy for detecting carcinoma of the hepatic flexure or the duodenum

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Esophagus

Achalasia

Presenting Signs and Symptoms

- Dysphagia for solids and liquids (typically in persons 20 to 40 years old)
- Nocturnal regurgitation of undigested food
- Aspiration (and recurrent pneumonia)

Common Causes

- Primary (idiopathic)
- Malignancy (primary or metastatic)
- Central and peripheral neuropathy
- Cerebrovascular accident
- Postvagotomy syndrome
- Chagas disease

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Not sensitive, but may demonstrate characteristic findings such as an absent gastric air bubble and an esophageal air–fluid level

2. **Barium swallow**
   - Dilated esophagus with distal “beak” or “rat-tail” narrowing and an esophageal air–fluid level
   - Absence of the gastric air bubble
3. **Manometry**
   - Incomplete relaxation of the lower esophageal sphincter
   - Absent peristalsis in the smooth-muscle portion of the esophagus

Cancer of the Esophagus

Presenting Signs and Symptoms

- Progressive dysphagia (first with solids, then liquids)
- Pain (substernal or in the back due to local invasion)
- Rapid weight loss
- Pulmonary aspiration

Risk Factors

- Ethanol abuse
- Smoking
- Lye ingestion and esophageal stricture
- Radiation exposure
- Head and neck cancer
- Achalasia
- Barrett's mucosa
- Tylosis

Approach to Diagnostic Imaging

1. **Barium swallow**
   - Preferred initial imaging examination that can detect superficial and early (small) tumors if the double-contrast technique is employed
   - Cannot identify carcinoma *in situ*
2. **Esophagoscopy (with biopsy and cytology)**
   - Most sensitive and specific test

Staging

1. **Computed tomography (chest/upper abdomen)**
   - Most effective staging procedure that can determine the potential surgical curability of an esophageal tumor in about 90% of patients
   - Accuracy of 97% for detecting tracheobronchial invasion and 94% for aortic and pericardial invasion
   - Demonstration of enlarged mediastinal or subdiaphragmatic lymph nodes is likely to represent involvement by metastatic tumor, although the absence of lymphadenopathy is an unreliable finding (since normal-sized nodes also may harbor metastases)
2. **Endoscopic ultrasound**
   - Superior to CT for evaluating the depth of tumor infiltration within the wall of the esophagus (local invasion) and lymph node involvement

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Note: US is not as effective as CT in assessing the extraesophageal spread of tumor, which relates directly to the duration of survival.

Diffuse Esophageal Spasm

Presenting Signs and Symptoms

- Intermittent substernal chest pain
- Dysphagia for both liquids and solids
- Symptoms frequently aggravated by very hot or cold liquids

Approach to Diagnostic Imaging

1. **Barium swallow**
   - “Corkscrew” esophagus with pseudodiverticula
2. **Manometry**
   - Most sensitive and specific description of the spasms
   - High-amplitude esophageal contractions of long duration with repetitive occurrence

Esophageal Laceration (Mallory-Weiss Syndrome)

Presenting Signs and Symptoms

- Repeated vomiting followed by hematemesis (especially in men older than age 50 with history of alcohol abuse)

Approach to Diagnostic Imaging

1. **Endoscopy**
   - Required to demonstrate the superficial lacerations or fissures near the esophagogastric junction (usually not seen on radiographic contrast studies)

Note: In rare cases, an esophagram shows contrast penetration into the wall of the esophagus.

Esophageal Perforation

Presenting Signs and Symptoms

- Sudden epigastric pain radiating to the shoulder blades after vomiting, retching, or even hiccups (especially after heavy drinking)
- Gravely ill appearance with pallor, sweating, tachycardia, and often shock

Common Causes

- Boerhaave's syndrome
- Penetrating trauma
- Complication of endoscopy

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Initial imaging study for detecting air dissecting within the mediastinum and soft tissues, often with pleural effusion or hydropneumothorax
2. **Barium swallow**
   - May demonstrate extravasation through a transmural perforation

     Caveat: *Water-soluble* contrast material must be used first (since barium cannot be cleared from the mediastinum); if the patient cannot protect the airway, use iso-osmolar, non-ionic oral contrast material; if no gross extravasation is shown, use barium (a better contrast agent) to exclude a small leak.
3. **Computed tomography**
   - Preferred study for defining the extent of an inflammatory process in the mediastinum secondary to an esophageal perforation

Reflux Esophagitis

Presenting Signs and Symptoms

- Heartburn
- Dysphagia (due to stricture)
- Upper gastrointestinal bleeding (due to esophageal ulceration)

Approach to Diagnostic Imaging

1. **Upper gastrointestinal series**
   - Frequent false-negative findings with gastroesophageal reflux and subtle esophagitis
2. **Endoscopy (with mucosal biopsy)**
   - Preferred study in a patient with active bleeding
   - Directly detects esophagitis and peptic strictures
   - May be normal in gastroesophageal reflux

Scleroderma

Presenting Signs and Symptoms

- Often asymptomatic
- Heartburn and dysphagia (due to reflux esophagitis secondary to incompetence of lower esophageal sphincter)

Approach to Diagnostic Imaging

1. **Barium swallow**
   - Dilated esophagus with absent peristalsis
   - Widely patent distal esophagus (in the region of the lower esophageal sphincter)

> **Note:** The distal esophagus may be narrowed in chronic disease because of secondary reflux esophagitis. Patients are at very high risk for developing Barrett's esophagus.

2. **Manometry**
   - Aperistalsis (due to atrophy of esophageal smooth muscle)
   - Incompetent lower esophageal sphincter (leading to reflux esophagitis and stricture formation)

Varices (Esophageal/Gastric)

Presenting Sign and Symptom

- Upper gastrointestinal bleeding

Common Causes

- Cirrhosis
- Obstruction of the splenic or portal vein (e.g., carcinoma of the pancreas)
- Hepatic vein obstruction

Approach to Diagnostic Imaging

1. **Endoscopy**
   - Procedure of choice for acute bleeding
2. **Barium swallow**
   - Can demonstrate characteristic tortuous, beaded filling defects in the distal esophagus and gastric fundus

Interventional Radiologic Alternative

1. **Transjugular intrahepatic portosystemic shunt (TIPS)**
   - An effective and reliable means of lowering portal venous pressure (particularly in patients with acute variceal bleeding unresponsive to sclerotherapy or with chronic variceal bleeding before liver transplantation)
   - Useful in the treatment of ascites and the Budd-Chiari syndrome

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Stomach/Duodenum

Cancer of the Stomach

Presenting Signs and Symptoms

- Progressive upper abdominal discomfort
- Weight loss, anorexia, nausea, vomiting
- Acute or chronic upper gastrointestinal bleeding
- Early satiety

Risk Factors

- Dietary habits (nitrates, smoked or heavily salted foods)
- Atrophic gastritis (pernicious anemia)
- Billroth II gastroenterostomy
- Adenomatous gastric polyps

Approach to Diagnostic Imaging

1. **Double-contrast upper gastrointestinal series**
   - Preferred initial imaging procedure
   - Requires meticulous technique to detect small, early lesions
2. **Endoscopy (with biopsy and cytology)**
   - Most sensitive and specific test (sensitivity of up to 98% if multiple biopsy specimens are taken from a suspicious lesion to decrease the risk of sampling error)
   - Much less accurate in detecting scirrhous lesions

Staging

1. **Computed tomography**
   - Most effective staging procedure for demonstrating the presence and extent of extragastric spread of tumor
   - More accurate in detecting distant lymphadenopathy than local lymph node enlargement

Peptic Ulcer Disease

Presenting Signs and Symptoms

- Burning epigastric pain (90 to 180 minutes after meals, often nocturnal, relieved by food)

- Chronic, recurring course
- Gastrointestinal bleeding (melena, hematemesis, hematochezia)
- Gastric outlet obstruction (about 5%)
- Acute abdomen (if free perforation)

Approach to Diagnostic Imaging

1. **Upper gastrointestinal series**
   - Signs of benignity include a smooth ulcer mound with tapering edges, an edematous ulcer collar with overhanging mucosal edge, projection of the ulcer beyond the expected lumen, and thin radiating folds extending into the crater
   - Size, depth, number, and location of the ulcer are of no diagnostic value in differentiating benign from malignant (except for ulcers in the cardia, which are virtually always malignant)
2. **Endoscopy**
   - May be preferable for suspected gastric ulcer, since biopsy can be performed to exclude malignancy (1% of radiographically benign-appearing ulcers prove to be malignant)
   - More reliable for detecting acute ulcer craters in a scarred duodenum
   - Fails to detect 5–10% of peptic ulcers

> **Caveat: Once the diagnosis of benign peptic disease has been made, recurrences should be treated symptomatically; there is no need to repeat an imaging procedure with each recurrence.**

Zollinger-Ellison Syndrome

Presenting Signs and Symptoms

- Refractory peptic ulcer disease (after medical therapy or surgery)
- Gastric hypersecretion
- Diarrhea
- Substantially elevated serum gastrin

Common Cause

- Gastrinoma (usually of the pancreas)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred study for detecting the underlying pancreatic tumor, which typically is small, often multiple, and intensely enhancing
2. **Upper gastrointestinal series**
   - May show characteristic pattern of markedly thickened gastric folds and ulcers distal to the duodenal bulb (seen in about half the patients)

Pyloric Stenosis

Presenting Signs and Symptoms

- Projectile, nonbilious vomiting
- Typically occurs in 2- to 6-week-old males
- Palpable midabdominal mass (“pyloric olive”)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred imaging technique with almost 100% sensitivity
   - Demonstrates characteristic “doughnut” or “target” lesion (hypoechoic wall surrounding echogenic mucosa) on transverse view and elongated pyloric channel on longitudinal scan
2. **Upper gastrointestinal series**
   - Indicated if US is negative and vomiting persists

Small Bowel

Small Bowel Obstruction

Presenting Signs and Symptoms

- Crampy abdominal pain and bloating
- Nausea and vomiting
- Abdominal tenderness and peritoneal signs
- Abdominal distension

- Increased high-pitched bowel sounds

Common Causes

- Adhesions
- Hernia
- Tumor
- Intussusception
- Extrinsic mass

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - Change in caliber of air-filled bowel (dilated proximally, collapsed distally)
   - String-of-beads sign on upright films
2. **Computed tomography (optional)**
   - Only required to confirm an obstruction if plain films are equivocal or if it is necessary to show the precise site of obstruction
   - Much more accurate than small bowel follow-through with oral contrast agent for demonstrating the underlying cause of the obstruction

> **Caveat: If CT scan is inconclusive and an oral contrast examination is needed to confirm an obstruction, use barium, *NOT* water-soluble agents, for small bowel follow-through (hyperosmolar contrast draws fluid into the bowel, diluting the opaque material and making it difficult to clearly show the site of obstruction). Before barium is given by mouth, it is necessary to exclude a large bowel obstruction (use water-soluble contrast).**

Intussusception

Presenting Signs and Symptoms

CHILDREN

- Colicky abdominal pain that waxes and wanes
- Vomiting, diarrhea, and other gastrointestinal symptoms in greater than 90% of patients
- Palpable abdominal mass in about 50% of patients
- Heme-positive or “currant jelly” stools
- Accounts for 80–90% of bowel obstruction in infants and children
- Peak incidence at 3 to 9 months (40%); 50% of cases occur at less than 1 year and 75% at less than 2 years; only 10% occur after age 3

ADULTS

- General signs and symptoms of bowel obstruction
- Often chronic and relapsing (diagnosis suggested by recurrent episodes of subacute obstruction and by variability of abdominal signs)
- Palpable mass may be present during the height of an attack and disappear completely when the patient is reexamined several hours later, by which time the symptoms have resolved
- Combination of an abdominal mass and the passage of blood per rectum suggests the diagnosis

Common Causes

CHILDREN

- Idiopathic in 95% (most commonly involves ileocolic region); mucosal edema and lymphoid hyperplasia often follow viral gastroenteritis
- Lead point in 5% (may be Meckel's diverticulum, lymphoma, duplication cyst, enterogenous cyst, inspissated meconium, Henoch-Schönlein purpura)

ADULTS

- Specific cause in 80% (benign tumor in 33%, malignant tumor in 20%; also Meckel's diverticulum, adhesions, sprue, scleroderma)
- Idiopathic in 20%

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - Normal in 25%
   - Small bowel obstruction in 25%
   - Abdominal soft-tissue mass highlighted by bowel gas (crescent sign)
2. **Contrast enema**
   - Characteristic “coiled-spring” appearance
   - Abrupt, beak-like narrowing of the contrast column demonstrating a central channel

- Barium enema can be employed both diagnostically and therapeutically in a medically stable child. Surgical consultation is needed prior to the study in case reduction is unsuccessful or a complication occurs.
- Water-soluble contrast or air can also be employed both diagnostically and therapeutically

Caveat: Reduction of an intussusception should *not* be attempted in adults.

3. **Ultrasound**
   - Shows a target or doughnut appearance on transverse scans and a “pseudokidney” sign on longitudinal scans
   - Most useful when the clinical suspicion is low and there is reluctance to perform a barium enema, or when a child is extremely ill and surgery is contemplated

Caveat: US is *not* recommended in adults.

4. **Computed tomography**
   - Used when evaluating a patient for suspected small bowel obstruction
   - May demonstrate a target sign, a sausage-shaped mass with alternating areas of low and high attenuation, or a reniform mass

Gastroenteritis

Presenting Signs and Symptoms

- Anorexia, nausea, vomiting
- Diarrhea of variable severity
- Abdominal discomfort
- Low-grade fever
- Travel history

Common Causes

- Bacterial, viral, or parasitic infection
- Enterotoxins (bacterial)
- Chemical toxins (mushrooms, shellfish, contaminated food)
- Food allergies

Approach to Diagnostic Imaging

- *No* imaging studies are required unless examinations of stool specimens and stool cultures are negative and symptoms persist

Meckel's Diverticulum

Presenting Signs and Symptoms

- Rectal bleeding (ulcerating gastric mucosa within a diverticulum)
- Bowel obstruction

Common Cause

- Omphalomesenteric duct remnant in distal small bowel within 100 cm of ileocecal valve

Approach to Diagnostic Imaging

1. **Radionuclide scan (technetium)**
   - Focal right lower quadrant accumulation of isotope by gastric mucosa lining the diverticulum

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Note: There is generally no indication for any other imaging study.

Colon

Antibiotic-Associated Colitis

Presenting Signs and Symptoms

- Range from transient mild diarrhea to a severe colitis that develops during a course of antibiotic therapy or up to 6 weeks after treatment has ended

Common Causes

- Toxin-producing strains of *Clostridium difficile* (especially after clindamycin, ampicillin, cephalosporins, or aminoglycosides)

Approach to Diagnostic Imaging

1. **Sigmoidoscopy**
   - Directly shows characteristic pseudomembranes
2. **Computed tomography**
   - Demonstrates mural thickening of a hypodense colon wall
   - Because symptoms may be misleading, may suggest the correct diagnosis before it is suspected clinically

> **Caveat: Although barium enema may show the extent of mucosal abnormalities, it is *contraindicated* in active or severe cases because of the risk of perforation.**

Appendicitis

Presenting Signs and Symptoms

- Sudden onset of epigastric or periumbilical pain that shifts to the right lower quadrant
- Rebound tenderness
- Low-grade fever
- Leukocytosis

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - Low sensitivity and specificity, but may detect a calcified appendicolith (about 15%), which is strongly suggestive of impending perforation
2. **Computed tomography**
   - “Gold standard” for the noninvasive diagnosis of appendicitis
   - With contrast enhancement, can make the diagnosis by identifying an abnormal appendix (dilated with a thickened, circumferentially enhancing wall) or pericecal inflammation and/or abscess associated with an appendicolith
   - More sensitive than US for revealing the normal appendix, a critical observation, since definitive exclusion of appendicitis requires visualization of the normal appendix in its entirety

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Note: Helical CT imaging is increasingly being used as an alternative to sonography for diagnosing possible appendicitis in nonpregnant patients, in grossly obese or large body habitus patients, in patients with severe abdominal pain, and in patients in whom sonography is inconclusive.

   - Highly accurate for showing unrelated intraabdominal disease that may mimic appendicitis and explain the patient's clinical presentation
   - Can be used to guide percutaneous abscess drainage
   - Detects appendicolith in about 30% of patients
3. **Ultrasound**
   - Highly sensitive and specific without need for ionizing radiation (especially in children and women during childbearing years)
   - Disadvantages include high operator dependence and limitations due to obesity, large amounts of intestinal gas, and patients with retrocecal appendix or severe abdominal pain

Cancer of the Colon

Presenting Signs and Symptoms

- Bright red rectal bleeding, altered bowel habits, abdominal or back pain (left-sided lesions)
- Iron deficiency anemia, occult blood in the stool, weight loss (right-sided lesions)

Risk Factors

- Diet (low in fiber, high in animal fat)
- Personal or family history of colorectal polyps
- Familial polyposis syndrome
- Family history of colorectal cancer
- Ulcerative colitis
- Crohn's colitis
- Hypercholesterolemia

Approach to Diagnostic Imaging

1. **Double-contrast barium enema**
   - Preferred initial imaging procedure
   - Requires meticulous technique to detect small, early lesions
2. **Colonoscopy/flexible sigmoidoscopy**
   - Slightly more sensitive and specific than barium enema, but associated with considerably higher cost and

complications
    - Blind spots behind folds or around the flexures

Staging

1. **Computed tomography**
    - Most effective staging procedure for demonstrating the presence and extent of extracolonic spread of tumor
2. **Transrectal ultrasound**
    - Most accurate imaging method for staging local rectal cancer (can assess the depth of invasion within the bowel wall and can suggest the presence of tumor in adjacent normal-sized lymph nodes)

Screening

- Indications for screening
    - General population: after age 50, every 5 years by either Double-contrast barium enema Colonoscopy
    - Positive family history or genetic screening: after age 30, every 2 years
    - Familial adenomatous polyposis: yearly double-contrast barium enema from puberty to age 22 (then optional colectomy and ileocecal anastomosis)

Crohn's Disease

Presenting Signs and Symptoms

- Abdominal pain
- Fever
- Anorexia and weight loss
- Diarrhea (often without blood)
- Fatigue
- Right lower quadrant mass or fullness
- Anorectal fissures, fistulas, abscesses (may be acute ileitis mimicking appendicitis or obstruction)
- Complications (bowel obstruction, internal fistulas, and bile salt malabsorption leading to gallstones or oxalate kidney stones)

Approach to Diagnostic Imaging

1. **Barium enema**
    - Demonstrates involvement of the terminal ileum and variable amounts of colon and more proximal small bowel disease characterized by nodularity and thickening of folds, aphthous ulcers, narrowing and rigidity, cobblestoning, string sign, skip areas, and fistulas
2. **Small bowel examination**
    - Required if the terminal ileum is not visualized because of an inability to reflux barium through a competent ileocecal valve
3. **Computed tomography**
    - In addition to showing thickening of the bowel wall, best modality for demonstrating mesenteric and extraintestinal extent of disease and abscess formation

Ulcerative Colitis

Presenting Signs and Symptoms

- Bloody diarrhea
- Mucus in stool
- Abdominal pain (ranging from mild lower abdominal cramping to severe peritoneal signs)
- Fever
- Complications (toxic megacolon, colon perforation, hemorrhage, increased risk of cancer)

Approach to Diagnostic Imaging

1. **Sigmoidoscopy**
    - Direct and immediate indication of the activity of the disease process
2. **Plain abdominal radiograph**
    - Must exclude toxic megacolon *before* attempting a barium enema
    - Distal extent of formed fecal residue gives a good indication (although not absolute) of the proximal extent of the colitis (may overestimate but does not underestimate extent of disease)
3. **Barium enema or colonoscopy**
    - To determine the full extent of the disease and detect the development of malignancy in patients with chronic disease

Diverticulitis

Presenting Signs and Symptoms

- Abdominal pain and tenderness (typically left lower quadrant)
- Altered bowel habits

- Fever
- Leukocytosis

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Demonstrates pericolonic fluid or a gas collection (abscess), usually with nonspecific thickening of the colon wall, narrowing of the colonic lumen, and inflammatory stranding in adjacent fat
   - Can be used to guide percutaneous abscess drainage
2. **Barium enema**
   - May demonstrate extravasation of contrast through a diverticular perforation *or* a pericolic soft-tissue mass (walled-off perforation) causing eccentric narrowing of the colon

> **Caveat: If free perforation into the peritoneal cavity is suspected, *water-soluble* contrast must be used.**

> **Note:** Plain abdominal radiographs are not needed unless there are peritoneal signs suggesting free perforation.

Diverticulosis

Presenting Signs and Symptoms

- Often asymptomatic
- Unexplained lower gastrointestinal bleeding
- Recurrent left lower quadrant pain
- Alternating constipation and diarrhea

Approach to Diagnostic Imaging

1. **Barium enema**
   - Contrast-filled outpouchings from the colon without evidence of extravasation or mass effect

> **Caveat: It can be extremely difficult to exclude a polyp or carcinoma in a segment of colon that is severely involved by diverticular disease.**

Fecal Incontinence

Presenting Signs and Symptoms

- Involuntary passage of stool through the anus

Common Causes

- Rectal prolapse
- Anorectal trauma
- Abnormal rectal compliance (inflammatory bowel disease, radiation proctitis, rectal ischemia)
- Irritable bowel syndrome
- Polyneuropathies
- CNS disorders (dementia, stroke, brain tumor, multiple sclerosis, spinal cord lesion)

Approach to Diagnostic Imaging

1. **Manometry**
   - Anal manometry is indicated to measure basal and squeeze pressures in the anal canal
   - Rectal balloon manometry is performed to measure rectal sensation, rectal compliance, anorectal inhibitory reflex, and anorectal contractile response
2. **Defecography**
   - Assesses the anorectal angle, perineal descent, and puborectalis muscle function
3. **Anal endosonography**
   - Evaluates the integrity of the sphincter
4. **Magnetic resonance imaging**
   - Evaluates the integrity of the sphincter

Hemorrhoids

Presenting Signs and Symptoms

- Bleeding (typically after defecation and noted on the toilet tissue)
- Pain (if ulcerated, thrombosed, or strangulated)
- Protrusion (may regress spontaneously or be reduced manually)

Approach to Diagnostic Imaging

- Imaging is *not* indicated
- Barium enema examination should only be performed if there is clinical evidence of a more serious cause of rectal bleeding (hemorrhoidal bleeding rarely leads to anemia or an acute exsanguinating hemorrhage)

Hirschsprung's Disease

Presenting Signs and Symptoms

- Constipation in the first month of life due to absence of ganglion cells in the myenteric plexus of the rectum and distal colon

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - Demonstrates distal bowel obstruction with a large amount of retained feces

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Notes: There is no indication for an upper gastrointestinal series.

2. **Contrast enema**
   - Shows precise level of colonic obstruction

Note: A normal contrast enema examination does not entirely exclude short-segment Hirschsprung's disease of the anus. An anorectal biopsy may be needed if the index of suspicion remains high.

Irritable Bowel Syndrome

Presenting Signs and Symptoms

- Symptoms triggered by stress or ingestion of foods
- Pasty, ribbon-like, or pencil-thin stools
- Mucus (not blood) in the stools
- Onset often before age 30 (especially in women)

Common Variants

- Spastic colon (chronic abdominal pain and constipation)
- Alternating constipation and diarrhea
- Chronic painless diarrhea

Approach to Diagnostic Imaging

1. **Barium enema**
   - Primarily performed to exclude inflammatory bowel disease or malignancy

Large Bowel Obstruction

Presenting Signs and Symptoms

- Gradually increasing constipation leading to obstipation and abdominal distension
- Lower abdominal cramps unproductive of feces
- Vomiting (if incompetent ileocecal valve)

Common Causes

- Malignant tumor
- Inflammatory stricture (e.g., diverticulitis)
- Volvulus
- Hernia
- Extrinsic lesion

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
   - Change in caliber of gas-filled colon at the site of obstruction
   - Lateral decubitus view (right side down) can allow gas to rise into the sigmoid and rectum and differentiate between colonic ileus (rectum/ sigmoid distended) and mechanical obstruction (rectum/sigmoid remain collapsed)

2. **Barium enema**
    - Shows site and character of the obstruction

> **Notes:** In patients with acute obstruction, water-soluble contrast material should be used (due to the danger of barium inspissation proximal to a colonic obstruction; if there is an adynamic ileus, retained barium will remain for a prolonged period and interfere with other imaging studies).
>
> In patients with intussusception or volvulus, a barium enema may be therapeutic as well as diagnostic.
>
> If endoscopy is to be performed, it should precede the barium enema.

3. **Computed tomography**
    - Especially valuable in patients without a history of surgery who have systemic signs suggesting infection, bowel infarction, or an associated palpable mass
    - Can demonstrate diverticulitis or appendicitis as the cause of an obstruction

> **Note:** Some radiologists recommend CT as the initial study (instead of barium enema) as a more direct means for establishing the diagnosis of large bowel obstruction.

Liver/Biliary Tract

Biliary Obstruction

Presenting Signs and Symptoms

- Yellowing of skin and sclera
- Abnormal liver enzymes
- Dark urine and pale, clay-colored stools

Common Causes

- Common duct stone
- Pancreatic carcinoma
- Cholangiocarcinoma
- Obstructing metastases

Approach to Diagnostic Imaging

1. **Computed tomography or ultrasound**
    - Demonstrates bile duct dilatation indicative of obstruction
    - CT is highly accurate for showing disease in adjacent structures (liver, porta hepatis, pancreas, adrenals, retroperitoneum)
    - Neither CT nor US can reliably exclude a common duct stone (sensitivity less than 80–85%), but no further imaging tests are needed when choledocholithiasis is diagnosed by these modalities
2. **Percutaneous transhepatic cholangiography**
    - Invasive procedure of choice for defining the precise site of obstruction in a dilated biliary system
    - Superior to ERCP for diagnostic and therapeutic maneuvers (e.g., balloon dilatation of strictures, brush biopsy, stone removal, insertion of an endoprosthesis) that involve lesions above the porta hepatis (intrahepatic)
3. **Endoscopic retrograde cholangiopancreatography**
    - Invasive procedure of choice if the bile ducts are not dilated (e.g., sclerosing cholangitis) and if the patient has abnormal bleeding parameters
    - Permits therapeutic procedures (e.g., sphincterotomy, stone extraction, brush biopsy of strictures, and insertion of an endoprosthesis) at the time of initial diagnosis
    - Highly operator-dependent (unsuccessful duct cannulation in 3–9% of patients) and substantial morbidity and mortality (7% and 1%, respectively)
    - Limited or no opacification of ducts proximal to a severe or complete obstruction
    - Routine sedation required
4. **Magnetic resonance cholangiopancreatography**
    - Preferred diagnostic approach if ERCP is unsuccessful, as in patients with surgical bypass procedures (Billroth II anastomosis, hepatojejunostomy), or those with acute pancreatitis (increased risk of complications from ERCP)

Cholecystitis (Acute)

Presenting Signs and Symptoms

- Acute colicky right upper quadrant pain and tenderness
- Fever
- Nausea and vomiting

- Mild jaundice (occasionally)
- Mild leukocytosis
- Mild elevation of serum bilirubin, alkaline phosphatase, and serum glutamic oxaloacetic transaminase (SGOT)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - May demonstrate gallstones, thickening of the gallbladder wall, pericholecystic fluid, and point tenderness directly over the gallbladder (sonographic Murphy's sign)
   - Permits detection of abnormalities of the liver, pancreas, or kidneys that may produce a clinical appearance mimicking acute cholecystitis (only about one-third of patients with symptoms of acute cholecystitis actually have that condition)
   - Indicated if there is strong clinical evidence of acalculous nonobstructing acute cholecystitis in the face of a negative cholescintigram
2. **Cholescintigraphy (technetium-IDA derivatives)**
   - Visualized gallbladder excludes acute cholecystitis (specificity 95%) by indicating patency of the cystic duct
   - Nonvisualized gallbladder after 4 hours strongly *suggests* acute cholecystitis (sensitivity 98%) if the patient is not a chronic alcoholic or undergoing total parenteral nutrition

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Note: With the use of morphine augmentation, the time required to perform a radionuclide study is reduced to 1.5 hours.

3. **Magnetic resonance cholangiopancreatography**
   - Indicated when US findings are not diagnostic
   - US is superior to MRCP for evaluating gallbladder wall thickness, but MRCP is better for depicting the cystic duct and obstructing calculi in the gallbladder neck

Cholecystitis (Chronic)

Presenting Signs and Symptoms

- Recurrent right upper quadrant pain and biliary colic

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred initial imaging technique
   - Demonstrates high-amplitude echo in the gallbladder lumen (reflecting from the surface of a gallstone) or in the gallbladder fossa (if the lumen is completely filled with calculi) associated with posterior acoustic shadowing
2. **Cholescintigraphy**
   - Cholecystokinin (CCK)-enhanced study can evaluate the ejection fraction of the gallbladder, which is diminished in chronic cholecystitis

> **Caveat: Plain abdominal radiographs are of limited value, since only about 20% of gallstones are radiopaque.**

Fatty Liver

Presenting Signs and Symptoms

- Asymptomatic hepatomegaly
- Possible right upper quadrant pain, tenderness, or jaundice

Common Causes

- Cirrhosis
- Chemicals/drugs: (e.g., alcohol, steroids, tetracyclines, carbon tetrachloride, methotrexate)
- Obesity
- Malnutrition
- Hyperalimentation
- Cystic fibrosis

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Noncontrast CT demonstrates diffuse low attenuation of the liver parenchyma (lower than that of the spleen)
   - Focal fatty infiltration may simulate a liver tumor (although vessels typically run their normal course through the area of involvement)
2. **Magnetic resonance imaging**
   - May be needed to exclude a hepatic mass when focal fat deposition is seen on CT or US in a patient with a malignancy

Hemangioma of the Liver

Presenting Signs and Symptoms

- Asymptomatic and discovered incidentally on US, CT, or MRI

Approach to Diagnostic Imaging

1. **Ultrasound, computed tomography, magnetic resonance imaging, or radionuclide scan**
   - US may show a typically well-defined, hyperechoic mass
   - CT may demonstrate a low-attenuation mass with well-defined borders on nonenhanced scans; after contrast injection, there may be characteristic filling in of the lesion in a centripetal fashion (entire mass becomes isodense)
   - MRI may show marked hyperintensity of the mass on T2-weighted images with an enhancement pattern similar to that on CT
   - Radionuclide scan using tagged red blood cells shows prolonged activity within the lesion on delayed images (preferred imaging study if the lesion is >3 cm)

Notes: If the lesion has a characteristic appearance, it should be left alone with no further imaging studies.

If the patient has a known malignancy, abnormal liver function tests, or symptoms, more than one imaging study should be performed.

Portal Hypertension

Presenting Signs and Symptoms

- Bleeding esophageal varices
- Ascites and edema
- Encephalopathy
- Nonspecific constitutional symptoms of fatigue, lethargy, anorexia

Common Causes

- Cirrhosis
- Obstruction of the extrahepatic portal vein (e.g., carcinoma of the pancreas)
- Hepatic vein obstruction

Approach to Diagnostic Imaging

1. **Color and duplex Doppler ultrasound**
   - Demonstrates patency and direction of blood flow in hepatic veins, portal veins, and collateral venous channels
2. **Computed tomography**
   - Documents presence of venous collaterals in the mesentery and retroperitoneum
   - Can better define the cause of extrahepatic portal vein thrombosis and any propagation into the liver
3. **Magnetic resonance angiography**
   - Indicated if intravenous contrast material may not be given or if CT is inconclusive

Hepatocellular Carcinoma (Hepatoma)

Presenting Signs and Symptoms

- Right upper quadrant pain
- Tender hepatomegaly
- Unexplained deterioration in a previously stable patient with cirrhosis
- Weight loss
- Fever (may simulate infection)
- Elevated serum a-fetoprotein (in 60–90%)

Risk Factors

- Chronic hepatitis B infection
- Cirrhosis (especially alcohol-induced)
- Hemochromatosis
- Thorotrast exposure (radiographic contrast agent used from about 1940 to 1960)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred initial imaging technique for demonstrating any of the three major patterns (diffuse infiltrative, solitary

massive, and multinodular)
    - Multiphasic helical CT scanning (including hepatic arterial phase) is needed to establish the diagnosis of this vascular tumor
2. **Ultrasound**
    - Used in high-prevalence areas (e.g., Japan) for screening of chronic hepatitis B virus carriers
3. **Magnetic resonance imaging**
    - May permit a specific diagnosis of hepatocellular carcinoma by demonstrating
        1. characteristic capsule of compressed liver or scar tissue,
        2. accumulation of fat within the tumor, and
        3. propensity of tumor spread into the hepatic and portal veins
    - Should be performed during the arterial phase following gadolinium administration

Liver Metastases

Presenting Signs and Symptoms

- Usually asymptomatic
- May have nonspecific weight loss, anorexia, fever, weakness
- Hepatomegaly (hard and often tender)
- Ascites
- Jaundice

Common Primary Tumors

- Gastrointestinal tract (colon, pancreas, stomach)
- Lung
- Breast
- Lymphoma
- Melanoma

Approach to Diagnostic Imaging

1. **Computed tomography**
    - Sensitive screening technique that is preferred to MRI if there is also a need to assess possible metastases in the adrenal glands, retroperitoneum, and other abdominal organs
    - Permits fine-needle aspiration biopsy for cytology to provide a definitive diagnosis
2. **Magnetic resonance imaging**
    - Sensitive technique for detecting liver metastases
    - Generally indicated in patients who cannot receive intravenous iodinated contrast or who are being considered for partial hepatectomy
    - Improved sensitivity with the use of contrast agents containing iron or manganese
3. **Ultrasound**
    - Less sensitive than MRI or CT, but is rapid and inexpensive and reliably identifies the majority of patients with hepatic metastases

> **Caveat: Radionuclide scan is less sensitive than other methods for detecting liver metastases and thus is not indicated for routine screening.**

Pancreas

Pancreatitis (Acute)

Presenting Signs and Symptoms

- Steady, boring midepigastric pain radiating straight through to the back
- Elevated serum amylase and lipase

Common Causes

- Biliary tract disease (e.g., stones)
- Alcoholism
- Drugs
- Infection (e.g., mumps)
- Hyperlipidemia
- ERCP
- Neoplasm
- Surgery or trauma

Approach to Diagnostic Imaging

1. **Computed tomography**
    - Imaging procedure of choice for demonstrating focal or diffuse enlargement of the gland and indistinctness of its margins
    - Superior to US for showing extrapancreatic spread of inflammation and edema and for detecting gas within a

pancreatic fluid collection (highly suggestive of abscess)
    - Can also be used to suggest the prognosis
2. **Ultrasound**
    - In addition to demonstrating symmetric enlargement of a relatively sonolucent gland, may show cholelithiasis, an important underlying cause of acute pancreatitis
    - Frequent occurrence of adynamic ileus with excessive intestinal gas may prevent adequate visualization of the gland
    - Useful for follow-up of specific abnormalities (e.g., fluid collections)

> **Caveat: Although plain abdominal radiographs are abnormal in 50% of patients, they usually show only generalized or localized ileus that is not specific for pancreatitis.**

Pancreatitis (Chronic)

Presenting Signs and Symptoms

- Midepigastric pain
- Weight loss, steatorrhea, and other signs and symptoms of malabsorption

Common Causes

- Alcoholism
- Hereditary pancreatitis
- Hyperparathyroidism
- Obstruction of main pancreatic duct (stricture, stones, cancer)

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph**
    - Demonstrates virtually pathognomonic pancreatic calcifications in 30–60% of patients
2. **Computed tomography or ultrasound**
    - Shows enlargement or atrophy of the gland, dilatation of the pancreatic duct, and pseudocyst formation
    - CT is more accurate in demonstrating the focal superimposition of a malignant mass, and is not adversely affected by the large amounts of intestinal gas that may accompany an acute exacerbation of inflammatory disease
3. **Endoscopic retrograde cholangiopancreatography**
    - Shows irregular dilatation of the main pancreatic duct and pruning of its branches

Cancer of the Pancreas

Presenting Signs and Symptoms

- Abdominal and back pain
- Weight loss and anorexia
- Painless jaundice
- Enlarged, palpable gallbladder (Courvoisier's sign)

Approach to Diagnostic Imaging

1. **Computed tomography**
    - Shows a mass with (or without) obstructive dilatation of the pancreatic or bile duct or both
    - Most effective modality for demonstrating lesions in the tail and for defining the extent of tumor spread (may prevent needless surgery in patients with nonresectable lesions)
2. **Ultrasound**
    - Useful imaging test (shows abnormalities in about 75% of patients) but may fail to detect small lesions in the body and tail
3. **Endoscopic retrograde cholangiopancreatography**
    - Most sensitive test for tumors of the pancreatic head (deformity/stricture of the bile duct)
    - Indicated if clinical suspicion remains high in the face of normal CT and US examinations
4. **Magnetic resonance imaging (with MRCP)**
    - May be helpful if other tests are inconclusive

Interventional Radiologic Alternatives

1. **Percutaneous fine-needle aspiration (under CT or US guidance)**
    - Often provides a precise histologic diagnosis
2. **Percutaneous stent placement for biliary drainage**
    - May be performed using either ERCP or PTHC

Trauma (Blunt Abdominal)

Approach to Diagnostic Imaging

1. **Plain abdominal and chest radiographs**

- Neither sensitive nor specific, but inexpensive and rapidly available studies that can direct attention to specific organ injuries
  - **SPLEEN**
    - Fractures of lower left ribs
    - Elevation of left hemidiaphragm
    - Left pleural effusion
    - Displacement of gastric air bubble
    - Irregular splenic outline
  - **LIVER**
    - Fractures of right lower ribs
    - Displacement of hepatic flexure
    - Irregular/enlarged hepatic outline
  - **RETROPERITONEUM**
    - Loss of psoas or renal shadow
    - Free retroperitoneal gas
    - Fracture of lumbar transverse process
  - **DIAPHRAGM**
    - Herniation of abdominal contents into chest
    - Abnormal position of nasogastric tube
    - Elevation and loss of definition of hemidiaphragm
    - Nonspecific pleural effusion and atelectasis

2. **Computed tomography**
   - Highest sensitivity and specificity for detecting injuries to the liver, spleen, kidneys, and retroperitoneum
3. **Radionuclide scan or ultrasound**
   - Only indicated if CT examination of the liver and spleen is ambiguous because of surgical clip artifacts or motion (or if an allergy to intravenous contrast precludes an enhanced CT study)
4. **Arteriography**
   - Only indicated if both CT and radionuclide scan are equivocal (especially valuable as both a diagnostic and therapeutic tool in patients with pelvic ring disruption who have evidence of severe bleeding)

> **Caveat: Although diagnostic peritoneal lavage is traditionally the generally accepted standard for the diagnosis of possible abdominal injury, it has been replaced in most centers by CT. Diagnostic peritoneal lavage can yield false-negative results in injuries to retroperitoneal structures (e.g., kidneys, pancreas, duodenum) or the diaphragm. In addition, a positive peritoneal lavage occurs in up to 25% of patients with trivial injuries who do not require laparotomy, and may occur in patients with pelvic fractures or as a result of a traumatic peritoneal tap.**

CHAPTER 4. URINARY

N. Reed Dunnick

SIGNS AND SYMPTOMS

Dysuria

Common Causes

- Urethritis (infection, catheters)
- Cystitis (infection, radiation, chemicals, catheters, stones)
- Prostatitis
- Bladder tumor
- Functional bladder syndrome

Approach to Diagnostic Imaging

Caveat: In most cases, the cause of dysuria is evident from clinical examination and urinalysis, and no imaging procedures are necessary.

1. **Excretory urography or voiding cystourethrography**
   - Can demonstrate diffuse, irregular thickening of the bladder wall in inflammatory disease, as well as a lucent filling defect resulting from a bladder stone or tumor

Hematuria (Painless)

Common Causes

- Neoplasm (kidney, ureter, bladder, urethra)
- Glomerulonephritis
- Vascular abnormality (aneurysm, malformation, arterial or venous occlusion)
- Papillary necrosis
- Urolithiasis

Approach to Diagnostic Imaging

1. **Computed tomography**
   - More sensitive than US or excretory urography for detecting renal masses
   - If combined with an unenhanced examination, will also detect urinary tract calculi
2. **Ultrasound**
   - Relatively efficient imaging technique for detecting neoplastic renal masses and vascular anomalies
3. **Excretory urography**
   - Excellent for detecting stones and papillary necrosis

Caveat: Excretory urography cannot exclude bladder or urethral pathology.

4. **Cystoscopy**
   - Required in any adult with unexplained hematuria because a normal US examination, cystogram, or excretory urogram does not exclude a bladder tumor or cystitis.

Hematuria (Painful)

Common Causes

- Ureteral calculus
- Trauma
- Infection (especially cystitis or urethritis)

Approach to Diagnostic Imaging

1. **Computed tomography (unenhanced)**
   - Can detect even poorly opaque stones (e.g., uric acid calculi)
   - Can detect dilatation of the collecting system proximal to an obstructing stone
   - Can detect secondary signs of ureteral obstruction such as perinephric stranding or extravasation
   - Presence of tissue (edematous ureter) surrounding a calcification (rim sign) can differentiate a ureteral calculus from a phlebolith or other extraurinary calcification
   - Stones larger than 5 mm may require endoscopic removal
   - Can detect extraurinary cause of abdominal pain such as cholelithiasis and appendicitis

- May be used in patients in whom intravascular contrast material is contraindicated

2. **Ultrasound**
   - Can demonstrate the presence and degree of ureteral dilatation proximal to an impacted stone
   - Can demonstrate a stone as an echogenic focus with acoustic shadowing in the patient with a nonopaque, completely obstructing stone causing loss of ipsilateral kidney function
   - Transvaginal US may be used to increase the sensitivity for detection of distal ureteral stones
   - Ureteral stones may be obscured by bowel gas
   - US may be the procedure of choice for pregnant patients
3. **Excretory urography**
   - Provides a broad range of morphologic and functional information concerning all portions of the urinary tract
   - Can define the site of an impacted ureteral stone and the degree of resulting ureteral obstruction, as well as post-traumatic extravasation of contrast material from the urinary tract

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Note: If there is complete ureteral obstruction, the excretory urogram may show nonvisualization of the ipsilateral kidney or a prolonged nephrogram with lack of filling of the ureter so that it may be impossible to determine the site of the impacted stone.

Renal Failure (Acute)

Presenting Signs and Symptoms

- Rapid, steadily increasing azotemia, with or without oliguria

Common Causes

PRERENAL

- Hypovolemia (diarrhea, vomiting, hemorrhage, overdiuresis, pancreatitis, peritonitis)
- Vasodilatation (sepsis, drugs, anaphylaxis)
- Cardiac (congestive heart failure, myocardial infarction, cardiac tamponade)
- Renal hypoperfusion (renal artery obstruction)

RENAL

- Acute tubular injury (ischemia, toxins, hemoglobinuria, myoglobinuria, radiocontrast agents)
- Acute glomerulonephritis
- Acute tubular nephritis (drug reaction, pyelonephritis, papillary necrosis)
- Precipitation of substances within the kidney (calcium, urates, myeloma protein)
- Arterial or venous obstruction
- Disseminated intravascular coagulopathy with cortical necrosis

POSTRENAL

- Calculi
- Prostatism
- Neoplasm (bladder, pelvic, retroperitoneal)
- Retroperitoneal fibrosis
- Urethral or bladder neck obstruction

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Imaging procedure of choice for assessing renal size, identifying renal parenchymal disease (diffuse increase in echogenicity with loss of corticomedullary differentiation), and excluding hydronephrosis (postrenal cause)

Note: In patients with acute renal failure and large (>12 cm) or normal-sized kidneys, biopsy is often required for definitive diagnosis of renal parenchymal disease; patients with small (<9 cm) kidneys usually have irreversible end-stage renal disease and do not benefit from biopsy.

   - If a vascular cause is suggested clinically, color Doppler studies may demonstrate patency or occlusion of the renal artery or vein. If this is unsuccessful, radionuclide renal scan or magnetic resonance imaging can show these vessels.

Caveat: Although arteriography and venography are more definitive tests for vascular occlusion, some physicians prefer not to use radiographic contrast agents in patients with acute renal failure.

Renal Failure (Chronic)

Presenting Signs and Symptoms

- Irreversible loss of renal function (uremia)
- Neuromuscular (peripheral neuropathy, muscle cramps, convulsions, encephalopathy)
- Gastrointestinal (anorexia, nausea and vomiting, peptic ulcer, unpleasant taste in the mouth)
- Cardiopulmonary (congestive heart failure, hypertension, pericarditis, pleural effusion)
- Skin (uremic frost, pruritus)
- Secondary hyperparathyroidism

Common Causes

- Diabetic nephropathy
- Hypertension
- Glomerulonephritis
- Polycystic kidney disease (autosomal dominant)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Imaging procedure of choice for assessing kidney size (usually small kidneys in chronic renal failure), as well as detecting hydronephrosis secondary to obstruction (especially in patients with risk factors such as known or suspected pelvic malignancy, or bladder outlet obstruction).

DISORDERS

Kidney

Inflammatory

Renal Abscess

Presenting Signs and Symptoms

- Fever, leukocytosis, and flank pain
- Frequently, a history of prior antibiotic therapy with relapse on cessation

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred study for demonstrating the thick-walled, low-attenuation mass within the kidney that may extend to the perirenal space (usually thickening of Gerota's fascia and strands of increased density in the adjacent fat)
   - Gas within the mass is virtually pathognomonic of renal abscess

     Caveat: There is no indication for excretory urography in the patient with a suspected renal abscess.
2. **Ultrasound**
   - Alternative method for demonstrating a renal or perinephric abscess, but less sensitive than CT
3. **Interventional radiology**
   - Percutaneous drainage using CT or US guidance is the preferred method of therapy because it provides satisfactory clinical results using local anesthesia and precludes the need for open surgical drainage.

Perinephric (Perirenal) Abscess

Presenting Signs and Symptoms

- Fever, leukocytosis and flank pain (at least a 2-week history of symptoms of urinary tract infection)
- Frequently a history of prior antibiotic therapy with relapse on cessation
- Referred pain to the thorax, groin, thigh, or hip (indicating that the disease has spread beyond the confines of the kidney)

Common Causes

PRIMARY

- Forms when an intrarenal abscess breaks through the renal capsule into the perirenal space

SECONDARY

- Hematogenous spread to the perirenal space from a distant focus or direct extension from an infection in an adjacent organ (e.g., ruptured appendix or diverticulitis)

Predisposing Factors

- Staghorn calculus

- Diabetes mellitus
- Pyonephrosis
- Neurogenic bladder
- Immunocompromised patient

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred study for demonstrating the low-attenuation mass (usually with an enhancing wall) as well as precisely defining the boundaries of the inflammatory process by detecting any extension into the psoas muscle and true pelvis
   - Gas within the mass is virtually pathognomonic of renal abscess

     Caveat: There is no indication for excretory urography in patients with a suspected perinephric abscess.
2. **Interventional radiology**
   - Percutaneous drainage using CT or US guidance is the preferred method of therapy because it provides satisfactory clinical results using local anesthesia, and precludes the need for open surgical drainage.

Pyelonephritis (Acute)

Presenting Signs and Symptoms

- Rapid onset of fever and chills, flank pain, nausea and vomiting
- Pyuria with white blood cell casts

Common Causes

- Ascending urinary tract infection (especially *Escherichia coli*)
- Obstruction is a predisposing factor (strictures, calculi, neurogenic bladder, vesicoureteral reflux)

Approach to Diagnostic Imaging

Caveat: Uncomplicated infection requires no imaging; imaging studies are indicated *only* in patients who fail to respond to treatment or who are severely ill.

1. **Computed tomography**
   - May demonstrate a complicating renal or perirenal abscess as a thick-walled fluid collection within the kidney that may extend to the perirenal space

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Notes: The “pre-abscess” state of focal bacterial infection appears as a focal wedge-shaped or rounded area of decreased density.

Uncomplicated disease appears as swollen, edematous kidneys, usually with patchy areas of decreased density or a striated parenchymal nephrogram.

2. **Ultrasound**
   - Also can demonstrate renal or perirenal abscess (but less sensitive than CT for detecting subtle changes in the renal parenchyma associated with uncomplicated pyelonephritis)
   - Can efficiently diagnose hydronephrosis if it is unclear whether urinary tract obstruction is a predisposing factor to the development of infection

     Caveat: Excretory urography is not indicated to confirm the diagnosis of acute pyelonephritis or to detect complications of the disease.

Pyelonephritis (Chronic)

Presenting Signs and Symptoms

- Progressive renal failure
- History of recurrent urinary tract infections (infrequently obtained except in children with vesicoureteral reflux)
- Pyuria with white blood cell casts

Common Causes

- Recurrent urinary tract infections (especially when associated with obstructive uropathy)
- Vesicoureteral reflux in children

Approach to Diagnostic Imaging

1. **Excretory urography**

- Demonstrates characteristic focal cortical scar overlying a blunted calyx

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Note: Although chronic pyelonephritis is typically lobar, with normal lobes interposed between diseased ones, there may be generalized calyceal dilatation with an irregular renal margin.

2. **Ultrasound**
   - Alternative approach that shows focal loss of renal parenchyma, increased echogenicity in the area of the scar, and extension of the central renal sinus echoes to the periphery of the kidney in the area of abnormality

Pyonephrosis

Presenting Sign and Symptom

- Signs of infection in an obstructed kidney

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred initial imaging modality for demonstrating the pathognomonic appearance of a dilated collecting system with layering of echogenic pus and debris
2. **Computed tomography**
   - May be superior to US in determining the precise site and cause of an obstruction and in defining an extrarenal abscess or fluid collection

     Caveat: Excretory urography is not indicated because the affected kidney functions poorly or not at all.
3. **Interventional procedure**
   - Placement of a ureteral stent or percutaneous nephrostomy catheter to relieve the obstruction (combined with antibiotic therapy) should be performed *promptly* to prevent rapid destruction of the renal parenchyma that can result if the condition is not properly treated

Urinary Tract Infection (Infant)

Major Predisposing Factors

- Obstruction of urinary tract (structural or functional)
- Vesicoureteral reflux

Approach to Diagnostic Imaging

1. **Radionuclide or voiding cystography**
   - Demonstrates the presence and degree of any observed vesicoureteral reflux

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Note: Radionuclide cystography is the most sensitive imaging technique for showing vesicoureteral reflux and delivers a substantially lower radiation dose to the gonads. It is especially valuable when multiple follow-up studies are needed to evaluate progression of disease and response to therapy.

2. **Ultrasound**
   - Preferred imaging study for detecting underlying anatomic abnormalities and significant renal scarring (simple, noninvasive, no ionizing radiation)

Note: A complete investigation of the urinary tract is important after an episode of urinary tract infection in an infant because of the relatively high probability of an underlying anatomic abnormality.

3. **Excretory urography**
   - Indicated if there is an abnormality shown by cystography or US to provide superior anatomic and functional information about the upper urinary tract

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Note: Disadvantages in children include ionizing radiation and the need for injection of contrast material; even with good renal function, superimposition of intestinal gas and fecal material may make it difficult to evaluate the kidneys and detect focal renal scarring.

Urinary Tract Infection (Female Child)

Approach to Diagnostic Imaging

Caveat: There is controversy as to whether female children (who constitute the overwhelming majority

of those affected) should be subjected to radiographic imaging after an initial urinary tract infection (because at least 75% have no abnormality and the risk of developing reflux nephropathy in girls with normal urinary tracts at the time of their first urinary tract infection is very small). But it is generally agreed that a workup of the urinary tract is indicated for repeat or relapsing infections.

1. **Radionuclide or voiding cystography**
   - Demonstrates the presence and degree of any observed vesicoureteral reflux

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Note: Radionuclide cystography is the most sensitive imaging technique for showing vesicoureteral reflux and delivers a substantially lower radiation dose to the gonads. It is especially valuable when multiple follow-up studies are needed to evaluate progression of disease and response to therapy.

2. **Ultrasound**
   - Preferred imaging study for detecting underlying anatomic abnormalities and significant renal scarring (simple, noninvasive, no ionizing radiation)
3. **Excretory urography**
   - Indicated to provide superior anatomic and functional information about the upper urinary tract if there is an abnormality shown by cystography or US

Note: Disadvantages in children include ionizing radiation and the need for injection of contrast material; even with good renal function, superimposition of intestinal gas and fecal material may make it difficult to evaluate the kidneys and detect focal renal scarring.

Urinary Tract Infection (Male Child)

Major Predisposing Factors

- Obstruction of urinary tract (structural or functional)
- Vesicoureteral reflux

Approach to Diagnostic Imaging

1. **Radionuclide or voiding cystography**
   - Demonstrates the presence and degree of any observed vesicoureteral reflux

---

Note: Radionuclide cystography is the most sensitive imaging technique for showing vesicoureteral reflux and delivers a substantially lower radiation dose to the gonads. It is especially valuable when multiple follow-up studies are needed to evaluate progression of disease and response to therapy.

2. **Ultrasound**
   - Preferred imaging study for detecting underlying anatomic abnormalities/significant renal scarring (simple, noninvasive, no ionizing radiation)
3. **Excretory urography**
   - Indicated to provide superior anatomic and functional information about the upper urinary tract if there is an abnormality shown by cystography or US

Note: Disadvantages in children include ionizing radiation and the need for injection of contrast material; even with good renal function, superimposition of intestinal gas and fecal material may make it difficult to evaluate the kidneys and detect focal renal scarring.

Urinary Tract Infection (Older Child/Teenager)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - A normal study indicates that there is no reflux nephropathy and that the child (by this age) is at little risk of developing intrinsic renal disease in the future

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Note: This is the only study needed if the child has only lower urinary tract signs and symptoms.

Caveat: There is *no* indication for excretory urography in older children or teenagers with an uncomplicated upper urinary tract infection.

Upper Urinary Tract Infection (Adult)

Presenting Signs and Symptoms

- Fever
- Flank pain
- Pyuria

Indications for Imaging

- Infection requiring hospitalization
- Impaired renal function
- Relapsing infection
- Infection in a male

> **Caveat: Uncomplicated infection in a woman requires no imaging (and often shows no abnormalities).**

Approach to Diagnostic Imaging

1. **Excretory urography**
   - Provides information on structure and function of urinary tract
   - Normal examination in a patient with acute urinary tract infection excludes pyonephrosis and other severe renal infections (although it does not eliminate the possibility of vesicoureteral reflux or a perinephric inflammatory process)
2. **Ultrasound**
   - Preferred imaging modality for evaluating the critically ill patient with suspected upper urinary tract infection
   - Preferred imaging modality for evaluating patients with impaired renal function
   - May demonstrate even minimal dilatation of the intrarenal collecting system, renal stones, and intrarenal masses
   - Excellent method for delineating and guiding drainage of a perinephric abscess
3. **Computed tomography**
   - Indicated if US or excretory urography is normal yet there is strong clinical suspicion of an infectious process involving the kidney or the perinephric space
   - Excellent method for delineating and guiding drainage of a perinephric abscess

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Mass

Renal Mass

Presenting Signs and Symptoms

- Flank pain
- Hematuria
- Palpable mass
- Fever (suggests renal abscess)
- Often discovered incidentally in an asymptomatic patient by excretory urography, US, or CT performed for unrelated abdominal pathology

Common Causes

- Cyst
- Neoplasm (benign or malignant)
- Abscess

Major Imaging Goal

- To separate benign renal cysts (the large majority of renal masses) from solid or cystic neoplasms

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> **Note:** The unequivocal imaging diagnosis of a benign cyst usually precludes the need for surgical confirmation.

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Highly accurate for demonstrating the characteristic findings of a simple cyst:
     - Absence of internal echoes
     - Strong, sharply defined distal wall with smooth, distinct margins
     - Enhanced through-transmission of the sound beam
     - Posterior acoustic enhancement
     - Spherical or slightly ovoid shape

Caveats: (1) Hemorrhagic or infected cysts may be indistinguishable sonographically from solid benign and malignant neoplasms and inflammatory masses; (2) US may be inadequate in obese patients.

2. **Computed tomography**
   - More sensitive than US for detecting renal masses
   - Highly accurate for demonstrating the characteristic findings of a simple cyst as a nonenhancing mass of water attenuation with clearly defined margins, compared with an enhancing mass that is typical of a solid neoplasm

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Note: Although generally considered the "gold standard" for evaluating renal mass lesions, CT is more expensive than screening US and requires intravenous contrast material. Therefore, in many centers, CT is indicated only when the US examination is indeterminate or technically inadequate due to obesity or overlying gas. Because CT is more sensitive than US for detecting a renal mass, it may be used in patients with a negative US examination for whom there is a strong clinical suspicion of a renal mass. It also is appropriate to proceed directly to CT if excretory urography indicates that the renal mass is complex or likely to be solid.

Caveat: Although renal masses are often first identified on a screening excretory urogram, this technique has a substantially lower sensitivity and specificity than US or CT for making the critical differentiation between a simple cyst and a solid, possibly malignant mass.

Renal Cyst

Presenting Signs and Symptoms

- Asymptomatic (discovered incidentally during US or CT performed for unrelated abdominal pathology)
- Occasionally, a palpable mass, flank discomfort or pain, or hematuria

Common Causes

- Unknown

Approach to Diagnostic Imaging

Note: The imaging goal is to separate benign renal cysts (the large majority of renal masses) from malignant neoplasms, because the unequivocal imaging diagnosis of a benign cyst usually precludes the need for surgical confirmation.

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Highly accurate for demonstrating the characteristic findings of a simple cyst:
     - Absence of internal echoes
     - Strong, sharply defined distal wall with smooth, distinct margins
     - Enhanced through-transmission of the sound beam
     - Posterior acoustic enhancement
     - Spherical or slightly ovoid shape

Caveat: Hemorrhagic or infected cysts may be indistinguishable sonographically from solid benign and malignant neoplasms and inflammatory masses.

2. **Computed tomography**
   - Indicated if the US appearance is atypical for a simple cyst (thick wall, calcification, internal debris)
   - Demonstrates a hemorrhagic cyst as a homogeneous mass that appears hyperdense to normal renal parenchyma on unenhanced scans and hypodense on contrast studies
   - Gas within a thick-walled mass strongly suggests an infected cyst

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Note: CT is indicated as the next imaging procedure if excretory urography detects a renal mass that most likely is complex or likely to be solid (rather than cystic).

Cancer of the Kidney

Presenting Signs and Symptoms

- Hematuria
- Flank pain
- Palpable mass
- Fever of unknown origin
- Increasingly being detected incidentally in asymptomatic patients during US or CT performed for unrelated abdominal pathology

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Contrast-enhanced CT is more sensitive than US for detecting renal masses
   - When combined with an unenhanced examination, CT can distinguish hemorrhagic cysts from solid tumors
2. **Ultrasound**
   - Can demonstrate a tumor as a solid, heterogeneous, hypoechoic or mildly hyperechoic mass that may contain cystic areas representing hemorrhage or necrosis
3. **Magnetic resonance imaging**
   - As sensitive as CT for detecting renal masses
   - Useful for patients with a contraindication to iodinated intravascular contrast material

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Note: Excretory urography is relatively insensitive for detecting renal masses and is not recommended as a screening procedure.

Staging

1. **Computed tomography or magnetic resonance imaging**
   - Most effective staging procedures for demonstrating the presence and extent of extrarenal spread of tumor (including invasion of the renal vein and inferior vena cava, which is still a surgically curable stage of disease if there are no distant metastases)

Note: Doppler US also can detect echogenic tumor thrombus within venous structures.

   - MRI may prove to be accurate in determining whether the small opacities seen in the perinephric space on CT in many patients represent patent vessels or lymphadenopathy
   - Chest CT should be performed for detection of pulmonary metastases prior to any potentially curative surgical procedure
2. **Radionuclide bone scan**
   - Should be performed to detect any skeletal metastases prior to any potentially curative surgical procedure
3. **Arteriography**
   - Presurgical embolization of a tumor may dramatically reduce its vascularity, making resection easier by diminishing blood loss

Medullary Cystic Disease

Presenting Signs and Symptoms

- Polyuria (with urinary sodium wasting)
- Unexplained uremia
- Retarded growth and evidence of bone disease
- Symptoms usually begin before age 20

Common Causes

- Genetic or congenital

Approach to Diagnostic Imaging

1. **Ultrasound**
   - May demonstrate the multiple medullary cysts within small, smooth kidneys or merely generalized increased echogenicity of the renal parenchyma (representing diffuse atrophy)

Note: Because the cysts may be few and small, they often cannot be detected by US.

Caveat: There is *no longer any* indication for excretory urography.

Multicystic Dysplastic Kidney

Presenting Signs and Symptoms

- Palpable abdominal mass in a neonate (asymptomatic)
- Usually unilateral (can be bilateral or segmental)

Common Causes

- Congenital developmental defect (resulting from occlusion of the fetal ureter, usually before 8 to 10 weeks of gestation)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Demonstrates numerous cysts of various sizes with variable amounts of intervening dysplastic renal tissue

Polycystic Kidney Disease (Adult)

Presenting Signs and Symptoms

- Initially asymptomatic (may be discovered incidentally on abdominal US or CT performed for another reason)
- Onset in early or middle life with symptoms related to the effects of the cysts (lumbar discomfort or pain, hematuria, infection, or colic due to nephrolithiasis)
- Hypertension (50% at time of diagnosis)
- Progressive renal dysfunction with uremic symptoms
- Cysts may also be present in the liver (in 50%)
- Aneurysms of the circle of Willis (in 15%) that may rupture to produce subarachnoid hemorrhage

Common Cause

- Autosomal dominant

Approach to Diagnostic Imaging

1. **Ultrasound or computed tomography**
   - Demonstrates progressive replacement of the renal parenchyma by multiple noncommunicating cysts of various sizes that commonly contain internal hemorrhage
   - Can detect associated cysts in the liver

> **Caveat: Although excretory urography has traditionally been used to show the large, irregular kidneys with compressed and elongated "spidery" renal pelvis and calyces, US and CT can make the correct diagnosis at a much earlier stage.**

Polycystic Kidney Disease (Childhood)

Presenting Signs and Symptoms

- In *neonates,* there is renal dysfunction with pulmonary hypoplasia (often a protuberant abdomen with huge kidneys and an enlarged liver)
- In *children,* signs and symptoms of portal hypertension (due to progressive hepatic fibrosis) become more prominent and renal insufficiency is only mild or moderate

Common Cause

- Autosomal recessive

Approach to Diagnostic Imaging

1. **Ultrasound**
   - *Prenatal* studies in late pregnancy usually can permit a presumptive diagnosis
   - In young children, ultrasound shows characteristic bilaterally enlarged, echogenic kidneys with dilated renal tubules arranged in a radiating pattern (may be so dilated as to appear as individual structures)
   - In older children and adolescents, ultrasound can show cysts in the kidneys and liver, as well as secondary signs, associated with hepatic fibrosis and portal hypertension

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Note: A final diagnosis may require renal and liver biopsies.

> **Caveat: There is no longer any indication for excretory urography.**

Vascular

Atheroembolic Renal Disease

Presenting Signs and Symptoms

- Sudden or gradual development of progressive renal failure (depending on amount of atheromatous material obstructing the renal arteries)
- May show evidence of embolic disease elsewhere (cholesterol emboli visible on fundoscopic examination, neurologic deficits, toe gangrene, livedo reticularis)
- Usually hypertension

Common Causes

- Spontaneous embolization of atheromatous plaques
- Embolization subsequent to vascular surgery, angioplasty, or arteriography

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Demonstrates a resulting renal infarction as a wedge-shaped area of low attenuation within an otherwise normal kidney

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> **Note:** Typically, the outer 2 to 4 mm of cortex are preserved, even if the entire renal artery is occluded, because capsular branches remain patent and enhance the outer rim of the kidney.

2. **Arteriography**
   - Defines vascular occlusion
   - Thrombolytic therapy is less likely to be successful with embolic disease than with acute thrombosis

Nephrosclerosis (Malignant)

Presenting Signs and Symptoms

- Severe hypertension and rapidly progressive renal failure

Common Causes

- Accelerated cardiovascular disease in the course of primary hypertension (especially untreated)
- May arise from secondary hypertension (due to acute glomerulonephritis, chronic renal failure, renovascular hypertension, vasculitis)

Approach to Diagnostic Imaging

Caveat: Imaging is seldom of value.

1. **Arteriography**
   - Demonstrates increased tortuosity and more rapid tapering of intrarenal arteries
   - May show filling defects and loss of cortical vessels

Renal Cortical Necrosis

Presenting Signs and Symptoms

- Abrupt anuria with gross hematuria and flank pain

Common Causes

NEONATES

- Abruptio placentae
- Bacterial sepsis

CHILDREN

- Infections
- Extracellular volume depletion
- Shock
- Hemolytic-uremic syndrome

ADULTS

- Accidents of pregnancy (abruptio placentae, placenta previa, uterine hemorrhage, puerperal sepsis, amniotic fluid embolism, intrauterine death, preeclampsia)
- Bacterial sepsis
- Hemolytic-uremic syndrome
- Hyperacute transplant rejection
- Burns
- Pancreatitis
- Poisoning (phosphorus, arsenic)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Initially shows enlarged kidneys (renal size progressively diminishes and may be reduced to about 50% of normal by 6 to 8 weeks)
2. **Plain abdominal radiograph**
   - Demonstrates characteristic late (6 to 8 weeks) sign of calcification that is often linear and is most marked at the corticomedullary junction

Renal Infarction

Presenting Signs and Symptoms

- Steady aching flank pain localized to the affected renal area
- May be asymptomatic (if a small branch of the renal artery is occluded)
- Usually, fever, nausea and vomiting, leukocytosis, proteinuria, and microscopic hematuria

Common Causes

- Renal artery occlusion (embolic, thrombotic, arteritis, sickle cell disease)
- Iatrogenic (after surgery, angioplasty, selective arteriography)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Demonstrates an infarction as a wedge-shaped area of low attenuation within an otherwise normal kidney

---

Note: Typically, the outer 2 to 4 mm of cortex are preserved, even if the entire renal artery is occluded, because capsular branches remain patent and enhance the outer rim of the kidney.

2. **Arteriography**
   - Defines vascular occlusion and often allows a diagnosis of vasculitis or emboli
   - May be useful for thrombolytic therapy if the infarction is due to acute thrombosis

> **Caveat: There is no indication for excretory urography because there is no renal function in the face of occlusion of the main renal artery.**

Renal Vein Thrombosis

Presenting Signs and Symptoms

ACUTE (ANY AGE)

- Flank pain
- Fever
- Hematuria, oliguria
- Edema
- Leukocytosis
- Renal failure

SLOWLY PROGRESSIVE (ADULTS)

- Gradual onset of proteinuria
- Deteriorating glomerular filtration rate
- Nephrotic syndrome

Common Causes

CHILDREN

- Diarrhea, dehydration
- Hypercoagulability

ADULTS

- Membranous glomerulonephritis
- Pregnancy
- Oral contraceptive use
- Trauma
- Extrinsic compression (lymph nodes, aortic aneurysm, tumor)
- Invasion by renal cell carcinoma

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Demonstrates an enlarged kidney in acute disease and an atrophic kidney in slowly progressive disease

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Note: If venous collateral vessels provide adequate drainage, the kidney may be unaffected.

   - Doppler studies may permit the direct detection of clot within the renal veins
2. **Computed tomography**
   - Absence of opacification of the renal vein on contrast-enhanced study
3. **Magnetic resonance imaging**
   - Detection of an abnormally strong signal from the renal veins (normally a dark flow void), suggesting stasis of flow
   - Slow-flowing laminar blood (paradoxical brightness) may outline a lower-signal clot within it
4. **Venography**
   - May demonstrate thrombus within the renal vein, or absence of venous opacification implying obstruction

Renovascular Hypertension

Clinical Indications Suggestive of a Renovascular Cause

- Onset of hypertension in a previously normotensive person older than age 50
- Onset of hypertension in a person younger than age 30
- Women between ages 30 and 50 who have no family history of hypertension (fibromuscular hyperplasia)
- Rapid acceleration or severe hypertension
- Presence of an abdominal or flank bruit
- Deteriorating renal function
- Poor control of blood pressure with medical therapy
- Severe hypertensive retinopathy

Common Causes

- Renal artery stenosis
- Fibromuscular dysplasia
- Takayasu's aortitis

Approach to Diagnostic Imaging

Note: Many radiographic screening tests have been used in patients with suspected renovascular hypertension; there is no consensus as to which is best. Choice may reflect local institutional bias, available equipment, physician interest or expertise, and characteristics of the patient population.

1. **Radionuclide renogram with captopril**
   - Noninvasive screening test
2. **Doppler ultrasound**
   - Limited by operator dependence
3. **Arteriography**
   - “Gold standard” for detecting renal artery stenosis (the presence of renal artery stenosis in a hypertensive patient does not necessarily mean that the patient has renovascular hypertension)

Note: Arteriography is infrequently used as a screening procedure because of its highly invasive nature.

4. **Computed tomography angiography**
   - Noninvasive technique that can detect renal artery stenosis, including fibromuscular dysplasia
5. **Magnetic resonance angiography**
   - Noninvasive technique that can detect renal artery stenosis
   - Resolution insufficient to detect rare segmental stenoses in renal artery branch vessels
   - Does not require iodinated intravascular contrast material and is safer for use in azotemic patients
6. **Interventional radiology**
   - Percutaneous renal angioplasty has become a widespread technique for the nonsurgical therapy of renal artery stenosis. The overall technical success rate is reported to be 80-95%, with 10-20% of stenoses recurring (most often when there has been incomplete dilatation of the lesion). Major complications occur in about 5% of patients.

Trauma

Bladder Trauma

Presenting Signs and Symptoms

- Gross hematuria
- Lower abdominal or suprapubic pain
- Hypotension
- Pelvic fracture

Approach to Diagnostic Imaging

1. **Cystography**
   - Sensitive imaging procedure for detecting extravasation of contrast material indicating intraperitoneal or extraperitoneal (more common) rupture

     Caveat: The urethra should never be catheterized if a urethral injury is suspected. Under such circumstances, the proper approach is to perform retrograde urethrography. Only if the urethra is shown to be normal should a catheter be passed into the bladder.
2. **Computed tomography**
   - In addition to demonstrating extravasation of contrast material, CT can precisely define the site and extent of extraperitoneal perivesical hematoma

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Note: CT of the abdomen and pelvis is usually performed to evaluate injury to other organs after major abdominal trauma.

Caveat: Bladder rupture may be missed on CT (or cystography) if the bladder is decompressed by a catheter or if it is incompletely filled. With current-generation CT scanners, the entire abdomen and pelvis may be imaged before contrast material reaches the bladder. Therefore, filling the bladder with dilute contrast through a Foley catheter or taking delayed images may be required to evaluate the bladder.

3. **Arteriography**
   - Indicated in the patient with a significant pelvic hematoma who has a decreasing hematocrit and no other apparent source of blood loss
   - Therapeutic embolization of a bleeding vessel may preclude the need for surgery

Renal Trauma (Blunt)

Presenting Signs and Symptoms

- Hematuria
- Flank pain and tenderness
- Hypotension or shock
- Associated injuries (skeletal fracture, signs of injury to the spleen, liver, or gastrointestinal tract)

Approach to Diagnostic Imaging

GENERAL APPROACH

1. *Unstable* patients should have immediate surgical exploration without waiting for imaging studies
2. In stable patients with *microscopic* hematuria and no suspected associated injuries or fractures, radiographic contrast studies have a very *low* likelihood of detecting significant renal injury
3. In stable patients with *gross* hematuria or microscopic hematuria and shock, the yield of radiographic contrast studies is sufficiently *high* to influence further therapy

1. **Computed tomography**
   - Most versatile imaging technique that, in addition to demonstrating morphologic and functional abnormalities of the kidneys, can show intraperitoneal and extraperitoneal hemorrhage, free intraperitoneal gas, and injuries to the liver, spleen, pancreas, and gastrointestinal tract

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Note: Unsuspected injuries to other organs are common and are more likely to be revealed by CT than any other imaging modality.

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2. **Excretory urography**
   - Simple, quick, and readily available study that can be used to promptly determine whether both kidneys are present and functioning in a patient with a negative diagnostic peritoneal lavage and little likelihood of injury to other organs
3. **Arteriography**
   - Seldom needed as a diagnostic test, since the integrity of the renal artery can be predicted on the basis of the CT examination
   - May be indicated as a prelude to surgery in a patient with a nonfunctioning kidney presumed to be due to

vascular occlusion

Caveat: In 90% of patients with complete arterial occlusion, renal function is irreversibly lost after 2 hours of ischemia. Therefore, the need for immediate surgery must be balanced against the time required to complete an arteriographic examination.

- Embolization of a bleeding vessel may permit stabilization of the patient and preclude the need for surgery

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Note: In patients in whom iodinated contrast material is contraindicated, US may be performed to evaluate renal morphology, and radionuclide scanning may be employed to assess renal perfusion and function.

Renal Trauma (Penetrating)

Presenting Signs and Symptoms

- Hematuria
- Flank pain and tenderness
- Hypotension or shock

Approach to Diagnostic Imaging

Caveat: In up to 6% of patients, significant occult injuries to the kidney are not suggested on clinical inspection of the wound. The absence of hematuria does not exclude renal injury. Studies have shown that (1) 30% of patients with penetrating flank and back trauma without hematuria had renal pedicle injuries; and (2) 15-42% of patients with flank or back trauma manifest only microscopic hematuria.

1. **Computed tomography**
   - Contrast-enhanced scans are the imaging procedure of choice for demonstrating renal laceration and extravasation of contrast material from the pelvicalyceal system
2. **Arteriography**
   - Needed to demonstrate a bleeding vessel
   - Therapeutic embolization of an actively bleeding vessel may preclude the need for surgery

Urethral Trauma

Presenting Signs and Symptoms

- Inability to urinate
- Blood at the urethral meatus
- Elevation of the prostate on digital rectal examination
- Perineal swelling or hematoma
- Pelvic fracture

Approach to Diagnostic Imaging

1. **Retrograde urethrography**
   - Imaging procedure of choice for demonstrating extravasation of contrast material through a partial or complete urethral tear

Caveat: If urethral injury is suspected, a retrograde urethrogram should always be obtained prior to transurethral bladder catheterization. If the bladder of a patient with a urethral injury is full, suprapubic catheterization may be performed.

Other

Glomerulonephritis (Acute)

Presenting Signs and Symptoms

- Sudden onset of hematuria (dark urine with red cell casts), oliguria
- Edema
- Hypertension
- Elevated blood urea nitrogen and creatinine

Common Causes

- Prior beta-hemolytic streptococcal infection
- Other prior infection (bacterial, viral, parasitic)
- Multisystem disease (systemic lupus erythematosus, vasculitis, Henoch-Schönlein purpura, Goodpasture's syndrome)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - May aid in distinguishing acute disease (usually normal or slightly enlarged kidneys) from an exacerbation of chronic disease (small kidneys)

Glomerulonephritis (Chronic)

Presenting Signs and Symptoms

- Insidious onset of slowly progressive impairment of renal failure associated with peripheral edema
- May be discovered incidentally on urinalysis in an asymptomatic patient (proteinuria, possibly hematuria)

Common Cause

- Most frequently, develops weeks or months after an episode of acute glomerulonephritis

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Demonstrates the nonspecific pattern of bilateral small kidneys (as with other causes of chronic renal failure)

Note: US can exclude obstructive hydronephrosis as the underlying cause of progressive renal failure.

Hydronephrosis

Presenting Signs and Symptoms

ACUTE

- Colicky pain

CHRONIC

- Asymptomatic
- Recurrent attacks of dull flank pain (resulting stasis may lead to formation of calculi and secondary infection)

Common Causes

NONOBSTRUCTIVE

- Vesicoureteral reflux
- Primary megacalyces

OBSTRUCTIVE

- Obstruction at the ureteropelvic junction (fibrous band, aberrant vessel, ureteral kinking, renal pelvis stone or tumor)
- Distal obstruction (stone, tumor, benign prostatic hyperplasia, ureteral stricture, retroperitoneal fibrosis, bladder outlet obstruction); in pregnancy, transient involvement of right ureter

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred initial imaging modality for detecting urinary tract dilatation
   - Dilatation of the renal pelvis appears as separation of the normal sinus echogenicity by anechoic urine in the collecting system
2. **Excretory urography**
   - Early signs of obstruction include:
     - Prolonged and increasingly dense nephrogram
     - Delay in appearance of contrast in the collecting system
     - Dilated pelvicalyceal system and ureter down to the point of obstruction
3. **Computed tomography**
   - Frequently permits identification of the cause of the obstruction, in addition to demonstrating dilatation of the ureter and collecting system

Medullary Sponge Kidney

Presenting Signs and Symptoms

- Usually asymptomatic
- Nephrocalcinosis may lead to symptomatic complications such as colic, hematuria, and infection (from urinary stasis)

Common Cause

- Congenital dysplastic dilatation of the collecting tubules

Approach to Diagnostic Imaging

1. **Excretory urography**
   - Shows characteristic striations or saccular papillary collections of contrast material (most commonly bilateral and symmetric)
   - Preliminary (scout) radiographs may show calcifications in the dilated tubules in the medullary pyramids

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Note: US is seldom useful because the cysts are small and located deep in the medulla; it may show papillary stones as echogenic foci.

Nephrocalcinosis

Presenting Signs and Symptoms

- Asymptomatic (unless complicated by hematuria, obstruction, or infection)

Common Causes

- Pathologic deposition of calcium may occur in Medulla
  - Hyperparathyroidism
  - Medullary sponge kidney
  - Renal tubular acidosis
  - Milk-alkali syndrome
  - Hypervitaminosis D
  - Hypercalcemic/hypercalciuric states
- Pyramids
  - Hyperuricemia
  - Infection (tuberculosis)
  - Sickle cell disease
- Cortex
  - Acute cortical necrosis
  - Chronic glomerulonephritis

Approach to Diagnostic Imaging

1. **Plain abdominal radiograph, ultrasound, or computed tomography**
   - Plain abdominal radiographs are the least expensive and most readily available, but US and especially CT are more sensitive for detecting subtle calcification in the renal parenchyma
   - Calculi appear opaque on plain radiographs, as echogenic lesions with acoustic shadowing on US, and as high-attenuation lesions on CT

Nephrolithiasis (Urinary Calculi)

Presenting Signs and Symptoms

- Asymptomatic (if not causing obstruction or passing down the ureter)
- Renal colic (excruciating intermittent pain, usually originating in the flank or kidney area and radiating to the groin)
- Hematuria
- Chills and fever
- Nausea, vomiting, and abdominal distension (clinical picture of adynamic ileus)

Common Types

- Calcium oxalate or calcium phosphate (80%)
- Struvite (magnesium ammonium phosphate) (13%)
- Uric acid (5%)
- Cystine (2%)

Approach to Diagnostic Imaging

1. **Computed tomography (unenhanced)**
   - Most sensitive method for detecting urinary tract calculi (even “radiolucent” stones are readily visible on CT)
   - Can detect dilatation of the collecting system or ureter proximal to an obstructing stone
   - Can detect rupture of the collecting system

- Can detect extraurinary causes of abdominal pain
- No risk of reaction to iodinated contrast material

2. **Excretory urography**
   - Initial plain film of the abdomen can demonstrate the majority of urinary calculi (about 80% contain enough calcium to be radiopaque)
   - Contrast study can demonstrate lucent stones and define the precise site of obstruction and the degree of proximal ureteral dilatation

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Note: Ureteral obstruction from calculi is most likely to occur at the ureteropelvic junction or the uretero-vesical junction (the narrowest points in the collecting system).

3. **Ultrasound**
   - Demonstrates both opaque and lucent stones as echodensities with acoustic shadowing
   - Shows the degree of ureteral dilatation proximal to an obstruction

Caveat: US may fail to detect small stones in the renal pelvis that do not cast acoustic shadows and thus blend in with renal sinus fat.

Retroperitoneal Hemorrhage

Presenting Signs and Symptoms

- Abdominal or back pain, often with symptoms of hypotension

Common Causes

- Rupture of abdominal aortic aneurysm
- Trauma
- Coagulopathy (anticoagulant medication or intrinsic blood dyscrasia)
- Hemorrhage into renal or retroperitoneal neoplasm
- Pancreatitis
- Iatrogenic (following groin puncture for arteriography or cardiac catheterization, a hematoma can spread from the pelvis into any of the retroperitoneal compartments)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Procedure of choice for demonstrating a ruptured aortic aneurysm, as well as for identifying most other morphologic causes of retroperitoneal hemorrhage
   - Clearly shows the location, size, and extent of the hematoma
2. **Ultrasound**
   - Best technique for evaluating the groin after femoral vein puncture
   - Procedure of choice for detecting arteriovenous fistulas and pseudoaneurysms
   - Of limited use in the retroperitoneum in obese patients
   - May be difficult to differentiate a hematoma from other retroperitoneal masses (tumor, abscess)
3. **Arteriography**
   - Indicated if CT suggests a discrete source of bleeding that could be treated with embolization (pseudoaneurysm, hemorrhage arising from a neoplasm)
4. **Magnetic resonance angiography**
   - May be an alternative for imaging major vessels noninvasively

Caveat: Unstable patients with massive hemorrhage should have emergency surgery without any diagnostic imaging studies.

Tubulointerstitial Nephritis (Acute Tubular Necrosis)

Presenting Signs and Symptoms

- Reversible renal failure, with or without oliguria
- Symptoms vary with underlying cause (e.g., fever, rash, and arthralgia if cause is an allergic reaction to a drug)

Common Causes

- Drug-induced (amphotericin, aminoglycosides, penicillins, sulfonamides, diuretics, nonsteroidal antiinflammatory drugs, heavy metals, radiocontrast agents)
- Systemic infections
- Pyelonephritis
- Immune disorders (transfusion reactions, transplant rejection)
- Metabolic diseases (hypercalcemia, hypokalemia, hyperuricemia)
- Neoplasm (lymphoma, leukemia, multiple myeloma)
- Vascular (sickle cell disease, arteriolar nephrosclerosis, shock)
- Crush injuries with myoglobinuria

- Burns

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Demonstrates nonspecific pattern of bilateral large, smooth kidneys and excludes obstruction as a cause for oliguria or anuria

     Caveat: Although excretory urography can demonstrate the prolonged bilateral nephrogram characteristic of acute tubulointerstitial nephritis, it generally is not required, and the contrast material may aggravate the process.

Tubulointerstitial Nephritis (Chronic)

Presenting Signs and Symptoms

- Progressive insidious renal failure

Common Causes

- Drug-induced (analgesics, especially aspirin and phenacetin)
- Obstructive uropathy
- Chronic pyelonephritis
- Immune disorders (transplant rejection)
- Metabolic diseases (nephrocalcinosis/nephrolithiasis, oxalosis, cystinosis, gout, diabetes mellitus)
- Inherited multisystem disorders (polycystic disease, multicystic kidney disease, medullary sponge kidney, sickle cell disease, hereditary nephritis)
- Malignancy (multiple myeloma)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Demonstrates nonspecific pattern of bilateral small, smooth kidneys

Urinary Incontinence

Presenting Signs and Symptoms

- Ranges from inability to control urine flow at all times to persistent dribbling to leakage of urine only during times of stress

Common Causes

WOMEN

- Pelvic relaxation (childbearing)
- Urethral diverticulum
- Urethritis/cystitis

MEN

- Following prostatectomy or repair of urethral stricture

BOTH

- Neurogenic bladder
- Medications (e.g., antipsychotics, diuretics)

Approach to Diagnostic Imaging

1. **Voiding cystourethrography**
   - Confirms the presence of incontinence
   - Can be used to classify the type of incontinence and identify the phase during which it occurs (filling, straining, coughing)
   - Assesses the size, contour, capacity, and contractility of the bladder
2. **Ultrasound**
   - Not used as primary imaging technique because it cannot directly visualize urine loss or identify the phase during which incontinence occurs
   - Can detect urethral diverticula and determine bladder wall thickness
   - Better for evaluating dilatation of the more proximal urinary tract and possible renal parenchymal loss

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Note: Some urologists prefer performing urodynamic studies instead of or in addition to imaging procedures.

Bladder

Cancer of the Urinary Bladder

Presenting Signs and Symptoms

- Hematuria, pyuria, frequency, dysuria, and burning

Predisposing Factors

- Aniline dyes
- Rubber and plastics manufacturing chemicals
- Tobacco tars (excretory products)
- Schistosomiasis
- Bladder calculi (irritative effects)
- Bladder exstrophy

Approach to Diagnostic Imaging

1. **Excretory urography**
   - May detect tumors >1.5 cm as irregular filling defects, but is less sensitive than cystoscopy

Caveat: Cystoscopic biopsy is required for histologic confirmation of the diagnosis.

Staging

1. **Magnetic resonance imaging**
   - Superior to CT for predicting the depth of bladder wall invasion (high-signal tumor disruption of the normally low-signal bladder wall on T2-weighted images)
   - Equal to or better than CT for showing tumor extension into the perivesical fat (low-signal tumor versus high-signal fat on T1-weighted images)
2. **Computed tomography**
   - Alternative procedure for staging if MRI is not available (although not as good as MRI for differentiating superficial noninvasive tumors from those invading the bladder muscle)
   - Superior to US for defining the pelvic structures and delineating enlargement of paraaortic lymph nodes

Neurogenic Bladder

Presenting Signs and Symptoms

- Partial or complete urinary retention
- Incontinence
- Predisposition to infection and calculus formation

Common Causes

- Acute spinal cord trauma
- Meningomyelocele
- Diabetes mellitus
- Central nervous system neoplasm (brain or spinal cord)
- Cerebrovascular accident
- Herniated intervertebral disc
- Demyelinating process (multiple sclerosis, amyotrophic lateral sclerosis)
- Poliomyelitis
- Syphilis

Approach to Diagnostic Imaging

1. **Excretory urography**
   - Demonstrates marked thickening of the bladder wall, which has an irregular contour due to muscular trabeculation

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Note: Although US also can show this appearance, it does not give any indication of the degree of kidney function.

Bladder Outlet Obstruction

Presenting Signs and Symptoms

- Partial or complete urinary retention
- Progressive urinary frequency, urgency, and nocturia (due to incomplete emptying and rapid refilling of the bladder)
- Overflow incontinence
- Predisposition to infection and calculus formation

Common Causes

- Benign prostatic hyperplasia
- Prostatic cancer
- Bladder neck obstruction (anatomic versus functional)
- Acquired bladder neck stricture (traumatic, postsurgical)
- Neurogenic bladder

Approach to Diagnostic Imaging

1. **Excretory urography**
   - Preferred imaging technique for demonstrating the size of the bladder (markedly dilated or small and shrunken)

Note: Excretory urography can also provide valuable information concerning the functional status of the upper urinary tracts. Characteristic findings may suggest prostate enlargement or neurogenic bladder. It is insensitive for detecting bladder tumors.

Cystitis

Presenting Signs and Symptoms

- Dysuria, frequency, urgency
- Hematuria
- Suprapubic pain

Common Causes

- Infection (bacteria, tuberculosis, schistosomiasis)
- Drug-induced (cyclophosphamide)
- Radiation

Approach to Diagnostic Imaging

Notes: Radiographic assessment of women with lower urinary tract infection is usually of little value and rarely provides information that aids in clinical management.

Because cystitis in men is often associated with obstruction of the lower urinary tract, evaluation should be directed at detecting underlying prostatic or urethral pathology.

1. **Voiding cystography or excretory urography**
   - Demonstrates a diffuse scalloped, irregular contour of the bladder wall and a small capacity bladder
   - Gas may be detected within the bladder wall in patients with emphysematous cystitis

Urethritis (Gonococcal)

Presenting Signs and Symptoms

- Dysuria
- Thick, purulent urethral discharge
- Primarily affects men

Approach to Diagnostic Imaging

Caveat: Uncomplicated infections require no imaging (indicated only to detect complications of the disease).

1. **Retrograde urethrography**
   - Preferred technique for demonstrating the location, size, length, and number of urethral strictures, as well as periurethral communications (especially when surgery is contemplated)

Note: Retrograde urethrography is also valuable in postoperative assessment, especially in detecting residual or recurrent stenoses.

Adrenal

Addison's Disease

Presenting Signs and Symptoms

- Weakness, fatigue, orthostatic hypotension (early)
- Increased pigmentation
- Weight loss, dehydration, hypotension (late)
- Small heart size
- Anorexia, nausea and vomiting, diarrhea
- Decreased cold tolerance

Common Causes

- Autoimmune process (idiopathic atrophy)
- Granulomatous process (tuberculosis, histoplasmosis)
- Neoplasm (lymphoma, metastases)
- Infarction
- Hemorrhage

Approach to Diagnostic Imaging

> **Note:** Addison's disease is a clinical diagnosis based on classic signs and symptoms and confirmed by laboratory tests.

1. **Plain abdominal radiograph**
   - May demonstrate adrenal calcification suggesting prior tuberculosis or histoplasmosis
2. **Computed tomography**
   - May demonstrate enlargement of the adrenal glands secondary to lymphoma or metastases
   - Idiopathic atrophy results in very small adrenal glands

Adrenal Virilism (Adrenogenital Syndrome)

Presenting Signs and Symptoms

- Hirsutism
- Male-pattern baldness
- Acne
- Deepening of the voice
- Amenorrhea and uterine atrophy
- Decreased breast size
- Increased muscularity

Common Causes

- Adrenal hyperplasia (infants)
- Adrenal adenoma or carcinoma (adults)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Procedure of choice for demonstrating the underlying adrenal neoplasm or hyperplasia

Primary Aldosteronism (Conn's Syndrome)

Presenting Signs and Symptoms

- Hypertension
- Hypokalemia
- Increased serum and urine aldosterone (radioimmunoassay)
- Low plasma renin activity

Common Causes

- Hyperfunctioning adrenal adenoma (80%)
- Bilateral adrenal hyperplasia (20%)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Procedure of choice for detecting the adenoma, which is usually small (<2 cm)

Note: Intravenous contrast is *not* needed.

Cushing's Syndrome

Presenting Signs and Symptoms

- Truncal obesity with prominent supraclavicular and dorsal cervical fat pads (“buffalo hump”)
- Rounded (moon) facies
- Generalized weakness and muscle wasting
- Poor wound healing and easy bruising
- Hypertension
- Osteoporosis
- Glucose intolerance
- Reduced resistance to infection
- Menstrual irregularities

Common Causes

- Adrenal hyperplasia (70%)
  - Pituitary microadenoma (ACTH-secreting)
  - Nonpituitary ACTH-secreting tumor (usually from lung tumor)
- Adrenal adenoma (20%)
- Adrenal carcinoma (10%)

Approach to Diagnostic Imaging

1. **Computed tomography (abdomen)**
   - Preferred initial imaging procedure if biochemical tests suggest an adrenal tumor

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Note: Intravenous contrast is *not* needed.

2. **Magnetic resonance imaging (pituitary)**
   - Procedure of choice for detecting a functioning microadenoma causing adrenal hyperplasia
3. **Plain chest radiograph**
   - Preferred screening study for detecting an underlying ACTH-producing lung tumor

Adrenal Metastases

Presenting Signs and Symptoms

- Asymptomatic

Common Primary Tumors

- Carcinomas of lung, breast, and kidney
- Melanoma
- Lymphoma

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Procedure of choice for detecting these relatively common metastatic lesions, which are often large, irregular, and inhomogeneous and invade adjacent structures

     Caveat: Small metastases tend to be homogeneous, well defined, and indistinguishable from benign adenomas. In addition, even in patients with known primary malignancy, more than 50% of small adrenal masses are benign adrenal lesions and not metastases.
   - Low density of a small, homogeneous adrenal mass on unenhanced CT allows a confident diagnosis of an adenoma
   - Analysis of the density of an adrenal mass over time (CT washout curve) may allow a confident diagnosis of an adenoma on a contrast-enhanced study
   - Percutaneous biopsy may still be required for high-density adrenal masses
2. **Magnetic resonance imaging**
   - Metastases have a higher signal intensity than benign adenomas on T2-weighted sequences
   - Metastases show greater enhancement than benign adenomas after gadolinium injection
   - On chemical-shift MRI, lipid-laden adenomas have low signal intensity, while metastases have intermediate or high signal
   - Chemical-shift imaging is highly accurate for identifying adrenal adenomas without biopsy, although CT-guided

biopsy is still required to identify the infrequent adenoma that contains little or no lipid

Pheochromocytoma

Presenting Signs and Symptoms

- Hypertension (persistent or paroxysmal)
- Tachycardia, diaphoresis, postural hypotension, tachypnea, flushing, cold and clammy skin
- Severe headache and tremors
- Elevated levels of catecholamines and their metabolites

Common Causes

- Catecholamine-secreting tumor of chromaffin cells
  - Adrenal medulla (90%)
  - Extraadrenal sites (paraaortic sympathetic chain, organ of Zuckerkandl near the bifurcation of the aorta, urinary bladder)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred imaging study for detecting tumors (usually >2 cm) involving the adrenal medulla
   - If no adrenal mass is found and clinical suspicion remains high, scanning must be extended to include the remainder of the abdomen and pelvis (most extraadrenal pheochromocytomas lie in the lumbar sympathetic chain)

     Caveat: Intravenous contrast material is unnecessary and could precipitate a hypertensive crisis.
2. **Magnetic resonance imaging**
   - Procedure of choice (if metaiodobenzylguanidine [MIBG] scanning is not available) to search for extraadrenal pheochromocytomas not found on CT
   - The tumor demonstrates extremely bright signal on T2-weighted images, allowing it to stand out from surrounding structures

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Note: Radionuclide scans using MIBG are highly sensitive for localizing ectopic pheochromocytomas, but this agent is not widely available.

CHAPTER 5. SKELETAL

Donald Resnick

SIGNS AND SYMPTOMS

Acute Monarticular Joint Pain

Common Causes

- Gout
- Calcium pyrophosphate deposition disease (CPPD)
- Septic arthritis
- Bursitis/tendinitis
- Trauma
- Hemarthrosis (bleeding diathesis)
- Localized manifestation of inflammatory polyarthritis (Reiter's syndrome, psoriatic arthritis)

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Preferred study for demonstrating soft-tissue swelling and calcification, bone erosions, joint space narrowing, and any underlying fracture

Polyarticular Joint Pain

Common Causes

- Rheumatoid arthritis
- Ankylosing spondylitis
- Reiter's syndrome
- Psoriatic arthritis
- Osteoarthritis
- Systemic lupus erythematosus
- Hypertrophic osteoarthropathy
- Polymyalgia rheumatica
- Diffuse appearance of a usually monarticular condition (gout, CPPD, calcium hydroxyapatite deposition disease, bacterial arthritis)

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Preferred study for detecting soft-tissue swelling, calcification, bone erosions, joint space narrowing, and osteophyte formation

DISORDERS

Osteoporosis

Presenting Signs and Symptoms

- Often asymptomatic
- Dull aching pain in the bones (particularly in the lower thoracic and lumbar area)
- Tendency to develop compression fractures of the vertebrae with minimal or no trauma
- Kyphosis of the thoracic spine
- Fractures at other sites (hip, wrist) with less trauma than required in normal patients

Common Causes

PRIMARY

- Postmenopausal/senile

SECONDARY (<5%)

- Endocrine dysfunction
- Drug-induced (e.g., steroids)

- Prolonged immobilization
- Chronic renal failure
- Osteogenesis imperfecta
- Leukemia

Approach to Diagnostic Imaging

1. **Plain radiograph (spine)**
   - May detect anterior wedging of vertebral bodies (especially in the lower thoracic and upper lumbar regions) and associated ballooning of intervertebral disc spaces, characteristic of compression fractures

     Caveat: Plain radiographs of the spine are otherwise of little value because abnormal radiolucency cannot be accurately diagnosed until at least 50–70% of bone substance has been lost.
2. **Measurements of bone mineral content**
   - Various methods (quantitative CT, single- and dual-photon absorptiometry, dual-energy x-ray absorptiometry) are available to assess the quantity of bone in the spine both for initial diagnosis and for following the response to therapy
   - There is much debate concerning which imaging method is superior and even whether or not knowing the bone mineral content is clinically more helpful than mere knowledge of a patient's age and sex (in itself fairly accurate for predicting bone-mass quantity)

Note: Most authors agree that knowing the axial bone mineral measurement does not help predict which patients are at risk for developing hip and vertebral body fractures.

Osteomalacia

Presenting Signs and Symptoms

- Diffuse skeletal pain and bony tenderness
- Bowing of long bones and loss of height of vertebral bodies (due to weight-bearing on progressively weakened bones)

Common Causes

- Vitamin D deficiency (lack of sunlight, dietary deficiency, or malabsorption due to chronic pancreatic insufficiency, gastrectomy, or malabsorption syndrome)
- Abnormal metabolism of vitamin D (anticonvulsant therapy, chronic liver disease)
- Kidney disease (chronic renal failure, renal tubular acidosis, Fanconi's syndrome)
- Chronic administration of aluminum-containing antacids
- Tumor-induced

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - May demonstrate osteopenia (particularly in the spine, pelvis, and lower extremities) with accentuation or indistinctness of secondary trabeculae, thinning of the cortices, and insufficiency fractures (lucent lines running perpendicular to the long axis of the bone)

Arthritides

Ankylosing Spondylitis

Presenting Signs and Symptoms

- Recurrent back pain (often nocturnal)
- Morning stiffness (usually relieved by activity)
- Kyphosis (flexed posture typically eases back pain and paraspinal muscle spasm)
- Chest pain and diminished chest expansion (from diffuse costovertebral involvement)
- Peripheral joint pain (especially hip or shoulder)
- Cauda equina syndrome
- Acute iritis (anterior uveitis) in 30%
- Constitutional symptoms of fever, fatigue, anorexia, weight loss, and anemia (may be severe)
- Primarily affects men (3:1), especially between ages 20 and 40

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Earliest finding is erosion and sclerosis involving the sacroiliac joints in a symmetric fashion
   - Characteristic abnormalities include squaring of vertebral bodies, syndesmophyte formation, and paraspinal ligamentous calcification that eventually produce the classic “bamboo spine”
2. **Computed tomography or magnetic resonance imaging**

- Transverse imaging occasionally allows diagnosis when routine radiographs are normal

Calcium Pyrophosphate Deposition Disease (CPPD or Pseudogout)

Presenting Signs and Symptoms

- *Acute* attack of pain, swelling, redness, and warmth of one or more joints (especially the knee) in about 25%
- *Chronic* progressive degenerative changes in multiple joints (at times with intermittent acute attacks)
- Most patients are asymptomatic

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - May demonstrate characteristic calcification of articular cartilage and menisci (chondrocalcinosis) in the knee, triangular fibrocartilage of the wrist, and the symphysis pubis and acetabular region
   - May show structural joint changes that resemble osteoarthritis but occur in sites not typically involved in osteoarthritis (shoulders, wrists, and patellofemoral joints) and are more severe

Gout

Presenting Signs and Symptoms

- *Acute* gouty arthritis is an exquisitely painful monarthritis that typically involves the metatarsophalangeal joint of the big toe (podagra) but also commonly involves the instep, ankle, knee, wrist, and elbow (may be precipitated by minor trauma, overindulgence in food or alcohol, surgery, fatigue, emotional stress, infection, or vascular occlusion)
- *Chronic* gout is characterized by tophaceous deposits of urate crystals in joints, walls of bursae, and tendon sheaths that may lead to chronic joint symptoms, permanent erosive changes, and joint deformity
- Increased serum urate concentration and hyperuricemia
- Nephrolithiasis

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - In chronic or recurrent disease, may demonstrate characteristic well defined “rat-bite” erosions with sclerotic borders and overhanging edges (especially in the first metatarsophalangeal joints) with osteoporosis or soft-tissue tophaceous deposits (especially about the elbow, patella, and hand)
2. **Magnetic resonance imaging**
   - Pattern of disease varies, but regions of persistent low signal intensity are characteristic

Neuropathic Arthropathy (Charcot Joint)

Presenting Signs and Symptoms

- Rapidly progressive destructive process with effusion, subluxation, and instability of affected joints
- Pain is often absent or less severe than would be expected from the degree of joint destruction
- “Bag of bones” appearance of involved joint (due to repeated fractures and bony metaplasia that produce loose fragments of cartilage or bone)
- Precise site of involvement depends on underlying disorder

Common Causes

- Diabetes mellitus (foot)
- Tabes dorsalis (knee and hip)
- Syringomyelia (upper extremity, especially elbow and shoulder)
- Spina bifida with meningomyelocele
- Leprosy
- Quadriplegia

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - May demonstrate extensive destructive changes and heterotopic new bone formation

Osteoarthritis

Presenting Signs and Symptoms

- Insidious onset and gradual progression of pain that typically involves one or only a few joints, increases with exercise, and may become worse at night or with weather changes
- *Primary* osteoarthritis typically involves weight-bearing joints (hips, knees) and frequently used joints (fingers)
- *Secondary* osteoarthritis is due to a predisposing factor (trauma, congenital abnormality, metabolic disorder) and may be unilateral, appear at an early age, or involve joints that usually are not affected
- Stiffness in the morning or after rest (usually brief)

- With progressive disease, joints may appear enlarged, motion becomes limited, flexion contractures and subluxations may develop, and tenderness and crepitus may occur

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Demonstrates the typical findings of irregular or asymmetric joint space narrowing, hypertrophic bone formation (osteophytes) at the periphery of joints, subchondral sclerosis (increased opacity), and subchondral pseudocysts (geodes)

Note: In the hands, osteoarthritis primarily involves the distal and proximal interphalangeal joints. In the wrist, the disease affects the joints at the base of the thumb. In the knee, the medial portion of the joint is more severely involved in men.

Psoriatic Arthritis

Presenting Signs and Symptoms

- Joint abnormalities in about 5% of patients with skin or nail disease

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Demonstrates characteristic proliferative erosions (usually affecting the distal and proximal interphalangeal joints of the fingers and toes), as well as possible resorption of terminal phalanges, bony ankylosis, or arthritis mutilans (aggressive, destructive form of the disease)
   - May be associated with spondylitis, sacroiliitis, or both (even in the absence of peripheral arthritis)

Reiter's Syndrome

Presenting Signs and Symptoms

- Urethritis
- Conjunctivitis
- Peripheral arthritis
- Mucocutaneous lesions (small painless superficial ulcers)

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Demonstrates asymmetric, polyarticular proliferative erosions, typically involving the lower extremities (especially the toes and the heels)
   - May be associated with sacroiliac involvement (leading to back pain), which may have a unilateral distribution

Rheumatoid Arthritis

Presenting Signs and Symptoms

- Symmetric polyarthritis of peripheral joints (especially in the hand, wrist, and foot) with pain, tenderness, and swelling
- Typically insidious and progressive joint involvement
- Morning stiffness
- Rheumatoid nodules (in 30–40% of patients)
- Deformities (particularly flexion contractures and ulnar deviation of the fingers)
- Carpal tunnel syndrome (due to synovitis of the wrist)
- Serum rheumatoid factor
- Primarily affects women (3:1) between ages 25 and 50

Approach to Diagnostic Imaging

1. **Plain radiograph (hands, wrists, feet)**
   - Demonstrates the characteristic appearance of soft-tissue swelling, periarticular demineralization, joint space narrowing, and marginal erosions that symmetrically involve the wrists and hands (primarily the metacarpophalangeal and proximal interphalangeal joints)
   - Similar findings at the metatarsophalangeal joints of the feet

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Note: The “rheumatoid variants” (psoriatic and Reiter's arthritis) more commonly are asymmetric and may involve the distal interphalangeal joints.

Infection

Infectious Arthritis (Septic Joint)

Presenting Signs and Symptoms

- Acute joint pain associated with warmth, tenderness, swelling, and effusion
- Fever, chills
- Leukocytosis
- May be little systemic or local response in patients receiving antiinflammatory drugs

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Neither sensitive nor specific, but may demonstrate joint effusion, joint space narrowing, and erosive changes

> **Note:** The diagnosis of infectious arthritis requires a high index of suspicion (especially in patients with underlying chronic joint disease). Therefore, even the remote possibility that a joint might be septic demands aspiration of synovial fluid and a search for the infecting organism by Gram stain and culture (even if plain radiographs are completely normal).

2. **Radionuclide bone scan or magnetic resonance imaging**
   - Not specific, but permit early diagnosis in a patient with a high likelihood of joint infection

Osteomyelitis (Direct Seeding or Contiguous Spread)

Presenting Signs and Symptoms

- Pain and fever with tenderness and soft-tissue swelling

Common Causes

- Trauma (open fracture, surgical reduction of closed fracture, penetrating trauma)
- Bacterial contamination of orthopedic prosthesis during surgery
- Diabetic or atherosclerotic arterial insufficiency of lower extremities (spread from cutaneous foot ulcer)
- Sinus or dental infection (osteomyelitis of skull)

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - May demonstrate bony destruction with the formation of lucent areas, radiopaque sequestra (foci of devitalized bone), and involucra
   - An infected prosthesis may show characteristic lucent areas within the shaft of the bone adjacent to the cement about the prosthesis (may also be seen with simple loosening)
2. **Computed tomography**
   - Indicated to detect sequestra, which usually indicate the need for surgical removal rather than antibiotics alone (as avascular sequestra will not be effectively treated with parenteral medication)

> **Caveat: Radionuclide bone scan is of little value because the isotope accumulates in many noninfectious conditions, such as fracture sites, uninfected nonunion of fractures, periosteal new bone, overlying cellulitis, neuropathic arthropathy, and aseptic loosening of prostheses.**

3. **Magnetic resonance imaging**
   - Sensitive (but not specific) for detecting osteomyelitis
   - Diagnostic difficulty occurs owing to the presence of bone marrow edema (neighborhood reaction) in cases of adjacent soft-tissue infection

Osteomyelitis (Hematogenous)

Presenting Signs and Symptoms

- Pain and fever with tenderness and soft-tissue swelling
- In *children,* most commonly involves the long bones (especially near the physeal plate at the end of the shaft)
- In *adults,* usually affects the vertebral bodies

Common Causes

- Intravenous drug abuse
- Hemodialysis
- Debilitating diseases

Approach to Diagnostic Imaging

1. **Radionuclide bone scan**

- Demonstrates increased activity early in the disease (evidence of bone destruction on plain skeletal radiographs usually does not appear for at least 1 week)

Caveat: Bone scans may take months to normalize after a bone infection becomes sterile, and thus it may be impossible to distinguish a chronic infection of bone from normal healing.

2. **Magnetic resonance imaging**
   - Equally sensitive as or even more sensitive than bone scintigraphy for detecting hematogenous osteomyelitis, although neither technique is specific

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Note: CT has a limited role in the early diagnosis of osteomyelitis.

Osteomyelitis (Vertebral)

Presenting Signs and Symptoms

- Insidious onset and gradual progression of back pain unrelieved by heat, rest, or analgesics and worsened by movement
- Fever typically is minimal or absent
- Tenderness to palpation and percussion over affected bone
- Paravertebral muscle spasm
- Guarding and splinting on motion

Approach to Diagnostic Imaging

1. **Radionuclide bone scan**
   - Demonstrates increased activity early in the disease (evidence of bone destruction on plain skeletal radiographs usually does not appear for at least 1 week)

Caveat: Increased radionuclide uptake may be impossible to distinguish from that occurring with tumors and fractures.

2. **Magnetic resonance imaging**
   - Sensitive for demonstrating a focal abnormal signal intensity in the bone marrow, but does not accurately distinguish between infection and tumor
   - Can effectively reveal the full extent of soft-tissue involvement (as can CT)

Notes: Plain radiographs of the spine are not sensitive for detecting vertebral osteomyelitis. However, the findings of vertebral body destruction and rapid loss of the adjacent intervertebral disc are highly suggestive of the diagnosis of bacterial infection.

Neoplasm

Skeletal Metastases

Presenting Signs and Symptoms

- Most often asymptomatic (discovered during staging procedures)
- Back pain

Common Primary Tumors

- Lung
- Breast
- Prostate
- Thyroid
- Kidney
- Lymphoma
- Melanoma

Approach to Diagnostic Imaging

1. **Radionuclide bone scan**
   - Preferred screening technique for detecting asymptomatic skeletal metastases, which appear as focal areas of increased radionuclide uptake (hot spots)

Note: False-negative results may occur if there is uniform, symmetric uptake of radionuclide by diffuse metastases (“superscan”). The proper diagnosis should be suggested by decreased or no labeling of the kidneys (all radionuclide taken up by skeletal structures so that little or none remains to be excreted by the usual renal route).

2. **Plain skeletal radiograph**
   - If the radionuclide scan is equivocal, plain films should be obtained to confirm that a hot spot represents a metastasis rather than one of the many benign processes that can also cause increased uptake (e.g., infection, degenerative disease, trauma)
   - Generally *not* indicated if there are multiple focal radionuclide scan abnormalities involving the axial skeleton that are virtually pathognomonic of metastases

     Caveat: Never order a "skeletal survey" to screen for metastases. Plain radiographs are insensitive (40–80% of cancellous bone must be destroyed before a lesion is apparent on these films).
3. **Computed tomography or magnetic resonance imaging**
   - Indicated to evaluate nonspecific focal abnormality on radionuclide scan or specific symptomatic areas that cannot be demonstrated or adequately characterized on plain radiographs

     Caveat: Neither CT nor MRI should ever be used as the initial screening test for suspected skeletal metastases, although either may be used to further define a symptomatic region of the body in a patient with a known primary malignant tumor.

Multiple Myeloma

Presenting Signs and Symptoms

- Persistent unexplained skeletal pain (especially in the back or thorax)
- Pathologic fractures and vertebral collapse
- Renal failure
- Recurrent bacterial infections (especially pneumococcal pneumonia)
- Anemia with weakness and fatigue
- Hypercalcemia
- Excess immunoglobulins
- Bence Jones protein

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Demonstrates either diffuse osteoporosis or multiple discrete osteolytic ("punched-out") lesions (due to replacement by expanding plasma cell tumors or elaboration of an osteoclast-stimulating factor); these lesions are often associated with pathologic fractures or vertebral collapse
   - Diffuse changes may be difficult to recognize unless thinning and expansion of the cortices are appreciated
2. **Magnetic resonance imaging**
   - Preferred imaging study for showing the characteristic diffuse marrow abnormalities (low-intensity tumor replaces normal high-intensity marrow fat on T1-weighted images)
   - Can demonstrate compression of the spinal cord secondary to vertebral collapse

     Caveat: Radionuclide bone scan is not indicated as a screening test for multiple myeloma because the process is primarily osteolytic with little bone production (thus radionuclide scans typically are falsely normal). "Skeletal survey" is not indicated as a screening test because it is insensitive.

Osteoid Osteoma

Presenting Signs and Symptoms

- Pain that classically is worse at night and relieved by small doses of aspirin
- Almost always in patients younger than 30 years

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - May demonstrate the characteristic appearance of a small radiolucent zone (nidus) surrounded by a large sclerotic zone (reactive bone)
2. **Radionuclide bone scan**
   - Indicated if plain film findings cannot distinguish osteoid osteoma from osteomyelitis

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Note: Because the nidus is extremely vascular, it avidly accumulates the radionuclide, producing the typical "double-density" sign representing an area of avid radionuclide uptake (nidus) surrounded by a region of moderately increased uptake (reactive bone). This is in contrast to the central photopenic area of osteomyelitis that represents an avascular focus of purulent material.

3. **Computed tomography**
   - Indicated to define the exact location of the nidus (if not clearly seen on plain films) prior to surgery (because removal of the nidus usually results in complete cessation of pain)

Caveat: MRI findings in osteoid osteoma include extensive marrow and soft-tissue edema resembling those of a malignant tumor or osteomyelitis.

Primary Malignant Tumors of Bone

Presenting Signs and Symptoms

- Pain, soft-tissue mass

Common Types

- Osteosarcoma, fibrosarcoma, chondrosarcoma, Ewing's sarcoma

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Preferred initial imaging study for demonstrating a lesion's site and appearance (which combined with a patient's age may permit a specific diagnosis)

Note: If a single lesion is detected that could represent a metastasis, a radionuclide bone scan (not a plain-film skeletal survey) is essential to detect any other clinically silent lesions.

Caveat: Although plain radiographic signs may aid in distinguishing benign from malignant lesions, none is infallible, and a biopsy may be required.

2. **Magnetic resonance imaging**
   - Best imaging modality for determining the bony and soft-tissue extent of a lesion (required prior to surgical resection)

Caveat: The ability of MRI to distinguish benignity from malignancy is controversial, and it may be impossible to determine whether high signal radiating from involved bone in some imaging sequences represents soft-tissue edema or tumor spread.

Soft-tissue Tumor of Extremity

Presenting Signs and Symptoms

- Asymptomatic (incidentally noted either by the patient or an examining physician)
- Variety of clinical manifestations, depending on the site and type of lesion

Common Causes

- Lipoma
- Melanoma
- Liposarcoma
- Malignant fibrous histiocytoma

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Neither sensitive nor specific, but usually performed initially to demonstrate the soft-tissue lesion, its effect on the underlying bone, and any associated calcification
2. **Computed tomography or magnetic resonance imaging**
   - Most accurate imaging procedures for defining the extent of a soft-tissue mass and its relationship to adjacent structures

Caveat: Although these techniques can sometimes suggest the nature of a soft-tissue neoplasm (especially those containing fat), a biopsy is generally required to determine the precise histologic diagnosis.

3. **Ultrasound**
   - Imaging modality of choice for determining whether a superficial soft-tissue mass thought to represent a cyst is truly fluid-filled
4. **Arteriography**
   - May be indicated as a preoperative study to determine the vascular anatomy
   - May be helpful in localizing an area within the mass that will most likely yield accurate biopsy data (the most malignant sites tend to have the greatest vascularity)

Trauma

Pathologic Fracture

Presenting Signs and Symptoms

- Evidence of a fracture following a trivial injury or without a history of trauma
- Concomitant evidence of preexisting abnormality (angular deformity, painless swelling, or generalized bone pain)

Common Causes

- Malignant neoplasms
- Metastases
- Benign lesions (e.g., simple bone cyst, enchondroma, giant cell tumor)
- Osteoporosis

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Preferred initial study for demonstrating that the fracture line traverses a large area of bone destruction or that adjacent or distant bones are riddled with additional lesions

     Caveat: If the underlying lesion is small, the fracture itself may obscure the abnormal lytic or sclerotic area (especially if there is displacement at the fracture site).
2. **Computed tomography or magnetic resonance imaging**
   - May be useful for detecting more subtle indications of underlying abnormal bone

Hip Fracture

Presenting Signs and Symptoms

- History of fall with inability or significant difficulty in weight bearing on involved extremity
- Pain and bruising in hip region

Common Causes

- Trauma
- Osteoporosis

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Provides definite diagnosis of fracture in the vast majority of cases
   - Angled projection may be necessary to demonstrate nondisplaced fracture of the femoral neck
2. **Magnetic resonance imaging**
   - Highly sensitive for detecting radiographically occult fracture
   - Indicated if there is a high clinical suspicion of fracture despite normal plain films
3. **Radionuclide bone scan**
   - If MRI is not available, can be used to detect or exclude occult fracture in patient with a high clinical suspicion despite negative plain films
   - Because false-negative results may occur in a small percentage of patients (especially the elderly) during the first 72 hours after fracture, a repeat scan may be required to reliably exclude a fracture

Pelvic Fracture

Presenting Signs and Symptoms

- History of major trauma to pelvis
- Pain and bruising in the pelvic region
- Substantial internal blood loss
- Hematuria

Common Cause

- Trauma

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Provides definite diagnosis of fracture in most cases (without the need to move the patient, who may have suffered multiple injuries)
   - Oblique and angled views (inlet, outlet, Judet) may be required to diagnose or exclude minor fracture
   - Second fractures are typical

     Caveat: Sacral foramina fractures may be difficult to detect.
2. **Computed tomography**

- Indicated if there is a high clinical suspicion of fracture despite normal plain films
- Especially valuable for detecting occult sacral fractures, as well as bone fragments in the hip joint associated with an acetabular fracture
- Can demonstrate hemorrhage and soft-tissue injuries that often occur in conjunction with pelvic fractures

3. **Magnetic resonance imaging**
   - May reveal marrow edema about the fracture site (although the fracture line itself is better seen with CT)

Note: In patients with massive hemorrhage, arteriography may be required to identify the bleeding site and permit transcatheter embolization therapy. Retrograde urethrography and cystography are indicated in fractures of the anterior pelvis to exclude injury to the posterior urethra and bladder.

Scaphoid Fracture

Presenting Signs and Symptoms

- Pain in the region of the anatomic snuff-box
- High incidence of complications (delayed union, nonunion, avascular necrosis)

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Preferred initial study (although it fails to detect up to 25% of nondisplaced fractures)
   - Delayed radiographs (after 1 to 2 weeks of immobilization) often demonstrate “initially occult” fractures because of resorption and better demarcation around the fracture line
2. **Magnetic resonance imaging**
   - High sensitivity for detecting fractures not evident on initial plain radiographs
   - Enables early diagnosis and definitive treatment (decreases risk of complications)
   - Acute fractures have decreased signal intensity of the proximal pole of T1-weighted images and increased signal on T2-weighted and fat-suppression sequences
   - Avascular necrosis classically has low signal intensity on all sequences
   - Gadolinium-enhanced sequences may be of value in selecting patients with acute fractures who are likely to develop avascular necrosis or delayed union, as well as in assessing surgical eligibility in those with established nonunion or avascular necrosis
3. **Radionuclide bone scan**
   - Traditionally considered the imaging modality of choice for early diagnosis of occult fractures (high sensitivity, with optimal imaging at 48 hours after injury)
   - Similar findings of increased uptake can be seen in disuse states, ligamentous injuries, and reflex sympathetic dystrophy
   - Lack of spatial resolution may necessitate further imaging studies (CT, MRI) for more precise anatomic information prior to definitive treatment
   - Negative bone scan virtually excludes the possibility of scaphoid or other occult fracture

Stress Fracture

Presenting Signs and Symptoms

- Activity-related pain relieved by rest (typically associated with the repetition of a new or different strenuous activity)
- Localized tenderness and soft-tissue swelling

Common Examples

- March fracture (metatarsals in military recruits)
- Lower extremity fractures in athletes, joggers, and dancers

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - May demonstrate a radiolucent line or a band of sclerosis associated with periosteal and endosteal thickening

     Caveat: Plain radiographic evidence of a stress fracture may not be detectable for several weeks.
2. **Radionuclide bone scan**
   - Sensitive for early detection of a stress fracture
   - May be impossible to differentiate shin splint from early stress fracture (treated differently)
   - Triple-phase technique should be used to maximize specificity
3. **Magnetic resonance imaging**
   - Extremely sensitive for detecting stress injuries and may prove to be more specific than radionuclide scanning
   - Usually reserved for cases in which radiographic findings are indeterminate
   - In early stress fractures, the marrow has low signal intensity on T1-weighted images and has progressively higher intensity with increased T2-weighting
   - Fat-saturation techniques are especially useful, with the increased water content of the associated medullary edema or hemorrhage resulting in high signal intensity against the dark background of suppressed fat

- Fracture line may not be seen

Meniscal Tear (Knee)

Presenting Signs and Symptoms

- Pain and swelling
- Click in movement of the joint
- Knee “giving way” or locking in a single position

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Imaging procedure of choice for detecting partial and complete meniscal tears, as well as associated abnormalities of the collateral and cruciate ligaments

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Note: Arthrography of the knee is not commonly performed.

Caveat: The need for both MRI and arthroscopy is controversial. Some studies have indicated that arthroscopy alone is sufficient and financially advisable, except perhaps in instances of recurrent knee pain following previous meniscal surgery or repair.

Rotator Cuff Tear

Presenting Signs and Symptoms

- Pain when the arm is raised above the shoulder or adducted across the chest, but not when the arm is held down by the side
- Weakness of shoulder abduction (due to underuse atrophy of the deltoid)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging (shoulder)**
   - Rapidly becoming the imaging procedure of choice for detecting partial and complete rotator cuff tears
   - Noninvasive and does not require the technical expertise required for shoulder arthrography

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Note: The imaging workup is based on the needs of the orthopedic surgeon. If all that is needed is the detection of full-thickness tears of the rotator cuff (as opposed to partial-thickness tears), arthrography of the glenohumeral joint is generally sufficient.

2. **Ultrasound**
   - Sensitive for diagnosing rotator cuff tear, but requires considerable examiner expertise

Child Abuse

Presenting Signs and Symptoms

- Nonaccidental intracranial and skeletal injuries (due to direct blows or shaking)
- Most commonly involves children younger than age 2
- May be bruises, seizures, coma, lethargy, retinal hemorrhage, shallow respirations

Approach to Diagnostic Imaging

1. **Plain radiographs (skeletal survey)**
   - Demonstrates multiple fractures of varying age or unusual fractures
   - Injuries highly specific for child abuse include metaphyseal (corner) fractures and fractures of the posterior ribs, sternum, scapula, and spinous processes
   - Less specific injuries include epiphyseal injuries, complex skull fractures, and fractures of the vertebral bodies, metacarpals, and metatarsals
   - Fractures of the clavicle and the shafts of long bones also are common
2. **Computed tomography or magnetic resonance imaging**
   - Indicated if there is a complex skull fracture or clinical evidence of intracranial injury to detect subdural hematoma, cortical contusion, shearing injury, or subarachnoid hemorrhage
3. **Radionuclide bone scan**
   - May be effective to survey the entire skeleton, although metaphyseal fractures may be missed

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Note: There is generally no indication for any other imaging study.

Other

Avascular Necrosis

Presenting Signs and Symptoms

- Pain (most commonly affecting the hip or knee, although the ankle, shoulder, and elbow also may be involved)

Common Causes

- Trauma
- Steroid therapy
- Alcoholism
- Pancreatitis
- Collagen vascular diseases
- Sickle cell disease and other hemoglobinopathies
- Renal transplantation
- Infiltrative diseases (e.g., Gaucher's disease)
- Caisson's disease (“the bends”)
- Legg-Calvé-Perthes disease

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Not sensitive, but ideal for following the disorder from patchy sclerosis and subchondral lucency (thin line beneath the articular surface) to collapse of the articular surface, dense bony sclerosis, and joint fragmentation
2. **Magnetic resonance imaging**
   - Most sensitive study for detecting the earliest changes of avascular necrosis when plain radiographs and radionuclide scans are normal
   - In the hip, may demonstrate a characteristic abnormal signal intensity area on some imaging sequences that virtually always involves the anterosuperior portion of the femoral head
3. **Radionuclide bone scan**
   - May show abnormal uptake when plain radiographs are still normal (although not as sensitive as MRI)

Carpal Tunnel Syndrome

Presenting Signs and Symptoms

- Pain, paresthesias, and sensory deficits in the distribution of the median nerve
- May be weakness or atrophy in the muscles controlling abduction and apposition of the thumb
- Positive Tinel's sign (paresthesias after percussion of the median nerve in the volar aspect of the wrist)

Predisposing Factors

- Occupations requiring repetitive hand and wrist motion
- Gout
- Calcium pyrophosphate deposition disease (CPPD)
- Acromegaly
- Myxedema
- Pregnancy
- Oral contraceptives

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Can show swelling of the median nerve at the proximal carpal tunnel, flattening of the nerve at the distal carpal tunnel, and signal abnormalities within or surrounding the median nerve
   - Excellent soft-tissue contrast allows demonstration of subtle soft-tissue changes and mild compression of the median nerve
   - Modality of choice for assessing surrounding bony structures
2. **Ultrasound**
   - Suggested as a low-cost alternative to MRI (similar imaging criteria)
3. **Computed tomography**
   - Can assess the fibrous roof of the carpal tunnel and analyze the structures coursing through the canal

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> **Note:** CT is of limited value because of the similar attenuation values of the contents of the carpal tunnel.

4. **Plain radiograph (wrist)**
   - Specific radiographic projections (including the carpal tunnel view) can permit an evaluation of the osseous structures bordering the carpal tunnel

Congenital Hip Dislocation

Presenting Signs and Symptoms

- Inability to completely abduct the thigh to the surface of the examining table when the hip and knee are flexed (Ortolani's sign)
- Hip click (audible or palpable “clunk”) with abduction and external rotation of the femur (as the femoral head reenters the acetabulum)
- If unilateral, shortened leg with asymmetric skin creases in the thigh

Predisposing Factors

- Female infants
- Breech presentation
- Positive family history

Approach to Diagnostic Imaging

Note: Congenital hip dislocation is a clinical diagnosis.

1. **Plain radiograph (hips)**
   - Often not diagnostic in the neonatal period, but may be of value as a baseline study (to permit comparison with subsequent radiographic assessment as the child grows and develops)
2. **Ultrasound**
   - Can confirm the clinical diagnosis, even in the neonatal period, with dynamic imaging (counterpart to clinical maneuvers used in physical examination)
3. **Magnetic resonance imaging**
   - May reveal structural abnormalities not evident on routine radiographs

Myasthenia Gravis

- Presenting Signs and Symptoms
- Ptosis, diplopia, and muscle fatiguability after exercise
- Dysarthria and dysphagia
- Bulbar symptoms (alteration in voice, nasal regurgitation, choking)
- Life-threatening respiratory muscle involvement (10%)
- Positive edrophonium test

Common Causes

- Autoimmune condition associated with thymoma in up to 30% of patients

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Note: A larger percentage (up to 50%) of patients with thymoma have or will develop myasthenia gravis.

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Initial imaging procedure for detecting a thymoma, which appears as a smooth or lobulated soft-tissue mass that typically arises near the origin of the great vessels at the base of the heart
2. **Computed tomography**
   - Most sensitive technique for detecting small thymomas not evident on conventional radiographs
   - Preferred method for demonstrating local invasion of tumor through thymic capsule to involve pleura, lung, pericardium, chest wall, diaphragm, and great vessels (occurs in 10–15% of patients)

     Caveat: Even CT may be unable to distinguish small thymic tumors from a normal or hyperplastic gland, especially in young patients with a large amount of residual thymic tissue.

Osgood-Schlatter Disease

Presenting Signs and Symptoms

- Pain, swelling, and tenderness over the anterior tibial tubercle (at the patellar tendon insertion)

Common Cause

- Trauma from excessive traction by the patellar tendon on its immature apophyseal insertion

Approach to Diagnostic Imaging

1. **Plain radiograph (knee)**
   - Demonstrates soft-tissue swelling associated with fragmentation of the anterior tibial tubercle

2. **Magnetic resonance imaging**
    - Often reveals diffuse thickening of the patellar tendon

Paget's Disease

Presenting Signs and Symptoms

- Usually asymptomatic (discovered incidentally on radiographs or routine laboratory studies)
- Symptoms (typically insidious onset) may include pain, pathologic fracture of weakened bone, deformities, high-output cardiac failure, headaches, decreased hearing, and increasing skull size
- Increasingly severe pain suggests fracture or sarcomatous degeneration (1% of patients)

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
    - Demonstrates cortical thickening and overall increased density of affected bones, which have an abnormal internal architecture and often show bowing or overgrowth
    - Detects pathologic fractures or microfractures (tibia, femur)
    - Shows areas of osteolysis in cases of sarcomatous degeneration
2. **Radionuclide bone scan**
    - Most efficient method for screening multiple areas of the skeleton to search for multicentric lesions

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Note: MRI and CT are the most accurate imaging modalities in the patient with suspected sarcomatous degeneration of Paget's disease.

Painful Prosthesis

Presenting Signs and Symptoms

- Pain in and around the affected joint
- Fever, leukocytosis (if infected)

Common Causes

- Loosening of prosthesis
- Infection
- Particle disease related to inflammatory reaction about polyethylene or cement fragments
- Pathologic fracture

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
    - Can demonstrate excessive lucency around the prosthesis, fracture of the prosthesis or adjacent bone, or prosthesis dislocation
2. **Radionuclide bone scan**
    - Indicated if there is a high clinical suspicion of loosening or infection despite normal plain films
    - Negative scan makes infection unlikely

Note: If there is clinical suspicion of infection, the joint is aspirated to obtain fluid for culture.

3. **Arthrography**
    - Can demonstrate loosening by showing gap between prosthesis, cement, and bone when contrast material is injected under pressure
    - Analysis and culture of fluid obtained during procedure can diagnose or exclude infection
4. **Magnetic resonance imaging**
    - Currently, no role in assessing the painful prosthesis containing metal, but can be used to assess synovitis related to Silastic™ implants

Reflex Sympathetic Dystrophy (Sudeck's Atrophy)

Presenting Signs and Symptoms

- Pain and tenderness (usually of a hand or foot) associated with vasomotor instability, trophic skin changes, and rapid development of osteopenia

Common Causes

- Local trauma
- Peripheral nerve injury

- Stroke

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - May demonstrate diffuse or patchy osteopenia of the involved extremity (especially the hands or feet)
2. **Radionuclide scan**
   - Demonstrates diffuse increased uptake in the involved area (but this is nonspecific)
   - May show foci of decreased radionuclide uptake in children

Slipped Capital Femoral Epiphysis

Presenting Signs and Symptoms

- Insidious onset of hip stiffness that improves with rest
- Limp
- Hip pain (radiating down the anteromedial thigh to the knee)
- In advanced cases, pain on motion of the affected hip, with limited flexion, abduction, and medial rotation
- May be associated with chondrolysis and avascular necrosis with epiphyseal collapse (if blood supply is compromised)
- Most commonly affects overweight teenagers (usually boys)

Approach to Diagnostic Imaging

1. **Plain radiograph (hip)**
   - Demonstrates widening of the physeal line and/or displacement (posterior and inferior) of the femoral head

Caveat: Early diagnosis dramatically improves the outcome because treatment becomes more difficult in advanced stages.

CHAPTER 6. NEUROLOGIC

Burton P. Drayer

SIGNS AND SYMPTOMS

Acute Altered Mental Status

Presenting Signs and Symptoms

- Vigorous stimuli required to elicit a response (stupor)
- Unarousable unresponsiveness (coma)

Common Causes

- Trauma (diffuse cerebral edema; epidural, subdural, intraparenchymal, or subarachnoid hemorrhage)
- Anoxia or ischemia (stroke, syncope)
- Epilepsy (postictal state)
- Exogenous toxins (alcohol, hypnotics, narcotics)
- Endogenous toxins (uremia, hepatic coma, diabetic acidosis, hypoglycemia, hyponatremia)
- Brain tumor, infarction, abscess, or meningitis

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Can rapidly determine whether there is extra-axial hemorrhage, mass lesion, or herniation requiring emergency surgical decompression

     Caveat: Because patients with disordered consciousness due to high intracranial pressure can deteriorate rapidly, therapy should not be delayed if CT cannot be obtained promptly.

2. **Magnetic resonance imaging**
   - Procedure of choice in *subacute* phase for better visualization of the temporal lobes (e.g., herpes encephalitis), brain stem (e.g., central pontine myelinolysis), white matter (e.g., gliomatosis cerebri), superior colliculi and mammillary bodies (Wernicke's), and globus pallidus (e.g., hepatic encephalopathy)

Note: Plain skull radiographs are of no value and should *not* be obtained.

Amaurosis Fugax

Presenting Sign and Symptom

- Ipsilateral blindness that usually resolves fully within 2 to 30 minutes (sudden onset and brief duration)

Common Causes

- Plaques or atherosclerotic ulcers involving the carotid artery in the neck
- Emboli arising from mural thrombi in a diseased heart

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging (brain)**
   - Can evaluate for infarction
2. **Magnetic resonance angiography (neck and head)**
   - Excellent screening study for excluding significant atherosclerotic narrowing, detecting vascular occlusion, and visualizing the vertebral and the anterior, middle, and posterior cerebral arteries (in addition to the carotids)

Note: The surgical criteria of 60% stenosis (Asymptomatic Carotid Artery Stenosis Trial [ACAST]) or 70% stenosis (North American Symptomatic Carotid Endarterectomy Trial [NASCET]) can be established using magnetic resonance angiography (MRA) of the neck and head. Although nonenhanced and three-dimensional time-of-flight MRA are excellent, the addition of a rapid bolus infusion of paramagnetic contrast material may improve visualization of the carotid bifurcation and definitely improves visualization of the aortic arch.

3. **Duplex, color-flow Doppler ultrasound**
   - Accurate noninvasive screening study that combines high-resolution, real-time imaging of the carotid arteries

with hemodynamic information about blood flow velocity provided by the Doppler technique
- When used with MR angiography, may obviate the need for presurgical angiography

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Note: Other noninvasive tests (ophthalmodyna-mometry, oculoplethysmography) are not indicated because they cannot accurately detect carotid plaques and ulcerations.

4. **Echocardiography**
   - Indicated to detect mural thrombi in the heart if no carotid lesion has been identified that could explain the patient's symptoms
5. **Intraarterial digital subtraction angiography**
   - Invasive study that provides the highest-resolution images of intraluminal vascular pathology
   - Indicated prior to surgical intervention if US demonstrates a high-grade stenosis or ulcerated plaque in the carotid artery
6. **Computed tomography (brain)**
   - Can evaluate for infarction, but less sensitive than magnetic resonance imaging (MRI)
7. **Computed tomography angiography**
   - May prove more sensitive than even color duplex US, but requires the rapid infusion of iodinated contrast material

Aphasia

Presenting Signs and Symptoms

- Language disorder (abnormal comprehension, inability to speak properly, incorrect usage of words)
  - Receptive aphasia (Wernicke's area)
  - Conduction aphasia (arcuate fasciculus)
  - Expressive aphasia (Broca's area)
- May be associated with right hemiparesis (usually due to a cortical lesion in the left middle cerebral artery distribution) or right hemisensory deficit
- Must be distinguished from dysarthria, an abnormality of motor speech articulation rather than language

Common Causes

- Cerebral infarction (dominant hemisphere)
- Intracerebral hematoma
- Intracerebral neoplasm or abscess (slower, subacute onset)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Rapidly identifies or excludes intracranial hemorrhage, infarction, or mass
   - Remains the “gold standard” for distinguishing acute intracerebral hematoma from cerebral infarction
2. **Diffusion-weighted magnetic resonance imaging**
   - Routinely perform T1-weighted, intermediate or FLAIR, and T2-weighted pulse sequences
   - Highly sensitive for diagnosing acute stroke within 3 hours of symptom onset
   - If negative, extremely accurate in excluding acute cerebral infarction
   - Provides improved localization and characterization of any cerebral abnormality detected by CT (e.g., vascular malformation, complicated hemorrhagic process, mass lesion) and improved specificity for distinguishing the etiology of aphasia
3. **Magnetic resonance angiography (neck and head)**
   - Can often detect the site of a stenosis or occlusion related to acute infarction

Caveat: Arteriography is indicated *only* if noninvasive studies suggest an underlying aneurysm or arteriovenous malformation *and* a surgical or interventional radiologic procedure is seriously being considered.

Ataxia

Presenting Signs and Symptoms

- Disorder of stance and gait
- Axial signs may predominate (midline cerebellar abnormality)
- Appendicular (extremity) signs may predominate (hemispheric cerebellar abnormality)
- May have associated tremor, nystagmus, or cranial nerve findings
- Must be distinguished from gait apraxia (frontal lobe abnormality) and gait instability related to lower motor neuron disease

Common Causes

- Any abnormality involving the cerebellum, cerebellar peduncles, or cerebellar pathways in the brain stem
- Common diseases include
  - Metabolic (alcohol- and anticonvulsant-related, remote effects of carcinoma)
  - Neurodegenerative (familial cerebellar degeneration, including olivopontocerebellar atrophy, Friedreich's ataxia,

and Holmes' cerebellar atrophy)
- Neoplasms (commonly medulloblastoma, astrocytoma, and ependymoma in children and metastases and hemangioblastoma in adults)
- Demyelinating (multiple sclerosis, acute disseminated encephalomyelitis, progressive multifocal leukoencephalopathy)
- Vascular (cerebellar hematoma or infarction)
- Cysts (arachnoid, epidermoid)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Procedure of choice in an *acute* case without a history of trauma to exclude an acute intraparenchymal hemorrhage or mass effect on posterior fossa structures
   - Less sensitive than MRI for evaluating the posterior fossa because of transverse artifacts from the temporal bones and single axial-plane visualization
2. **Magnetic resonance imaging**
   - Procedure of choice for *chronic* or *progressive* gait disturbance
   - Nonenhanced study is generally adequate in terms of sensitivity and provides the added benefit of delineating secondary abnormalities (e.g., basal ganglia abnormalities in olivopontocerebellar atrophy, additional lesions in metastases)
   - Contrast enhancement may improve specificity (e.g., enhancing peripheral nodule in cystic hemangioblastoma, detection of multiple metastases)

     Caveat: Arteriography is indicated *only* if noninvasive studies suggest an underlying aneurysm or arteriovenous malformation and a surgical or interventional radiologic procedure is seriously being considered.

Carotid Bruit (Asymptomatic)

Presenting Signs and Symptoms

- Asymptomatic
- High-pitched sound heard over the region of the carotid artery bifurcation in the neck (must be distinguished from a venous hum, which is continuous, heard best with the patient sitting or standing, and eliminated by compression of the ipsilateral internal jugular vein)

Common Cause

- Narrowing of the lumen of the extracranial carotid artery related to atherosclerotic cerebrovascular disease

Approach to Diagnostic Imaging

1. **Duplex, color-flow Doppler ultrasound**
   - Accurate noninvasive screening study that combines high-resolution, real-time imaging of the carotid arteries with hemodynamic information about blood flow velocity provided by the Doppler technique (negative predictive value greater than 99%)
   - Should be performed in patients with cervical bruits who are scheduled to undergo major vascular surgery elsewhere (greater than 80% carotid stenosis increases the risk for transient ischemic attack or stroke during surgery)
   - About 20% of carotid arteries considered to be completely occluded may still have some lumen patency.

Note: Although some advocate a battery of noninvasive tests, including ophthalmodynamometry and oculoplethysmography, these generally only add unnecessary expense.

2. **Magnetic resonance imaging (brain)**
   - Can evaluate for infarction
3. **Magnetic resonance angiography (neck and head)**
   - Excellent screening study for excluding significant atherosclerotic narrowing, detecting vascular occlusion, and visualizing the vertebral and the anterior, middle, and posterior cerebral arteries, in addition to the carotids

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Note: If a flow gap is present (greater than 60% stenosis), then Doppler US is performed for better determination of whether the lesion falls within the surgical guidelines of 60% stenosis (ACAST) or 70% stenosis (NASCET).

4. **Intraarterial digital subtraction angiography**
   - Invasive study that provides the highest-resolution images of intraluminal vascular pathology
   - Indicated prior to surgical intervention if US demonstrates a high-grade stenosis of the carotid artery
5. **Computed tomography (brain)**
   - Can evaluate for infarction, but less sensitive than MRI

6. **Computed tomography angiography**
    - May prove more sensitive than even color duplex US, but requires the rapid infusion of iodinated contrast material

Dementia or Movement Disorder

Presenting Signs and Symptoms

- Permanent or progressive decline in intellectual function (recent memory, concentration, judgment, orientation, ability to speak or read)
- Parkinsonian symptoms (including bradykinesia, rigidity, tremor)

Common Causes

- Alzheimer's disease (also Pick's disease, frontobasal degeneration)
- Parkinson's disease
- Multi-infarct
- Metabolic/nutritional/endocrine (including Wernicke-Korsakoff syndrome)
- Brain tumor
- Chronic central nervous system infection
- Normal pressure hydrocephalus
- AIDS encephalopathy
- Repetitive trauma (e.g., boxers)
- Chronic subdural hematoma
- Creutzfeldt-Jakob (prion) encephalopathy

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
    - Most sensitive for demonstrating large masses, hydrocephalus, and other treatable abnormalities, as well as ischemic white matter disease, small infarctions, and Wernicke-Korsakoff syndrome
    - Increased iron in the corpus striatum (T2-weighted, 1.5-T studies) suggests Parkinson's disease that will not be responsive to drug therapy (multiple system atrophy)
    - Increased signal in the globus pallidus on T1-weighted imaging (manganese accumulation) is seen with hepatic failure
    - Hyperintense signal in the putamen on T2-weighted imaging and in the cortex on diffusion imaging suggests Creutzfeldt-Jakob encephalopathy
2. **Positron emission tomography (PET)**
    - Can be used as an adjunct examination in patients with suspected Alzheimer's disease because the glucose usage pattern is relatively specific

      Caveat: Because brain “atrophy” increases with age in persons with normal mental status, MRI (or CT) provides *no* reliable indication of intellectual impairment in the elderly population.

Developmental Disorders

Presenting Signs and Symptoms

- Broad spectrum of neurologic deficits

Common Types

- Cephaloceles
- Chiari malformations
- Tuberous sclerosis
- Sturge-Weber syndrome
- Von Hippel-Lindau disease
- Cerebellar dysplasia
- Posterior fossa cystic malformations (e.g., Dandy-Walker deformity)
- Neurofibromatosis
- Holoprosencephaly
- Migration disorders (lissencephaly, pachygyria, polymicrogyria, heterotopic gray matter, schizencephaly, abnormalities of the corpus callosum)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
    - Imaging procedure of choice for characterizing and defining the extent of developmental disorders of the CNS
    - Other advantages include multiplanar imaging and the ability to image the spinal canal, as well as the brain
2. **Computed tomography**
    - If the patient is uncooperative and heavy sedation is contraindicated, ease of access and rapid scanning may permit performance of CT
    - Useful for follow-up of shunt function

Headache

Common Causes

- Increased intracranial pressure (neoplasm, abscess, hemorrhage, meningeal irritation)
- Vascular disturbance (migraine, hypertension, cluster headaches)
- Toxins (alcoholism, uremia, lead, systemic infection)
- Trauma
- Extracranial site (disorders of paranasal sinuses, eye, ear, teeth, cervical spine)
- Temporal arteritis (in elderly population)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Most sensitive technique for detecting cerebral lesions responsible for headache (especially in patients who have coexistent abnormal neurologic signs)
   - Imaging evaluation is usually unnecessary in patients with no neurologic abnormalities and who have either continuous headaches of long duration (many months or years) or intermittent recurrent headaches.
   - If an aneurysm is suspected even though CT is normal, a lumbar puncture and MRA of the head can be performed

Caveat: Patients with severe *acute* headaches should be imaged with noncontrast head CT because of the suspicion of subarachnoid hemorrhage, acute hydrocephalus, or an enlarging intracranial mass.

Note: There is *no* indication for conventional skull radiographs. If disease of the paranasal sinuses is suspected, a limited coronal CT study can be performed.

Hearing Loss: Conductive

Sites of Dysfunction

- Any process that impedes transmission of sound waves from the auricle to the oval window

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Note: Audiometry and careful clinical examination are essential to distinguish conductive from sensorineural hearing loss.

Common Causes

- Complete obstruction of external auditory canal
  - Congenital atresia or stenosis
  - Neoplasm (exostosis)
  - Cholesteatoma
  - Cerumen impaction
- Disorders of tympanic membrane
  - Chronic inflammation
  - Recurrent inflammation and healing (myringosclerosis)
  - Perforation
- Disorders of middle ear
  - Congenital
  - Inflammation and infection (effusion)
  - Neoplasm (glomus tympanicum tumor)
  - Trauma (ossicular disruption, hemotympanum)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Thin bone algorithms demonstrate the location and extent of middle ear neoplasms (rather than tumor enhancement) to allow the diagnosis
   - Contrast-enhanced imaging with soft-tissue algorithms is useful to evaluate extratemporal extension of tumors
2. **Magnetic resonance imaging**
   - Thin-section, T2-weighted images may highlight the presence and extension of inflammatory and neoplastic abnormalities

Hearing Loss: Sensorineural

Sites of Dysfunction

- Neuroepithelial hair cells of cochlea (sensory loss)

- Neurons of spiral ganglion and central auditory pathways (neural loss)

Note: Hearing loss may have associated vestibular symptomatology.

Audiometry and careful clinical examination are essential to distinguish conductive from sensorineural hearing loss.

Common Causes

- Congenital (genetic abnormalities, intrauterine exposure to drugs, toxins, infection)
- Infection (viral, mumps, syphilis, labyrinthitis ossificans)
- Neoplasm (acoustic schwannoma, meningioma, meningeal carcinomatosis, metastasis, epidermoid)
- Trauma (cochlear “concussion,” fracture through labyrinth or internal auditory canal)
- Autoimmune (systemic lupus erythematosus, Wegener's granulomatosis, polyarteritis nodosa, Cogan's syndrome, sarcoidosis)
- Vascular (compromise of inner ear blood supply, sickle cell disease)
- Metabolic (hypothyroidism, diabetes mellitus)
- Multiple sclerosis (brain stem)

Approach to Diagnostic Imaging

TEENAGER/ADULT

1. **Magnetic resonance imaging**
   - Best modality for demonstrating small tumors, abnormal labyrinth signal intensity, leptomeningeal enhancement, and brain parenchymal disease
   - Routine use of thin-section axial and coronal images using T1- and T2-weighted and enhanced T1-weighted images
2. **Computed tomography**
   - Indicated for patients with trauma or suspicion of labyrinth dysplasia
   - Thin-section axial and coronal images using bony algorithms

INFANT/CHILD

1. **Computed tomography**
   - Preferred modality for showing inner ear dysplasia

     Caveat: Be aware of radiation dosage.
2. **Magnetic resonance imaging**
   - Indicated for patients with suspected brain parenchymal disease who have a normal CT scan

Hearing Loss: Mixed

Sites of Dysfunction

- Combination of sensorineural and conductive hearing loss

Common Causes

- Otosclerosis
- Osteogenesis imperfecta
- Paget's disease
- Osteopetrosis (marble-bone disease)
- Engelmann's disease (progressive diaphyseal dysplasia)
- Pyle's disease (craniometaphyseal dysplasia)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Thin bone algorithms are employed to detect conductive component
   - Contrast-enhanced imaging with soft-tissue algorithms of the internal auditory canal and brain are used to identify sensorineural component
2. **Magnetic resonance imaging**
   - Utilize 3-mm sections in the axial and coronal planes
   - Infusion of contrast material is helpful for defining small tumors in the internal auditory canal region and multiple schwannomas

Proptosis

Presenting Signs and Symptoms

- Anterior displacement of the globe (exophthalmos)

- Redness and irritation of the eye

Common Causes

- Trauma
- Graves' disease (thyroid ophthalmopathy)
- Orbital neoplasm
- Orbital inflammatory disease

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Procedure of choice for detecting fracture, retrobulbar hematoma, radiopaque foreign body, or abnormality of the globe
   - Detection of calcification often assists in improving diagnostic accuracy
   - Provides excellent visualization of extraocular muscles, orbital apex, and orbital vasculature
2. **Magnetic resonance imaging**
   - Indicated if CT is equivocal or if there is clinical suspicion of intracranial extension of an orbital abnormality, carotid–cavernous mass, or carotid–cavernous fistula

     Caveat: MRI is *contraindicated* if there is evidence or strong suspicion of metallic foreign bodies in or around the orbits.

Seizure Disorder (Epilepsy)

Presenting Signs and Symptoms

- Sudden brief attacks of altered consciousness, motor activity, sensory phenomena, or inappropriate behavior

Common Causes

- Congenital or developmental brain defects (usual onset of seizures at an early age)
- Idiopathic (typically begins between ages 2 and 18)
- Acute infection (febrile convulsion in child)
- Trauma
- Brain tumor
- Metabolic disturbance (hypoglycemia, uremia, hepatic failure, electrolyte abnormality)
- Toxic agent (lead, alcohol, cocaine)
- Cerebral infarction or hemorrhage
- Mesial temporal sclerosis

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Most sensitive technique for detecting underlying cerebral abnormality (indicated in all adults with an unexplained first seizure)
   - Follow-up MRI (at 3 to 6 months) is often of value if the initial examination failed to detect a source of the seizure disorder

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Note: Examination consists of a routine brain study plus high-resolution, thin-section (2–3 mm) coronal T2-weighted images.

2. **Positron emission tomography**
   - Using F-18 deoxyglucose, this modality improves localization of the seizure focus, particularly in a patient with complex partial (temporal lobe), medically intractable seizures who has had a normal MRI scan
3. **Computed tomography**
   - Noncontrast scan is recommended as the initial study if the patient is in the immediate postictal state, or if residual neurologic deficit is present at the time of imaging
   - Less sensitive than MRI

Note: In pediatric patients, contrast enhancement is generally not required because congenital anomalies, rather than tumor, are the most common structural cause of seizures.

Tinnitus

Presenting Signs and Symptoms

- Perception of sound in the absence of an acoustic stimulus (ringing, buzzing, roaring, whistling, hissing) that may be intermittent, continuous, or pulsatile
- Often associated with hearing loss

Common Causes

- Virtually any ear disorder (obstruction, infection, cholesteatoma, neoplasm, eustachian tube obstruction, otosclerosis)
- Cerebellopontine angle tumor
- Drugs (salicylates, quinine, alcohol, certain antibiotics and diuretics)
- Cardiovascular disease (hypertension, arteriosclerosis, aneurysm)
- Trauma

Approach to Diagnostic Imaging

1. **Computed tomography (temporal bone)**
   - Preferred study for showing morphologic abnormality of ear bones

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Note: Thin (1.5 mm) sections in axial and coronal planes are required.

2. **Magnetic resonance imaging**
   - If CT fails to detect a cause of symptoms, high-resolution, thin-section MRI is the preferred study for demonstrating small tumors (e.g., neurinoma) of the intracanalicular portion of the 8th cranial nerve as well as vascular abnormalities in the region of the cerebellopontine angle
   - Contrast infusion is often used, but may be unnecessary if thin-section (2–3mm), axial, and coronal T1-weighted and coronal T2-weighted fast spin-echo images are obtained

Transient Ischemic Attacks

Presenting Sign and Symptom

- Focal neurologic deficit that resolves fully within 24 hours (sudden onset and brief duration)

Common Causes

- Plaques or atherosclerotic ulcers involving the carotid or vertebral arteries in the neck
- Emboli arising from mural thrombi in a diseased heart

Approach to Diagnostic Imaging

Note: The results of two clinical trials indicate the need to accurately detect carotid artery stenosis: (1) NASCET confirmed the value of carotid endarterectomy for stenosis (>70%) to prevent stroke and improve quality of life; (2) ACAST suggested surgery to prevent stroke for carotid stenosis (>60%).

1. **Duplex, color-flow Doppler ultrasound**
   - Accurate noninvasive screening study that combines high-resolution, real-time imaging of the carotid arteries with hemodynamic information about blood flow velocity provided by the Doppler technique
   - When used with MRA, may obviate the need for presurgical arteriography

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Note: Other noninvasive tests (ophthalmodyna-mometry, oculoplethysmography) are not indicated because they cannot accurately detect carotid plaques and ulcerations.

2. **Magnetic resonance angiography**
   - Accurate noninvasive screening study for detecting not only disease of the carotid bifurcation but also narrowing of the vertebral arteries
   - Reconstitution sign (flow gap) confirms >60% stenosis (i.e., surgical disease).
   - If surgery is contemplated, brain MR imaging and angiography can complete the diagnostic workup and preclude the need for catheter arteriography
   - Contrast-enhanced MRA facilitates visualization of the aortic arch and the origins of the carotid and vertebral arteries
3. **Echocardiography**
   - Indicated to detect mural thrombi in the heart if no carotid lesion has been identified that could explain the patient's symptoms
4. **Intraarterial digital subtraction angiography**
   - Invasive study that provides the highest-resolution images of intraluminal vascular pathology
   - Indicated prior to surgical intervention if US demonstrates a high-grade stenosis or ulcerated plaque in the carotid artery
5. **Computed tomography angiography**
   - Requires infusion of iodinated contrast material
   - Most often utilized in the acute setting or for individuals who are too claustrophobic for an MRA examination to be performed

Vertigo

Presenting Signs and Symptoms

- Impression of movement in space or of objects, loss of equilibrium, nausea, vomiting, nystagmus

Common Causes

- Labyrinthine or middle ear infection or tumor
- Head trauma
- Toxic agent (alcohol, opiates, streptomycin)
- Meniere's disease
- Cerebellopontine angle tumor (neurinoma, meningioma, metastasis, epidermoid)
- Transient vertebrobasilar ischemic attacks
- Motion sickness
- Multiple sclerosis (focal brain stem lesion)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred study for detecting abnormalities of the posterior fossa and cerebellopontine angle (using high-resolution and thin-sections)
   - Contrast enhancement is helpful for detecting a small acoustic neurinoma

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Note: If paramagnetic contrast material is not used, an additional thin-section, coronal T2-weighted fast spin-echo sequence should be obtained.

2. **Computed tomography**
   - Indicated if middle ear pathology is suspected

Note: Thin-section (1.5 mm) scanning in the axial and coronal planes using a bone-highlighting algorithm is required.

Visual Loss (Unilateral Optic Nerve Impairment)

Presenting Signs and Symptoms

- Purely monocular visual loss
- Normal ocular examination (or only optic atrophy) of both the symptomatic and asymptomatic eye

Common Causes

- Optic neuritis (e.g., in association with multiple sclerosis)
- Ischemic optic neuropathy
- Compressive–infiltrative optic neuropathies (optic nerve glioma, lymphoma, leukemia, sarcoidosis)
- Extrinsic compression by orbital mass (meningioma, metastasis)
- Orbital pseudotumor
- Thyroid ophthalmopathy

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Axial 3-mm axial sections provide clear distinction of the optic nerves, extraocular muscles, and the globe, as well as calcification
   - Because CT is superb for detecting the presence of calcification (very useful in the differential diagnosis of orbital masses) and orbital fat provides excellent contrast, some recommend this modality as the initial and often the definitive imaging study for orbital pathology.
2. **Magnetic resonance imaging**
   - Has the advantage of multiplanar imaging

Note: Contrast enhancement and fat suppression generally are required to detect orbital masses.

Visual Loss (Optic Chiasm Lesion)

Presenting Signs and Symptoms

- Bitemporal visual-field defects (although deficit may be substantially greater in one eye than in the other)

Common Causes

- Pituitary tumor
- Parasellar mass (meningioma, craniopharyngioma, aneurysm)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred study for detecting a lesion compressing the optic chiasm because of its ability to image the sella and parasellar regions in the axial, coronal, and sagittal planes
   - Can clearly demonstrate the entire course of the optic nerves, optic chiasm, and optic radiations, as well as the cavernous sinuses and carotid arteries

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Note: Paramagnetic contrast enhancement is often helpful when multiple sclerosis or sarcoidosis is suspected.

Visual Loss (Postchiasmal Visual System Dysfunction)

Presenting Signs and Symptoms

- Bilateral homonymous hemianopia (visual-field defects on same side of the vertical median for each eye)
- Normal visual acuity, pupillary reflexes, and ophthalmoscopy

Common Causes

- Tumor (primary or metastatic)
- Abscess
- Infarction
- Arteriovenous malformation
- Hematoma

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred study for evaluating the optic tracts, optic radiations, and visual cortex

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Note: T1-, intermediate-, and T2-weighted axial images are usually sufficient.

DISORDERS

Infectious Processes

Brain Abscess

Presenting Signs and Symptoms

- Headache
- Nausea, vomiting
- Papilledema
- Lethargy
- Seizures
- Focal neurologic deficits
- Fever, chills, and leukocytosis
- Underlying immune deficiency

Common Causes

- Direct extension of cranial infection (osteomyelitis, mastoiditis, sinusitis, subdural empyema)
- Penetrating trauma
- Hematogenous spread (bacterial endocarditis, intravenous drug abuse, bronchiectasis, congenital heart disease with right-to-left shunt)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Most sensitive study for detecting the typically ring-enhancing mass lesion and associated edema and mass effect
   - Superior to CT for detecting multiple brain abscesses
   - Demonstrates decreased diffusion (increased signal on diffusion-weighted imaging)
2. **Computed tomography**

- Contrast-enhanced study can identify the high-attenuation capsule surrounding the hypodense necrotic center (if MRI is not available)

Central Nervous System Manifestations in AIDS

Presenting Signs and Symptoms

- Spectrum of neurologic deficits depending on region and extent of involvement

Common Causes

- HIV encephalitis
- Cytomegalovirus
- Toxoplasmosis
- Cryptococcosis
- Lymphoma (primary CNS)
- Progressive multifocal leukoencephalopathy (PML)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Most sensitive imaging study in symptomatic patients for demonstrating single or multiple lesions of abnormal signal intensity or diffuse changes in the deep white matter
   - If nonenhanced MRI is positive, contrast enhancement is helpful in differentiating abscess and lymphoma (enhancing) from HIV encephalitis and PML (nonenhancing)
   - Elevated choline and lipid/lactate peaks on proton spectroscopy suggest lymphoma

HIV Encephalopathy

Presenting Signs and Symptoms

- Progressive encephalopathy, somnolence, slow speech, word-finding difficulty, flat affect, and diminished attention in an HIV-positive patient

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - In addition to showing central atrophy out of proportion to the patient's age, this modality is the most sensitive for demonstrating high-signal lesions (on T2-weighted images) that are focally or diffusely distributed throughout the deep white matter
   - Demonstrates decreased signal intensity on T1-weighted images in the clivus and prominent lymphoid tonsillar tissue

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Note: Although there is poor correlation between the extent of atrophy and the severity of dementia in AIDS, symptomatic HIV-positive patients are more than three times as likely to have abnormal MRI examinations. Routine MRI screening of neurologically asymptomatic HIV-positive patients is *not* cost-effective. When an abnormality is found on nonenhanced MRI, paramagnetic contrast material assists in distinguishing HIV encephalitis and PML (which do *not* enhance) from abscess and primary CNS lymphoma (which *do* enhance).

Acute Bacterial Meningitis

Presenting Signs and Symptoms

- Prodromal respiratory illness, or sore throat, headache, stiff neck, fever, vomiting, seizures, impaired consciousness

Common Organisms

- Meningococci, *Haemophilus influenzae* type b, pneumococci, gram-negative organisms

Common Causes

- Extension from nearby infected structures (sinuses, mastoid air cells)
- Communication of cerebrospinal fluid with exterior (penetrating trauma, myelomeningocele, spinal dermal sinus, neurosurgical procedures)

Approach to Diagnostic Imaging

Note: The most important role of imaging is to exclude a mass (abscess) prior to performance of a lumbar puncture (the primary diagnostic test).

1. **Computed tomography (head)**
   - Contrast scans may demonstrate characteristic enhancement of the subarachnoid spaces, in addition to small ventricles and effacement of the sulci secondary to cerebral edema
   - May demonstrate the underlying cause for the development of meningitis (brain abscess, sinus or mastoid infection, congenital anomaly)

Note: MRI may be normal in patients with meningitis if contrast material is not used.

Caveat: Because acute bacterial meningitis (especially meningococcal) can be rapidly lethal, use of antibiotics should not be delayed pending results of diagnostic tests.

Subacute/Chronic Meningitis

Presenting Signs and Symptoms

- Similar to acute bacterial meningitis (but developing over weeks rather than days)

Common Causes

- Chronic infection (fungal, tuberculosis, syphilis, amebic)
- Immunosuppressive therapy
- AIDS
- Neoplasm (leukemia, lymphoma, melanoma, carcinomas, gliomas)
- Sarcoidosis
- Ruptured dermoid
- Lyme disease

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Contrast scans are required to demonstrate the characteristic enhancement of the subarachnoid spaces, as well as an underlying neoplasm
   - Can demonstrate associated brain edema, abscess, or neoplasm, as well as inflammation of the paranasal sinuses or mastoids
   - Superior to CT for evaluating complications of meningitis such as subdural empyema, dural venous thrombosis, infarction, and abscess
2. **Plain chest radiograph**
   - Indicated to search for evidence of underlying tuberculosis or sarcoidosis

Subdural Empyema

Presenting Signs and Symptoms

- Headache
- Lethargy
- Vomiting
- Fever
- Focal neurologic deficits
- Seizures
- Often rapid clinical deterioration (an emergency condition)

Common Causes

- Extension from nearby infected structure (sinusitis, ear infection, osteomyelitis, brain abscess)
- Penetrating trauma
- Surgical drainage of a subdural hematoma
- Bacteremia (especially from pulmonary infection)

Approach to Diagnostic Imaging

1. **Computed tomography or magnetic resonance imaging**
   - Demonstrates characteristic crescentic or lentiform extra-axial fluid collection that is of low attenuation on CT and mildly hyperintense to CSF on T2-weighted MRI
   - Contrast studies show an intensely enhancing surrounding membrane

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Note: Subdural empyema is far easier to visualize using MRI (because it can be extremely difficult on CT to detect the extracerebral collection adjacent to the skull unless wider windowing is used).

Neoplastic Processes

Acoustic Neurinoma

Presenting Signs and Symptoms

- Hearing loss (sensorineural)
- Tinnitus
- Dizziness and unsteadiness

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred study for detecting abnormalities of the cerebellopontine angle and posterior fossa
   - May identify small intracanalicular tumors because of their intense contrast enhancement

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Note: A thin-section, multiplanar, high-resolution study is required.

2. **Computed tomography**
   - Indicated if there is conductive hearing loss to evaluate bony abnormality in the petrous portion of the temporal bone

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Note: Thin sections with bone windows are required.

Brain Tumor

Presenting Signs and Symptoms

- Slowly progressive focal neurologic deficits (depending on the site of the lesion)
- Nonfocal symptoms due to increased intracranial pressure
- Seizures
- Mental symptoms (drowsiness, lethargy, personality changes, impaired mental faculties, psychotic episodes)
- Signs of herniation

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred screening technique for detecting and characterizing intracranial masses (may not require contrast infusion)
   - Surgical planning or tumor biopsy can be performed using an MRI-compatible stereotaxic frame
   - Potentially improved specificity using proton spectroscopy

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Note: CT is only indicated to demonstrate bone erosion (especially at the skull base) and intramass calcification (although gradient-recalled echo sequences increase the sensitivity of MRI to calcification), as well as for CT-guided biopsy.

Epidural Spinal Metastases

Presenting Signs and Symptoms

- Back pain
- Progressive weakness and sensory symptoms (numbness and paresthesias)
- Bowel and bladder dysfunction
- Corticospinal tract signs

Common Primary Neoplasms

- Lung
- Breast
- Prostate
- Melanoma
- Lymphoma
- Kidney
- Gastrointestinal tract

Approach to Diagnostic Imaging

1. **Plain spinal radiograph**
   - Demonstrates single or multiple, lytic or blastic lesions or compression fractures in 60–85% of patients with epidural metastases
   - Ineffective for detecting early metastases because about 50% of cancellous bone in the region must be

destroyed before lytic lesions show on plain radiographs

2. **Magnetic resonance imaging**
   - Most sensitive technique that can simultaneously demonstrate the bone marrow abnormalities of vertebral metastases (hypointense on T1-weighted images and hyperintense on T2-weighted scans) and epidural extension effacing and displacing the spinal cord and nerve roots

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Note: Differentiation of benign from malignant causes of vertebral body fracture can be accomplished by MRI. Factors consistent with malignancy include complete (or nearly so) tumor replacement of marrow in vertebral bodies and posterior elements, multilevel involvement, and paravertebral masses.

Caveat: Contrast enhancement may obscure evidence of destructive changes in the vertebral bodies. Always perform a nonenhanced T1-weighted sagittal image sequence.

Intracerebral Metastases

Presenting Signs and Symptoms

- Headache
- Focal neurologic deficits
- Drowsiness
- Papilledema
- Seizures

Common Primary Neoplasms

- Lung
- Breast
- Melanoma
- Gastrointestinal tract
- Kidney
- Thyroid

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Nonenhanced MRI is extremely sensitive for detecting brain metastases (predominantly located at the gray–white junction)
   - Contrast enhancement makes this modality even more sensitive for detecting brain metastases
   - Associated vasogenic edema, seen on T2-weighted images, consists of pure edema with no tumor extension

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Note: Enhanced CT is limited by artifacts in the temporal lobes and posterior fossa.

Pineal Region Tumors

Presenting Signs and Symptoms

- Precocious puberty (especially in boys)
- Paralysis of upward gaze (Parinaud's syndrome relating to compression of tectal plate)
- Noncommunicating hydrocephalus (due to obstruction at the aqueduct of Sylvius)
- Papilledema and other signs of increased intracranial pressure

Common Causes

- Germinoma
- Teratoma
- Glioma

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Most sensitive study for detecting a neoplasm in the pineal region, but rarely specific enough to provide a histologic diagnosis (except for the heterogeneous appearance of intratumoral fat and calcium in a teratoma)
   - Combination of axial and sagittal images permits visualization of even small tumors. Obstruction of the aqueduct may obliterate the normal pulsatile signal void
   - A benign pineal cyst may measure up to 25 mm and have a signal intensity not precisely the same as that of cerebrospinal fluid. The benign nature of the lesion is confirmed by the absence of obstructive hydrocephalus and the unchanging size on serial examinations

Caveat: Enhancement may occur normally in the pineal region. This appearance should *not* be mistaken for tumor enhancement.

Vascular Disorders

Acute Brain Infarction (Stroke)

Presenting Signs and Symptoms

- Abrupt, dramatic onset of focal neurologic deficit that does not resolve within 24 hours
- Possible headache or seizure

Common Causes

- Infarction (secondary to an embolism from the heart or extracranial circulation or to hemorrhage)
- Narrowing of intracranial or extracranial artery (atherosclerosis, thrombus, dissection, vasculitis)
- Thrombus of the cerebral venous system
- Rupture of an aneurysm or arteriovenous malformation (causing subarachnoid hemorrhage or intracerebral hematoma)
- Decreased perfusion pressure or increased blood viscosity with inadequate blood flow reaching the brain

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred initial procedure for assessing a suspected acute stroke because it can:
   - Rule out hemorrhage (subarachnoid or intracerebral)
   - Define patterns of ischemic injury
   - Show areas of abnormal vascular calcification (e.g., giant aneurysm)
   - Exclude a mass lesion

Note: The above information is critical for the clinician faced with determining the need for lumbar puncture, vascular surgery, anticoagulation, or other therapies.

2. **Magnetic resonance imaging**
   - The combination of nonenhanced MR imaging and angiography is more sensitive than CT for detecting infarction and ischemic edema (especially involving the brainstem), clearly delineating an occluded or stenotic artery or vein, and distinguishing hemorrhagic from ischemic infarction

   Caveat: Arteriography is indicated *only* if noninvasive studies suggest an underlying aneurysm or AVM *and* a surgical or interventional radiologic procedure is seriously being considered.

3. **Diffusion-weighted magnetic resonance imaging**
   - This most sensitive marker of acute infarction is generally positive within 2 hours of the clinical event and thus plays a critical diagnostic role
   - The hyperintense signal (hypointensity on ADC map) is possibly related to cytotoxic (intracellular) edema
   - A negative study is highly predictive for excluding an acute brain infarction and thus is valuable in directing further diagnostic and therapeutic planning

Intraparenchymal Cerebral Hemorrhage

Presenting Signs and Symptoms

- Abrupt onset of headache followed by steadily increasing neurologic deficits
- Loss of consciousness
- Nausea, vomiting
- Delirium
- Focal or generalized seizures
- Signs of transtentorial herniation

Common Causes

- Trauma
- Hypertensive hematoma (common locations: putamen-external capsule, caudate, thalamus, pons, cerebellum, cerebral hemisphere)
- Congenital aneurysm or arteriovenous malformation
- Amyloid angiopathy (causes polar hemorrhage)
- Mycotic aneurysm
- Blood dyscrasia (bleeding diathesis)
- Collagen disease
- Hemorrhagic infarction (arterial or venous)
- Metastases (e.g., melanoma)
- Glioblastoma multiforme
- Cavernous malformations

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred imaging technique for detecting a focal region of increased attenuation within the brain parenchyma in *acute* trauma, suspected aneurysm rupture (because of superior detection of subarachnoid hemorrhage and patient comfort), or hypertensive episode

     Caveat: Although it is unusual, CT may at times fail to detect subarachnoid blood found at lumbar puncture.

2. **Magnetic resonance imaging**
   - Preferred study for detecting *subacute* and *chronic* stages of intraparenchymal hemorrhage
   - Hemosiderin- or ferritin-laden macrophages that develop due to prior bleeding appear as hypointense foci on T2-weighted images, persist throughout the patient's life, and are best seen on gradient echo images
   - MR angiography or venography may prove helpful for detecting aneurysms, arteriovenous malformations, or venous occlusions
3. **Arteriography**
   - Remains the “gold standard” for imaging suspected aneurysms or arteriovenous malformations and also provides a therapeutic portal
   - Best modality for visualizing narrowing of branch vessels due to arteritis

Subarachnoid Hemorrhage

Presenting Signs and Symptoms

- Sudden onset of excruciating headache
- Rapid loss of consciousness
- Vomiting
- Severe neck stiffness (usually not present initially but occurring within 24 hours)
- Progressive palsies (reflecting pressure effects on the 3rd, 4th, 5th, and 6th cranial nerves)

Common Causes

- Trauma
- Rupture of congenital intracranial aneurysm
- Arteriovenous malformation
- Mycotic aneurysm (in patients who have infective endocarditis or systemic infection or are immunocompromised)
- Blood dyscrasia (bleeding diathesis)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred study for demonstrating acute subarachnoid hemorrhage
   - Initial noncontrast scan to detect the presence of high-attenuation blood in the subarachnoid space
   - Subsequent contrast-enhanced CT or MRI/MRA may detect the underlying aneurysm or vascular malformation

     Caveat: Lumbar puncture to demonstrate blood in the subarachnoid space is indicated *only* if CT fails to make the diagnosis *and* shows no evidence of a mass or obstructive hydrocephalus (lest herniation occur).

2. **Arteriography**
   - Indicated to localize and characterize the anatomy of an aneurysm or arteriovenous malformation
   - If there is an aneurysm, must also evaluate for vasospasm

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Note: Must selectively catheterize (or, less optimally, reflux contrast material into) both carotid and both vertebral arteries.

3. **Magnetic resonance imaging**
   - Relatively insensitive to subarachnoid hemorrhage in the *acute* stage
   - Superior to CT for demonstrating chronic blood staining of the meninges (hemosiderosis)
   - Role of MRA in aneurysm detection is emerging, although the “gold standard” remains selective catheter arteriography

Cerebral Aneurysm

Presenting Signs and Symptoms

- Asymptomatic
- Signs of intraparenchymal or subarachnoid hemorrhage (if rupture)
- Compression of cranial nerves or brain parenchyma (if large)

Common Causes

- Congenital (berry aneurysm)
- Atherosclerosis
- Mycosis
- Trauma

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Detects subarachnoid hemorrhage and intracerebral hematoma in the acute setting
2. **Arteriography**
   - If cerebral aneurysm is suggested by CT or MRI evidence of intraparenchymal or subarachnoid hemorrhage, arteriography can:
     - Identify the presence of any and all aneurysms
     - Delineate the relationship of a given aneurysm to the parent vessel and adjacent penetrating branches
     - Define the potential for collateral circulation to the brain
     - Assess for vasospasm
3. **Computed tomography or magnetic resonance imaging**
   - Can demonstrate a patent suprasellar aneurysm as an intensely enhancing mass (CT) or as a high-velocity flow void with signal heterogeneity due to turbulence (MRI)
4. **Magnetic resonance angiography or computed tomography angiography**
   - Demonstrates the parent artery and the size and orientation of the neck and dome of the aneurysm
   - Useful screening study in asymptomatic patients, as well as in those with a family history of aneurysms or a familial disorder associated with cerebral aneurysms

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Note: Future technical refinements will permit detection of progressively smaller aneurysms.

Arteriovenous Malformation

Presenting Signs and Symptoms

- Asymptomatic
- Sudden headache and neurologic deficits (secondary to intraparenchymal or subarachnoid hemorrhage)
- Focal seizures (incited by the lesion)
- Progressive focal neurologic sensorimotor deficit (due to enlarging arteriovenous malformation acting as a mass or progressive ischemic lesion)
- May have arterial bruit detectable on the overlying cranial vault

Common Cause

- Congenital tangle of dilated blood vessels with direct flow from arterial afferents into venous efferents

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Demonstrates AVMs as tangled flow voids with prominent feeding and draining vessels
   - Superior to CT for demonstrating *subacute* and *chronic* hemorrhage and secondary changes (mass effect, edema), as well as ischemic changes in the adjacent brain
   - Optimal for detecting low-flow and angiographically occult vascular malformations (cavernous angioma, telangiectasia, venous angioma)

Note: Gradient echo MRI is the most sensitive method for detecting even small, chronic, subtle foci of blood.

2. **Arteriography**
   - Required to precisely demonstrate the anatomic blood supply and drainage prior to any surgical or neurointerventional procedure
   - Can distinguish among pial, dural, and mixed types of AVMs

Lacunar Infarction

Presenting Sign and Symptom

- Focal neurologic deficit that can be pinpointed to a locus less than 15 mm in diameter

Common Causes

- Embolic, atherosclerotic, or thrombotic lesions in long, single, penetrating end-arterioles supplying the deep cerebral white matter, thalamus, basal ganglia-capsular region, and pons

- Hypertension (common)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - *Only* modality that can consistently demonstrate the well-delineated round or slit-like lesions that are hypointense to brain on T1-weighted images and hyperintense to brain on intermediate and T2-weighted images
   - Diffusion-weighted imaging is extremely helpful in distinguishing acute from chronic lacunae

> **Note:** Because of their small size, most true lacunar infarctions are difficult to see on CT scans.

   - Magnetic resonance angiography is usually negative because of the involvement of small blood vessels (arterioles), but it can detect occlusion of a parent artery (e.g., middle cerebral artery occlusion causing infarction in the distribution of the lenticulostriate perforators) when the lacunar distribution of the infarction is larger than expected

Trauma

Acute Head Trauma

Presenting Signs and Symptoms

- Focal neurologic deficits (caused by intracerebral and extracerebral hematomas)
- Generalized or focal cerebral edema that may lead to symptoms of herniation (through tentorium or foramen magnum)
- Concussion (post-traumatic loss of consciousness)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred study for detecting skull fracture, *acute* intraparenchymal bleeding, and extra-axial hemorrhage (acute subdural and epidural hematoma)
   - The use of wider windows improves ability of CT images to delineate isodense extracerebral hematoma
   - Demonstrates ventricular shift and sulcal effacement, subtle findings that should raise suspicion of an isodense subdural hematoma
2. **Magnetic resonance imaging**
   - Indicated only in those unusual cases in which CT has failed to detect an abnormality in the presence of strong clinical suspicion of intracranial hemorrhage (primarily in the posterior fossa or high on the convexity, areas in which CT may be limited because of overlying bone)
   - Particularly valuable in *subacute* and *chronic* phases of head trauma to define temporal and inferior frontal lobe hemorrhagic contusion and edema, as well as shear injuries (subtle hemorrhage seen as low signal on gradient echo images) at the gray–white junctions and posterior corpus callosum

> **Note:** There is *no* indication for plain skull radiography in this condition. The mere detection of a skull fracture generally has little effect on subsequent medical or surgical management. In addition, skull fractures usually are easily recognizable on CT, which can also delineate any accompanying abnormality in the underlying brain.

Epidural Hematoma

Presenting Signs and Symptoms

- Symptoms developing within minutes or hours after injury (often after a lucid interval of relative neurologic normalcy)
- Increasing headache, deterioration of consciousness, motor dysfunction, and pupillary changes indicate an *emergency* situation

Common Cause

- Trauma (causing arterial laceration in the epidural space)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred study for demonstrating the characteristic appearance of a collection that is hyperintense hemorrhage convex to the brain that is located in the temporal region (middle meningeal artery) and often associated with a skull fracture

> **Note:** There is *no* indication for plain skull radiographs in this condition.

Acute Subdural Hematoma

Presenting Signs and Symptoms

- Progressive neurologic deterioration with signs of herniation
- Progressive loss of consciousness
- Hemiplegia

Common Cause

- Head trauma

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Preferred study for detecting the characteristically hyperintense, medially concave, lenticular extraaxial collection of blood in the subdural space

     Caveat: Thin subdural hematomas may be obscured by overlying bone (especially if they are located high on the convexity). Subfrontal or subtemporal hematomas may be difficult to detect on axial views and may require coronal reformatting or direct coronal imaging.
   - Effacement of cortical sulci on three or more adjacent images
   - Hematoma may be isodense if the hematocrit is less than 30 mL/dL
2. **Magnetic resonance imaging**
   - Not as sensitive for detecting acute bleeding, but ability of MRI to directly obtain coronal images may be of value if CT fails to demonstrate a subdural hematoma in the face of strongly suggestive clinical findings

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Note: There is no indication for plain skull films in this clinical setting.

Chronic Subdural Hematoma

Presenting Signs and Symptoms

- History of head trauma (2 to 4 weeks or more prior to clinical presentation) that may have been relatively trivial and forgotten
- Increasing headache
- Fluctuating drowsiness or confusion
- Mild-to-moderate hemiparesis
- Typically occurs in alcoholics and patients older than age 50

Common Cause

- Head trauma

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred study for detecting hemorrhages more than a few days old as hyperintense lesions on both T1- and T2-weighted sequences
   - Of particular value in detecting hemorrhages in the posterior fossa and high on the convexity (difficult areas for CT because of bone artifacts)
   - Clearly defines secondary findings (brain contusion or hematoma, axonal shear injury at the gray–white junction and posterior corpus callosum, occipital infarction secondary to prior transtentorial herniation, communicating hydrocephalus, atrophy)
   - Subtle axonal shear injuries may only be detected on gradient echo pulse sequences

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Note: Unlike CT, where hemorrhage becomes isodense after several weeks and thus may be impossible to recognize, hemorrhage on MRI remains hypointense for the lifetime of the patient.

Blow-Out Fracture of the Orbit

Presenting Signs and Symptoms

- History of trauma
- Extraocular eye movement abnormality

Approach to Diagnostic Imaging

1. **Plain radiograph (Waters view)**

- Preferred screening study for showing bony discontinuity and the presence of a soft-tissue mass in the superior aspect of the maxillary antrum

2. **Computed tomography (axial and coronal)**
   - Definitive studies for showing the fracture and the extent of herniation of orbital tissues through the defect into the superior aspect of the maxillary antrum

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Note: If a blow-out fracture is suspected clinically, CT can be the initial imaging procedure (omitting plain radiography).

Facial Fracture

Presenting Signs and Symptoms

- Facial swelling and ecchymoses

Approach to Diagnostic Imaging

1. **Plain radiograph**
   - Preferred screening study for demonstrating facial fractures (most commonly involving the nose, zygomatic arches, lateral walls of the maxillary antra, and floors of the orbits)
2. **Computed tomography**
   - Indicated if plain radiographs demonstrate a complex fracture that must be defined or suggest a blow-out fracture of the floor of the orbit

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Note: Both axial *and* coronal 3-mm-section scans are usually required for full evaluation.

Temporal Bone Fracture

Presenting Signs and Symptoms

- Various symptoms depending on the fracture site (hearing loss, vertigo, nystagmus, facial paralysis)
- Hemorrhage behind the tympanic membrane

Common Cause

- Trauma

Approach to Diagnostic Imaging

1. **Computed tomography**
   - In addition to demonstrating the lucent fracture line (often requiring thin cuts), CT may show secondary signs of fracture such as fluid within the mastoid air cells or tympanic cavity, intracranial gas, gas within the temporomandibular joint, and disruption of the ossicular chain

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Note: Always check the temporomandibular fossa for dislocation.

Cervical Spine Trauma

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph**
   - Preferred initial screening procedure that is quickly and inexpensively performed without significant disruption of other resuscitation efforts

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Note: Cross-table lateral view is generally obtained first, to avoid moving a patient who might have a cervical fracture; if it appears normal, additional films (including odontoid, oblique, flexion, and extension views) may be obtained.

Caveat: It is absolutely *imperative* that all seven cervical vertebral bodies be seen, to avoid missing a lower cervical spine fracture obscured by the shoulders. If the entire cervical spine is not seen, the film must be repeated with the shoulders lowered.

2. **Computed tomography**
   - Indicated if plain skeletal radiographs are equivocal, fail to adequately image portions of the spine, or show a complex fracture of the cervical spine (especially involving the foramen transversarium housing the vertebral artery, which may be compromised by cervical trauma)
   - May be required in a trauma victim whose plain films are negative but who has substantial neck pain or neurologic deficits
3. **Magnetic resonance imaging**
   - Best procedure for detecting cord contusion and edema (and its sequela, myelomalacia), herniated disk, canal

compromise, or epidural hematoma complicating trauma to the cervical spine

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Note: In a patient with suspected nerve root avulsion, either CT myelography or MRI can confirm the diagnosis.

Endocrine Disorders

Acromegaly/Gigantism

Presenting Signs and Symptoms

- Soft-tissue and bony overgrowth (increased size of hands, feet, jaw, and cranium)
- Coarsening of facial features
- Peripheral neuropathies
- Headache
- Impaired glucose tolerance

Common Cause

- Pituitary adenoma (excessive secretion of growth hormone)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred study for detecting and defining the extent of the underlying pituitary tumor (superb sensitivity and multiplanar capability)
   - Thin-section coronal and sagittal T1-weighted images should be obtained
   - Paramagnetic contrast material is generally not required for initial screening
   - Permits clear distinction of the sphenoid sinus and the position of the carotid artery for surgical planning
   - If an aneurysm is suspected on MR imaging, MR angiography is obtained

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Note: There is *no* indication for plain radiographs of the sella in this condition.

Diabetes Insipidus

Presenting Signs and Symptoms

- Excretion of excessive quantities of urine (polyuria) that is very dilute but otherwise normal
- Excessive thirst (polydipsia)
- Dehydration and hypovolemia (develops rapidly if urinary losses are not continuously replaced)

Common Causes

PRIMARY (IDIOPATHIC)

- Marked decrease in hypothalamic nuclei of neurohypophyseal system and deficient production of vasopressin (antidiuretic hormone)

SECONDARY (ACQUIRED)

- Hypophysectomy
- Cranial injury (especially basal skull fracture)
- Suprasellar and intrasellar neoplasm (primary or metastatic)
- Histiocytosis X
- Granulomatous disease (tuberculosis, sarcoidosis)
- Vascular lesion (aneurysm, thrombosis)
- Infection (encephalitis, meningitis)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred study for demonstrating any underlying lesion of the hypothalamus, pituitary gland, or pituitary stalk (superb sensitivity, multiplanar capability)

Note: High-resolution, thin-section study is required; contrast enhancement improves sensitivity.

Galactorrhea/Amenorrhea

Presenting Signs and Symptoms

WOMEN

- Galactorrhea
- Menstrual disturbances
- Infertility
- Symptoms of estrogen deficiency (hot flashes, dyspareunia)

MEN

- Loss of libido and potency
- Infertility (occasional galactorrhea or gynecomastia)

Common Causes

- Prolactinoma of pituitary gland
- Drugs (phenothiazines, antihypertensives)
- Primary hypothyroidism
- Hypothalamic/pituitary stalk disease

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred study for demonstrating the prolactin-secreting pituitary microadenoma (usually <1 cm) that is the underlying cause in about 50% of patients
   - Requires thin-section imaging in both coronal and sagittal planes

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Note: There is *no* indication for plain films of the sella in this condition.

Hypopituitarism

Presenting Signs and Symptoms

- Variable depending on which specific pituitary hormones are deficient (gonadotropins, growth hormone, thyroid-stimulating hormone, adrenocorticotropic hormone)

Common Causes

PITUITARY LESION

- Tumor (adenoma, craniopharyngioma)
- Infarction or ischemic necrosis
- Inflammatory or infiltrative process (e.g., sarcoidosis)
- Iatrogenic (irradiation or surgical removal)

HYPOTHALAMIC LESION

- Tumor
- Inflammation
- Trauma

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred study because of its superb sensitivity and ability to directly image the sella and parasellar regions in multiple planes

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Note: Paramagnetic contrast enhancement is helpful in older patients with Addison's disease and in detecting sarcoidosis. To define tiny microadenomas, imaging should begin immediately after contrast infusion to avoid obscuring a late-enhancing adenoma.

There is *no* indication for plain films of the sella in this condition.

Spinal Disorders

Herniated Nucleus Pulposus

Presenting Signs and Symptoms

- Pain in the distribution of compressed nerve roots (may be sudden and severe or more insidious)
- Pain increased by movement or Valsalva maneuver
- Paresthesias or numbness in the sensory distribution of the affected roots
- Reduced or absent deep tendon reflexes in the distribution of involved nerve roots
- Weakness and eventual atrophy of muscles supplied by affected nerves
- Positive straight leg raising test (lumbosacral region)
- Urinary incontinence or retention (from loss of sphincter function in lumbosacral involvement)
- Most common in the lower lumbosacral and lower cervical regions

Common Cause

- Degenerative disk disease

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Most sensitive study for demonstrating bulging, protrusion, extrusion, or free fragmentation of disk material, as well as impingement on the spinal cord and individual spinal nerve roots
   - Can show degeneration of the disk as loss of signal on T2-weighted images (although this may be of little clinical importance)
   - Can distinguish among canal stenosis, degenerative facet overgrowth, herniated disk, and synovial cyst
   - Permits routine visualization of conus medullaris
2. **Computed tomography**
   - Useful for detecting herniated disk and canal stenosis, but limited by single imaging plane, poor visualization of the conus without intrathecal contrast material, and poor assessment of the postoperative spine

Caveat: *Plain spinal radiographs* may demonstrate disk space narrowing and hypertrophic spurring. However, they do not give any indication of whether there is critical impingement on the vertebral canal or nerve roots, and are therefore of little value when MRI or CT is employed.

***Myelography* should be reserved for special applications, often related to surgical planning.**

Sciatica

Presenting Signs and Symptoms

- Pain radiating down one or both buttocks and the posterior aspect of the leg(s) to below the knee (the distribution of the sciatic nerve)

Common Causes

- Peripheral nerve root compression (intervertebral disk protrusion or intraspinal tumor)
- Compression within the spinal canal or intervertebral foramen (tumor, osteoarthritis, spondylolisthesis)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Most sensitive study for demonstrating bulging, protrusion, extrusion, or free fragmentation of disk material, as well as impingement on the spinal cord, conus, and individual nerve roots
2. **Computed tomography**
   - Still valuable for detecting herniated disk and bony foraminal or canal stenosis
   - Disadvantages include poor visualization of the conus, inability to distinguish herniated disk from scar in the postoperative spine, essentially single axial-plane imaging, and radiation exposure

Caveat: *Plain spinal radiographs* may demonstrate disk space narrowing and hypertrophic spurring. However, they do not give any indication of whether there is critical impingement on the spinal cord or nerve roots.

***Myelography* is not indicated in the evaluation of sciatica and generally is not required if MRI or CT has been performed.**

Scoliosis

Presenting Signs and Symptoms

- Structural lateral curvature of the spine that may be suspected when one shoulder appears higher than the other or if clothes do not hang straight
- Fatigue in the lumbar region after prolonged sitting or standing that may be associated with muscular backaches

Common Causes

- Idiopathic
- Vertebral anomaly
- Hydromyelia and dysraphic states

Approach to Diagnostic Imaging

1. **Plain spinal radiograph**
   - Demonstrates the site and severity of the curvature (typically convex to the right in the thoracic area and to the left in the lumbar area so that the right shoulder is higher than the left)
2. **Magnetic resonance imaging**
   - Indicated to exclude an intraspinal abnormality if scoliosis is severe or has an early age of onset, or if plain radiographs show a vertebral anomaly
   - The cervicomedullary junction should be reviewed to detect low-lying cerebellar tissue

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Note: MRI is required to detect serious anomalies, such as tethered cord, that must be addressed before the spine undergoes mechanical straightening. Coverage from the cervicomedullary junction to the sacral level is generally needed (T1-weighted images are often sufficient).

Spinal Stenosis

Presenting Signs and Symptoms

- Pain in buttocks, thighs, or calves on walking, running, or climbing stairs, not relieved by standing still but by flexing the back, sitting, or lying down

Common Causes

- Degenerative disease (hypertrophy of facets or ligamentum flavum, disk protrusion, postoperative scarring, synovial cyst)
- Paget's disease
- Achondroplasia
- Trauma
- Severe spondylolisthesis

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging or computed tomography**
   - Demonstrate bony and soft-tissue changes causing compression of the thecal sac or spinal cord centrally, as well as encroachment on the nerve root in the neural foramen or lateral recess
   - MRI is the study of choice because of multiplanar capability and ability to better visualize the conus, while CT is superior for demonstrating bony degenerative changes

Caveat: *Plain spinal radiographs* may demonstrate disk space narrowing and hypertrophic spurring. However, they do not show whether there is critical impingement on the spinal cord or nerve roots. Disk space narrowing and vertebral body alignment are better defined using MRI.

Caveat: *Myelography* is not indicated (except in some cases for presurgical planning) to evaluate disease involving the intervertebral disks or the spinal canal. Risk of epidural injection and severe discomfort are greatest in patients with spinal stenosis.

Failed Back Syndrome

Presenting Signs and Symptoms

- No relief of neurologic symptoms after surgical procedure for herniated nucleus pulposus
- Occurs in the lumbar region in about 10–25% of patients

Common Causes

- Recurrent or residual disk
- Scarring
- Lateral or central canal stenosis
- Adhesive arachnoiditis
- Conus abnormality

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**

- Most accurate technique for making the crucial distinction between recurrent/residual disk and scar
- Scar appears hyperintense to the annulus on T2-weighted scans (recurrent disk is hypointense) and enhances homogeneously after contrast administration (chronic disk herniation may have some peripheral enhancement because of surrounding granulation tissue)
  Must be analyzed carefully for canal stenosis, far-lateral herniated disc, and conus mass

Syringomyelia/Hydromyelia

Presenting Signs and Symptoms

- Spasticity and weakness of the lower extremities
- Sensory defect (typically beginning in the cervical region and often extending to a cape-like defect over the shoulders and back)

Common Causes

- Congenital (often associated with Chiari malformation and encephalocele)
- Intramedullary tumor (if there is no associated Chiari I malformation)
- Trauma (post-traumatic syrinx or cystic myelomalacia)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Demonstrates an atrophic (chronic) or enlarged spinal cord with central cystic, haustrated cavity
   - Commonly associated with Chiari I malformation
   - Upper margin of the hydromyelia cavity is at the level of the pyramidal decussation (cephalad cervical cord)
   - If there is no Chiari malformation or the cystic central cord lesion does not respect the pyramidal decussation boundary and extends above the cervicomedullary junction, contrast infusion is indicated to detect an underlying spinal cord neoplasm (hemangioblastoma, ependymoma, astrocytoma)

Tethered Cord (Low Conus)

Presenting Signs and Symptoms

- Back pain
- Dysesthesias
- Neurogenic bladder
- Spasticity
- Congenital/developmental kyphoscoliosis

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred study for showing the low-lying (below L-2–L-3 level), posteriorly tethered conus medullaris and thickened filum terminale that may terminate in a lipoma or dermoid

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Note: MRI of the entire spine is generally performed to evaluate for hydrosyringomyelia and any abnormality at the cervicomedullary junction.

Transverse Myelitis (Acute)

Presenting Signs and Symptoms

- Sudden onset of local back pain followed by sensory symptoms and motor weakness ascending from the feet
- Urinary retention and loss of bowel control

Common Causes

- Unknown (may be related to a prior viral illness, vasculitis, intravenous use of heroin or amphetamine, multiple sclerosis, AIDS myelopathy, or dural vascular malformation)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Shows focal enlargement of the spinal cord
   - T2-weighted imaging demonstrates high signal throughout the region of involvement
   - An acute lesion shows contrast enhancement
   - Often assists in defining the etiology of a lesion by the distribution of hyperintense signal, best defined on axial T2-weighted images

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Note: The role of MRI is more to exclude treatable conditions, such as unsuspected cord compression, than to make a specific diagnosis.

Other Disorders

Anosmia

Presenting Sign and Symptom

- Loss of sense of smell

Common Causes

- Head trauma (especially in young adults)
- Viral infection (especially in older adults)
- Chronic nasal obstruction (polyps)
- Neoplasm (interfering with olfactory apparatus)
- Granulomatous disease
- Male hypogonadism (Kallmann's syndrome)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Can detect a subfrontal mass (e.g., meningioma, metastasis or direct extension from squamous cell carcinoma, esthesioneuroblastoma)
   - Used for planning prior to surgery or radiation therapy
2. **Computed tomography**
   - Can detect a neoplasm or unsuspected fracture of the floor of the anterior cranial fossa
   - Can demonstrate polyps or other neoplastic or granulomatous processes resulting in nasal obstruction

Bell's Palsy

Presenting Signs and Symptoms

- Unilateral facial paralysis (sudden onset)
- Pain behind the ear (may precede facial weakness)
- Widening of palpebral fissure (prevents closure of eye)

Common Causes

- Unknown (presumably swelling of the facial nerve due to immune or viral disease with resultant ischemia and compression of the nerve as it passes through its narrow canal in the temporal bone)
- Trauma, Schwannoma, vascular malformation, sarcoidosis

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Indicated to exclude a mass or demyelinating lesion within or adjacent to the facial nerve (from its brain stem origin to the parotid gland) if symptoms are recurrent, prolonged, progressive, or associated with dysfunction of other cranial nerves

Note: High-resolution axial and coronal imaging with contrast enhancement is required.

   - Demonstrates contrast enhancement in almost 80% of patients with clinical Bell's palsy (most commonly in the labyrinthine segment and descending facial nerve canal) that may persist past the point of clinical improvement

     Caveat: Unfortunately, the side of enhancement may not always correlate with the clinical symptoms.

Cerebrospinal Fluid Leak

Presenting Signs and Symptoms

- Leakage of CSF (identified by its glucose content) from the nose (rhinorrhea) or ears (otorrhea)

Common Causes

- Fracture with dural tear
- Communication develops between the subarachnoid space and the paranasal sinuses or the middle ear (in association with disruption of the tympanic membrane)

Approach to Diagnostic Imaging

1. **Radionuclide cisternography**
   - Procedure of choice that is extremely sensitive in demonstrating tiny amounts of radionuclide in cotton pledgets placed in the nostrils or external ears

     Caveat: This technique is unsatisfactory for localizing the precise site of leakage.
2. **Computed tomography (CT cisternography)**
   - Thin-section scanning is performed both before and after the intrathecal injection of nonionic, iodinated contrast material via lumbar puncture

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Note: Delayed imaging may be required a few hours later to detect subtle leakage.

Caveat: CSF leakage often cannot be detected even using both radionuclide and CT cister-nography.

Multiple Sclerosis

Presenting Signs and Symptoms

- Various focal neurologic dysfunctions characterized by erratic remissions and exacerbations
- Paresthesias (extremity, trunk, or face)
- Weakness or clumsiness of leg or hand
- Visual disturbances (optic neuritis)
- Abnormalities of gait and coordination

Common Causes

- Unknown (possibly viral or immune-related)
- Increased risk in persons living in northern climates (e.g., northern United States, Canada, Scandinavia) before puberty

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Most sensitive study for detecting the scattered plaques of demyelination that are hyperintense to brain on T2-weighted sequences
   - Greater specificity with lesions involving the inferior corpus callosum, white matter about the temporal horn, and middle cerebral peduncle, as well as discrete lesions in the pons or the posterior column of the cervical portion of the spinal cord

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Note: Lesions involving the optic nerve or chiasm are difficult to detect without contrast enhancement and fat suppression.

Caveat: CT should *not* be requested except in patients who are too claustrophobic to undergo MRI (since CT is not as sensitive as MRI).

Normal Pressure Hydrocephalus

Presenting Signs and Symptoms

- Dementia
- Gait disturbance
- Urinary incontinence

Common Causes

- Previous surface inflammation of the brain due to subarachnoid hemorrhage, diffuse meningitis (postulated to cause scarring of arachnoid villi over brain convexities where CSF absorption usually occurs), or meningeal carcinomatosis

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Demonstrates the dilated ventricular system (out of proportion to the degree of sulcal prominence)
   - Can exclude the various causes of noncommunicating obstructive hydrocephalus
   - Sagittal scans show thinning of the corpus callosum and decreased mamillopontine distance, as well as accentuation of the signal void in the aqueduct of Sylvius and the posterior part of the third ventricle

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Note: Distinguishing normal pressure hydrocephalus from neurodegenerative atrophy in the geriatric population is extremely difficult.

2. **Radionuclide cisternography**
   - Demonstrates “reflux” of radionuclide into the lateral ventricles and delayed clearance of isotope from the lateral ventricles and cerebral convexities (“stasis”)

Note: This can be a nonspecific finding in older patients with large ventricles and sulci.

Obstructive Hydrocephalus

Presenting Signs and Symptoms

- Headache
- Nausea, vomiting
- Drowsiness
- Diplopia, blurred vision
- Papilledema
- Palsy of the 6th cranial nerve
- Pupillary dilatation, coma, decerebrate posturing, abnormal respirations, systemic hypertension, and bradycardia (may develop if increased intracranial pressure is not controlled)

Common Sites of Obstruction and Causes

- Foramen of Monro
  - Neoplasm
- Posterior fossa (aqueduct of Sylvius, fourth ventricle, foramen of Luschka, foramen of Magendie)
  - Congenital stenosis
  - Neoplasm
  - Cerebellar infarction/hematoma
  - Posterior fossa extra-axial and Dandy-Walker cyst
- Subarachnoid spaces
  - Meningitis
  - Sarcoidosis
  - Carcinomatosis
  - Subarachnoid hemorrhage
- Other
  - Venous thrombosis
  - Choroid plexus papilloma

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Not only demonstrates the dilated ventricular system but may also demonstrate the underlying cause of obstruction to the flow of CSF in the noncommunicating type of hydrocephalus
   - Excellent for imaging lesions of the posterior fossa
   - Contrast enhancement may assist in distinguishing a congenital posterior fossa cyst from an enhancing cystic neoplasm

Optic Neuritis

Presenting Signs and Symptoms

- Visual loss (ranging from a small central or paracentral scotoma to complete blindness) that is usually unilateral
- Depressed direct pupillary light reflex
- Impairment of color vision

Common Causes

- Multiple sclerosis
- Viral illness
- Ischemia (e.g., temporal arteritis)
- Meningitis
- Syphilis
- Sarcoidosis
- Systemic lupus erythematosus

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - In addition to showing enlargement and contrast enhancement of the optic nerve (also seen on CT), MRI is the preferred study for detecting the characteristic white matter demyelination changes of multiple sclerosis (the most common cause of optic neuritis in adults)

- Fat suppression imaging best visualizes enhancement in the optic nerves

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Note: Optic neuritis may be associated with transverse myelitis (Devic's disease).

Orbital Pseudotumor

Presenting Signs and Symptoms

- Acute onset of painful proptosis, chemosis, and decreased motility of the extraocular muscles
- Usually unilateral (85%) and exquisitely sensitive to steroids

Common Causes

- Idiopathic inflammatory reaction (most likely autoimmune, but may be associated with systemic diseases such as Wegener's granulomatosis, lymphoma, fibrosing mediastinitis, thyroiditis, cholangitis, and vasculitis)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Confusing spectrum of findings includes a discrete soft-tissue mass within the retrobulbar fat and thickening and contrast enhancement of the extraocular muscles, sclera, optic nerve, and lacrimal gland

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Note: It may be difficult to distinguish orbital pseudotumor from thyroid ophthalmopathy, which (in descending order of severity) involves the inferior, medial, and superior rectus muscles.

Progressive Multifocal Leukoencephalopathy

Presenting Signs and Symptoms

- Hemiparesis
- Seizures
- Blindness
- Intellectual dysfunction
- Cerebellar or brain stem dysfunction that is relentlessly progressive

Common Causes

- Papovavirus (universal childhood infection that is reactivated in immunosuppressed patients with AIDS, leukemia, or lymphoma)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Demonstrates asymmetric focal white matter lesions in both the cerebrum and cerebellum that typically show mild or no mass effect and no contrast enhancement (blood–brain barrier remains intact)

Note: CT is not as effective in showing this primarily white matter process.

   - Absence of contrast enhancement distinguishes PML from abscess and primary CNS lymphoma

Pseudotumor Cerebri (Benign Intracranial Hypertension)

Presenting Signs and Symptoms

- Headache and papilledema (increased intracranial pressure) in an otherwise apparently healthy patient
- Partial or complete monocular visual loss in 5% (usually intact visual acuity and central visual fields)

Common Causes

- Unknown (spontaneous onset and eventual disappearance; patients are often overweight)
- In children, may follow withdrawal of steroid therapy or excessive ingestion of vitamin A or tetracycline

Risk Factors

- Obesity
- Endocrine dysfunction
- Sinovenous thrombosis
- Hematologic disorders
- Increased CSF protein

- Meningitis

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging or computed tomography**
   - Excludes a space-occupying mass or venous occlusion causing increased intracranial pressure
   - May show associated enlargement of the sella turcica and/or enlargement of the CSF spaces surrounding the optic nerve
   - Ventricles are small or normal in size

Radiation Necrosis

Presenting Signs and Symptoms

- Progression of neurologic deficit (some patients exhibit no new symptoms)
- Onset usually delayed (>6 months) after radiation

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Imaging modality of choice for demonstrating both the acute and delayed effects of therapeutic radiation
   - Relatively homogeneous, sheet-like increased signal intensity in the radiation field (radiation injury) on T2-weighted sequences
   - Heterogeneous and abnormal contrast enhancement may be present (radiation necrosis)

Note: MRI is substantially more sensitive than CT for detecting the predominantly white matter alterations caused by radiation necrosis and radiation injury.

   - Proton spectroscopy (no choline peak elevation) may distinguish radiation necrosis from recurrent glioma
2. **Positron emission tomography**
   - In the absence of clinical or radiographic criteria, imaging using ^{18}F-FDG as a marker of cellular metabolism may help distinguish recurrent or residual tumor (hypermetabolic) from areas of radiation necrosis (hypometabolic)

Note: A clear distinction is often difficult because of hypermetabolism that may be seen in radiation necrosis and the common concurrent presence of radiation necrosis and glioma.

CHAPTER 7. HEAD AND NECK

William Dillon

DISORDERS

Endocrine Disorders

Hyperparathyroidism

Presenting Signs and Symptoms

- May be asymptomatic (50%)
- Renal disease (nephrolithiasis and nephrocalcinosis)
- Peripheral neuromuscular disease (proximal muscle weakness, fatiguability, atrophy)
- Gastrointestinal disease (peptic ulcers, pancreatitis)
- Neuropsychiatric dysfunction

Common Causes

PRIMARY

- Parathyroid adenoma (89%)
- Parathyroid hyperplasia (10%)
- Parathyroid carcinoma (1%)

SECONDARY

- Chronic renal failure

PARANEOPLASTIC SYNDROMES

- Bronchogenic carcinoma
- Renal cell carcinoma

Approach to Diagnostic Imaging

1. **Plain skeletal radiograph (hands, other skeletal sites)**
   - May demonstrate characteristic:
     - Subperiosteal resorption of radial aspect of the middle phalanges of the hand
     - Resorption of phalangeal tufts
     - Erosion of distal clavicles
     - Sclerotic stripes in vertebral bodies (“rugger jersey” spine)
     - Punched-out lesions in the skull (“salt-and-pepper” appearance)

> **Note:** Although once routinely obtained, there is no need for a “metabolic bone survey” (including the long bones and spine), because the yield of positive findings is extremely low and a positive finding rarely affects treatment. If any radiographic study is required, plain films of the hands should suffice.

Detection of Parathyroid Gland Abnormality

1. **Ultrasound**
   - Preferred imaging technique that can detect 80-85% of abnormal parathyroid glands located near the thyroid
   - Parathyroid carcinomas tend to have a more heterogeneous internal architecture than adenomas
2. **Computed tomography or magnetic resonance imaging**
   - Generally required to detect abnormal parathyroid tissue at ectopic sites such as the thymus (10-15%), the posterior mediastinum (5%), the carotid sheath, and the retroesophageal or parapharyngeal region
3. **Radionuclide subtraction imaging (technetium and thallium)**
   - Detects parathyroid adenomas (sensitivity 75%; specificity 90%) because they take up only radioactive thallium (appearing as a residual focus of activity when the technetium image is subtracted from the thallium image), whereas thyroid tissue concentrates both thallium and technetium

> **Caveat: False-positive results can result from thallium uptake in thyroid nodules, sarcoid lymph nodes, or metastases to the neck.**

Hyperthyroidism

Presenting Signs and Symptoms

- Goiter
- Weight loss with increased appetite
- Warm, moist skin
- Heat intolerance
- Tremor
- Irritability and insomnia
- Palpitations and tachycardia
- Muscle weakness
- Exophthalmos
- Frequent bowel movements
- Thyroid storm (thyrotoxicosis)
- Proptosis

Common Causes

- Graves' disease (toxic diffuse goiter)
- Toxic multinodular goiter (Plummer's disease)
- Toxic adenoma
- Thyroiditis (subacute or painless)
- Thyrotoxicosis factitia (ingestion of thyroid hormone tablets)

Approach to Diagnostic Imaging

> **Caveat: The diagnosis of hyperthyroidism is made clinically by routine thyroid hormone determinations, and there usually is no need for routine imaging studies.**

1. **Radionuclide thyroid scan**
   - Indicated to distinguish Graves' disease from multinodular goiter or a single toxic adenoma
2. **Radioactive iodine uptake**
   - Although long used to measure thyroid function, this test has been supplanted by radioimmunoassay techniques and the development of accurate methods to measure serum levels of thyroid hormones and stimulating factors
   - Radioactive iodine uptake currently is performed primarily for differentiating Graves' disease (high uptake) from subacute or painless thyroiditis (low uptake), and in assisting in the calculation of the dose of radioactive iodine for the treatment of Graves' disease
3. **Computed tomography (orbits)**
   - May be required in Graves' ophthalmopathy, in which diffuse enlargement of the extraocular muscles results in proptosis, chemosis, and occasionally visual loss from compression of the optic nerve

Hypercalcemia

Presenting Signs and Symptoms

- Usually asymptomatic (discovered incidentally during routine laboratory screening)
- Constipation, anorexia, nausea and vomiting, abdominal pain, adynamic ileus
- Nephrolithiasis (or urolithiasis) and nephrocalcinosis; polyuria, nocturia, and polydipsia; renal failure
- Skeletal muscular weakness
- Emotional lability, confusion, delirium, psychosis, stupor, coma

Common Causes

- Hyperparathyroidism (primary)
- Chronic renal failure (secondary hyperparathyroidism)
- Excessive gastrointestinal absorption and/or intake (milk-alkali syndrome, vitamin D intoxication, sarcoidosis)
- Endocrine dysfunction (hypothyroidism, Addison's disease)
- Skeletal metastases, myeloma
- Humoral hypercalcemia of malignancy (no bone metastases)
- Immobilization
- Drug therapy (thiazides, lithium, aluminum-containing antacids)

Approach to Diagnostic Imaging

- Clinical assessment is necessary to direct the imaging approach
- Radiographs of the hands, pelvis, and spine are useful for evaluating hyperparathyroidism (hands) or metastasis or myeloma (pelvis, spine)

Note: See individual underlying disorders.

Hypothyroidism (Myxedema)

Presenting Signs and Symptoms

- Weight gain
- Dull facial expression with hoarse voice and slow speech
- Periorbital swelling and drooping eyelids
- Cold intolerance
- Sluggishness
- Sparse, coarse, dry hair
- Coarse, dry, scaly skin
- Constipation

Common Causes

- Dietary iodine deficiency (endemic goiter)
- Chronic thyroiditis (Hashimoto's disease)
- Treated hyperthyroidism (radioactive iodine or surgery)
- Failure of hypothalamic-pituitary axis (deficient secretion of thyrotropin-releasing hormone or thyroid-stimulating hormone)

Approach to Diagnostic Imaging

> **Caveat: The diagnosis of hypothyroidism is made clinically by routine thyroid hormone determinations, and there usually is no need for routine imaging studies.**

Note: Although long used to measure thyroid function, radionuclide iodine uptake has been supplanted by radioimmunoassay techniques and the development of accurate methods to measure serum levels of thyroid hormones and stimulating factors.

Masses

Cancer of the Larynx

Presenting Signs and Symptoms

- Neck mass (cervical adenopathy) in a smoker older than age 40 (men more often than women)
- Hoarseness
- Stridor

Common Sites

- True vocal cord
- Supraglottic

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Thin-section CT is the best modality for demonstrating the extent of tumor and the presence of any nodal disease
2. **Magnetic resonance imaging**
   - Preferred modality for evaluating the mucosa and cartilages
   - Superior to CT for defining the infraglottic spread of disease

> **Caveat: Because postbiopsy changes may simulate occult carcinoma, CT and MRI should be performed before biopsy, if possible.**

Cancer of the Pharynx

Presenting Signs and Symptoms

- Neck mass (cervical adenopathy) in a smoker older than age 40 (men more often than women)
- Referred otalgia (ear pain)
- Chronic sore throat or tongue ulceration
- Cranial nerve palsy
- Decreased hearing (due to serous effusion within ear)

Common Sites

- Tongue, floor of mouth, tonsil, oropharynx, base of tongue, pyriform sinus (nasopharynx is less common)

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred modality for evaluating the pharyngeal mucosa and other sites where occult disease may reside
   - Superior technique for defining intracranial spread of disease and involvement of the carotid artery
2. **Computed tomography**
   - High-speed CT may permit evaluation of the site of the neck mass and cervical adenopathy

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Note: Contrast infusion is required to differentiate lymph nodes from vessels on CT.

Caveat: Because postbiopsy changes may simulate occult carcinoma, MRI and CT should be performed before biopsy, if possible.

Thyroid Mass

Common Causes

- Diffuse or nodular goiter
- Thyroiditis
- Abscess
- Cyst
- Neoplasm (adenoma, carcinoma, metastases, lymphoma)

Approach to Diagnostic Imaging

1. **Radionuclide thyroid scan**
   - Preferred imaging procedure for demonstrating hypofunctioning (cold) nodules (10-20% representing carcinoma) and hyperfunctioning (hot) nodules (rarely malignant)

     Caveat: Although radionuclide scan can detect thyroid nodules, it cannot discriminate benign from malignant processes.
2. **Ultrasound**
   - Primarily indicated to determine whether a nonfunctioning thyroid mass detected on a radionuclide scan is cystic or solid (purely cystic or hyperechoic masses are rarely malignant)
   - Of special value in patients in whom exogenous iodine contamination from prior contrast studies precludes a radionuclide scan

     Caveat: As with radionuclide scan, US cannot determine whether a hypoechoic mass is benign or malignant.
3. **Magnetic resonance imaging**
   - Useful in defining the extent of neoplasms

Note: CT and MRI are primarily used to demonstrate a substernal thyroid that cannot be detected by US because of overlying bone.

Cancer of the Thyroid

Presenting Signs and Symptoms

- Asymptomatic (felt by the patient or detected on physical examination)
- Recurrent laryngeal palsy
- Hoarseness
- Metastasis to cervical nodes or remote sites

Approach to Diagnostic Imaging

1. **Radionuclide thyroid scan**
   - Single hypofunctioning (cold) nodule has a 10–20% chance of being malignant

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Note: A history of neck irradiation, especially in childhood, increases the risk of malignancy by 5–10 times.

2. **Ultrasound**
   - Primarily indicated to determine whether a nonfunctioning thyroid mass detected on a radionuclide scan is cystic or solid (purely cystic or hyperechoic masses are rarely malignant)
   - Of special value in patients in whom exogenous iodine contamination from prior contrast studies precludes a radionuclide scan

     Caveat: Because neither radionuclide scan nor US (nor CT nor MRI) can definitely determine

whether a nonfunctioning, hypoechoic mass is benign or malignant, aspiration biopsy is required in every suspicious case.

Note: Regression of nodule size following thyroid hormone therapy is a sign of a benign nodule.

Staging

1. **Computed tomography or magnetic resonance imaging**
   - Procedures of choice for demonstrating involvement of adjacent muscles, larynx, esophagus, and other neck structures by a large invasive tumor
   - MRI may better demonstrate the relationship of the carotid vessels to the tumor; CT is easier for imaging the chest and mediastinum
2. **Whole-body radionuclide scan (iodine-131)**
   - Effectively demonstrates thyroid metastases following thyroidectomy for *papillary* carcinoma

Caveat: This technique is of no value for medullary and anaplastic carcinomas because these tumors do not take up iodine.

Detecting Recurrences

1. **Magnetic resonance imaging**
   - Modality of choice for detecting recurrent tumor, which appears as an area of high signal intensity on T2-weighted images

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Note: On T2-weighted images, fibrosis has low signal intensity that is less than or equal to that of adjacent muscle.

2. **Whole-body radionuclide scan (iodine-131)**
   - Focal activity in the lungs, skeleton, or neck remote from the thyroid bed is evidence of recurrence

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Note: Uptake of radionuclide in the thyroid bed often represents residual thyroid tissue; uptake in the stomach, bowel, bladder, and salivary glands reflects physiologic traces of normal iodine distribution; and uptake in the breast also may be a normal finding.

Salivary Gland (Parotid) Neoplasm

Presenting Signs and Symptoms

- Palpable mass (slightly tender or nontender)
- Facial palsy
- Parapharyngeal mass
- If *benign cyst,* tends to develop quickly over several days, may be tender if infected, and often has a history of prior recurrent episodes
- If *benign tumor,* slow-growing, painless, nontender, and mobile
- If *malignant tumor,* tends to enlarge rapidly over several weeks and be slightly painful and minimally tender, hard and fixed on palpation, and often associated with facial nerve paralysis

Approach to Diagnostic Imaging

1. **Computed tomography or magnetic resonance imaging**
   - Preferred studies for identifying:
     - Presence of a mass or multiple masses
     - Mass location within the gland and position relative to the facial nerve
     - Whether the mass is smoothly marginated or infiltrating and necrotic, or cystic or solid
     - Whether the mass is confined to the gland or has extended outside the gland capsule into the upper neck and skull base
     - CT is superior to MRI for detecting an underlying calcified stone (calculus)
     - MRI is superior to CT for sharply outlining the margins of the mass (what CT shows as a vague fullness may appear as a discrete mass on MRI; or what CT shows as several different masses may be shown to be a highly lobulated solitary mass on MRI)

Caveat: The distinction between a benign and a malignant mass often cannot be made purely on the basis of CT or MRI. However, when imaging findings are combined with clinical findings, an accuracy rate of about 90% can be achieved.

Note: Fine-needle biopsy, often performed under CT guidance, can provide a precise pathologic diagnosis in more than 90% of patients.

Occult Primary with Positive Lymphadenopathy

Presenting Sign and Symptom

- Neck mass in a smoker older than age 40 (men more often than women)

Common Causes

- Squamous carcinoma of the pharynx, pyriform sinus, nasopharynx, or base of the tongue

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred imaging modality for evaluating the pharyngeal mucosa and other sites where the occult malignancy may reside
2. **Computed tomography**
   - High-speed studies may detect the site of an occult carcinoma in about 25% of cases (thus permitting directed biopsy by endoscopy)

> **Caveat: Because postbiopsy changes may simulate occult carcinoma, MRI and CT should be performed before biopsy, if possible.**

Neck Mass

Presenting Signs and Symptoms

- Enlarging neck mass, either in or off the midline
- Usually painless, unless infected

Common Causes

PRIMARY

- Midline mass
  - Thyroglossal duct cysts
  - Dermoid/epidermoid cysts
- Paramedian neck mass
  - Branchial cleft cyst
  - Cystic hygroma
  - Neuroma (rare)

SECONDARY

- Nodal mass (usually metastatic)
- Nodal infection (signs of infection)

Approach to Diagnostic Imaging

1. **Computed tomography**
   - Thin-section (3 mm) helical CT with contrast is the best modality for demonstrating the extent of disease
2. **Magnetic resonance imaging**
   - Preferred modality for evaluating mucosal surfaces in patients with suspected carcinoma
   - Sagittal imaging is useful for delineating the cranial–caudal dimension of thyroglossal duct cysts

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Other

Sinusitis

Presenting Signs and Symptoms

- Pain, tenderness, and swelling over the involved sinus
- Fever, chills (suggesting extension of infection beyond the sinuses)

Predisposing Factors

- Recent acute viral upper respiratory infection
- Dental infection

Approach to Diagnostic Imaging

1. **Computed tomography**

- Procedure of choice for exquisitely defining the sinonasal anatomy

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Note: Coronal imaging is the best method for patients with suspected chronic sinusitis or suspected complications such as mucocele or osteomyelitis.

2. **Magnetic resonance imaging**
   - Indicated for suspected neoplasm underlying sinusitis, intracranial disease, or neurologic symptoms
   - May be the best modality for detecting and characterizing a mucocele
   - Contrast MRI is the best technique for detecting subdural or epidural empyema
3. **Plain radiograph (sinus)**
   - Limited role in assessing sinus disease
   - Waters view is useful for monitoring treatment of acute sinusitis

Caveat: MRI should be restricted to assessing complications of sinusitis and should not be used as a screening examination.

Epiglottitis

Presenting Signs and Symptoms

- Stridor
- Difficulty swallowing, drooling
- Rigid neck
- High fever in acutely ill patient (typically ages 3 to 6)

Common Cause

- *Haemophilus influenzae* type B infection

Approach to Diagnostic Imaging

1. **Plain lateral radiograph of the neck (soft-tissue technique)**
   - Preferred imaging technique for demonstrating characteristic enlargement of the epiglottis (“thumb sign”) that narrows the airway

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Note: There is no indication for any other imaging study.

Vocal Cord Paralysis

Presenting Signs and Symptoms

- Unilateral or bilateral, complete or incomplete
- Signs and symptoms relate to the underlying pathologic process, which often arises at some distance from the larynx

Common Causes

- Chest lesions affecting the recurrent laryngeal nerve (e.g., bronchial or esophageal carcinoma, metastatic mediastinal nodes, pulmonary tuberculosis, aortic arch aneurysm, cardiac surgery)
- Neck lesions affecting the recurrent laryngeal nerve (e.g., thyroid surgery, penetrating wound, malignant cervical nodes, carcinoma of the hypopharynx, thyroid, or esophagus)
- Previous surgical procedure in the neck or chest
- Lesion affecting the vagal nerve (nasopharyngeal carcinoma, jugular foramen tumor, idiopathic)

Uncommon Cause

- Brain stem lesions affecting vagal nerve nuclei in the medulla

Approach to Diagnostic Imaging

1. **Plain chest radiograph**
   - Initial procedure for excluding lung cancer or apical thoracic tuberculosis
2. **Barium swallow**
   - Indicated if there is clinical evidence of a primary esophageal cause
3. **Computed tomography**
   - Excellent imaging study for detecting any structural abnormality of the neck or chest affecting the recurrent laryngeal nerve
   - Reformatted images may be particularly informative
4. **Magnetic resonance imaging**
   - Examination of choice if a brain stem or skull base etiology is suspected
   - Ability to image in coronal and sagittal planes makes MRI superior to CT for detecting apical chest lesions

- May be better than CT for assessing the neck (due to high soft-tissue resolution)
- Complementary with CT in evaluating lesions in or near the skull base

Cranial Neuropathy

Common Causes

- Neoplasm (primary of perineural spread)
- Infection (viral or bacterial)
- Radiation therapy

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Study of choice for assessing cranial neuropathy of undetermined cause

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> **Note:** This study should be performed using contrast-enhanced, fat-saturated imaging perpendicular to the course of the affected cranial nerve.

Caveat: MR scans must examine the entire course of the nerve from its origin in the brain stem to its distal ramifications.

2. **Computed tomography**
   - Less sensitive than MRI for detecting early spread of carcinoma along cranial nerves

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> **Note:** CT should be performed using thin sections oriented to the appropriate plane of section and perpendicular to the involved nerve.

Specific Cranial Nerves

TRIGEMINAL NEUROPATHY (NOT TIC DOULOUREUX)

- Most commonly due to a cerebellopontine angle mass or to perineural spread of tumor from the oral cavity or the head and neck

FACIAL PALSY

- Most common cause is Bell's palsy (viral neuritis)
- Does not require imaging unless facial function is slow to return or there is some other complicating factor (pain, dysfunction of other cranial nerves, parotid mass)
- Must exclude parotid malignancy and temporal bone tumors (hemangioma, cholesteatoma, neurinoma)

> **Note:** MRI is the imaging study of choice for the brain stem and parotid gland; CT may be useful for evaluating the temporal bone.

LOWER CRANIAL NERVES (9–12)

- Most commonly due to a tumor at the skull base, which is best demonstrated by MRI
- Differential diagnosis includes paraganglioma, meningioma, metastasis, and primary skull base tumor (e.g., chondrosarcoma)
- Vocal cord paralysis may be due to a lesion anywhere from the skull base down to the hila of the lung (therefore, CT is the optimal imaging study)

THIRD CRANIAL NERVE

- Common causes include diabetes, infarction, and trauma
- If third nerve palsy is acute, MRI or conventional arteriography is required to exclude an aneurysm of the carotid or posterior communicating artery

Internal Disk Derangement of Temporomandibular Joint

Presenting Signs and Symptoms

- Clicking or popping sound when opening the mouth (displacement with reduction)
- Painful limitation of jaw movement (displacement without reduction)

Common Causes

- Chronic spasm of the lateral pterygoid muscle
- Trauma

- Arthritic changes in articular surfaces

Approach to Diagnostic Imaging

1. **Magnetic resonance imaging**
   - Preferred modality for evaluating displacement of the disk and whether there is reduction during function (should be performed in the open- and closed-mouth positions with the use of surface coils)

Note: Arthrography and CT are not as effective as MRI for imaging internal disk derangements of the temporomandibular joint.

CHAPTER 8. BREAST

Edward A. Sickles

Breast Cancer

Presenting Signs and Symptoms

- Asymptomatic (detected by screening with mammography or physical examination)
- Variable clinical manifestations, including mass, focal pain, breast enlargement, nipple discharge, nondescript thickening in the breast, lymphedema (peau d'orange), skin or nipple retraction, and evidence of matted or fixed axillary or supraclavicular lymph nodes

Risk Factors

MAJOR

- Prior *in situ* or invasive breast cancer (risk of developing cancer in the contralateral breast after mastectomy is approximately 0.5–1% for every year of follow-up)
- Family history (first-degree relative, especially if premenopausal or bilateral)
- Prior biopsy showing atypical hyperplasia, especially in association with a positive family history
- BRCA1 or BRCA2 gene

MINOR

- Early menarche
- Late menopause
- Late first pregnancy
- Radiation exposure before age 30

Note: Possible but not definite minor risk factors include prolonged use of oral contraceptives before first pregnancy, postmenopausal estrogen replacement therapy, and a high-fat diet.

Approach to Diagnostic Imaging

1. **Mammography**
   - Procedure of choice for detecting nonpalpable cancer because it demonstrates early signs of malignancy such as microcalcifications, small spiculated lesions, and subtle distortion of breast architecture
   - Permits preoperative needle/wire localization of nonpalpable lesions that are suspicious for malignancy
   - Allows assessment of asymptomatic areas in the ipsilateral breast and the contralateral breast for clinically occult but mammographically suspicious abnormalities that should be biopsied concurrently
   - Provides definitive diagnosis for selected benign lesions that happen to be palpable, including calcified fibroadenoma, intramammary lymph node, oil cyst of fat necrosis, lipoma, and breast implant rupture
2. **Ultrasound**
   - If mammography suggests a cyst, indicated to make the critical distinction between a simple cyst (always benign and requiring no further workup) and a complex or solid mass (may be malignant and requiring further investigation)
   - Sufficiently characterizes an intramammary lymph node to establish the diagnosis

   Caveat: US cannot provide a definitive diagnosis of other solid or complex masses.
3. **Fine-needle aspiration biopsy**
   - Provides material for definitive cytologic examination
   - Can be performed with stereotactic or US guidance
4. **Core biopsy**
   - Provides material for definitive histologic examination
   - Can be performed with stereotactic or US guidance

Mammography Screening

American Cancer Society Guidelines

- For women age 40 and older, *yearly* mammograms are recommended

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Note: In several screening studies involving asymptomatic women, about 40% of cancers were detected by mammography but not physical examination. Conversely, about 10% of cancers were evident only on examination. Therefore, physical examination and mammography should be considered as complementary procedures.

Caveat: US, MRI, and CT are not used as screening procedures.

- Thermography, diaphanography, and transillumination should *never* be used for screening or diagnosis of breast disease

Screening Outcomes

Note: The following outcomes are representative for 1,000 asymptomatic women undergoing bilateral screening mammography for the first time.

- 70 to 100 (7–10%) will be recalled for more studies (magnification or other special views; US)
- 15 to 20 (1.5–2%) will require biopsy
- 5 to 7 (0.5–0.7%) will have cancer detected
- Recall rate, biopsy rate, and cancer detection rate will be approximately 50% of subsequent screening examinations

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Note: Of cancers detected on screening studies, more than 40% will be minimal (ductal carcinoma in situ of any size, invasive cancer <1 cm), and more than 75% will be node-negative.

Palpable Breast Mass

Approach to Diagnostic Imaging

1. **Mammography**
   - Procedure of choice for determining whether a palpable mass is unequivocally benign (e.g., calcified fibroadenoma, intramammary lymph node, oil cyst, lipoma), thus avoiding biopsy
   - If the palpable mass is suspicious for malignancy, the primary purpose of mammography is to assess the affected breast for multifocal disease and the contralateral breast for clinically occult but mammographically suspicious abnormalities that should be biopsied concurrently

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Note: The palpable mass should always be indicated by placing a radiopaque marker over the site to ensure that the palpable abnormality is included on available images, and to determine whether it corresponds to any mammographic lesion that is visualized.

2. **Ultrasound**
   - Indicated as a confirming procedure if physical examination or mammography suggests that the palpable mass may represent a simple cyst or intramammary lymph node. Can be diagnostic of a simple (benign) cyst or intramammary lymph node if rigid interpretive criteria are used
   - Indicated (as an alternative to needle aspiration) to diagnose a simple cyst in a patient with a palpable mass and dense breasts who has a negative mammogram

Caveat: US cannot provide a definitive diagnosis of other solid or complex masses.

3. **Fine-needle aspiration biopsy**
   - Provides material for definitive cytologic examination
4. **Core biopsy**
   - Provides material for definitive histologic examination

Note: Many radiologists recommend that fine-needle aspiration or core biopsy be performed with image guidance, even when a lesion is palpable, to ensure that tissue samples are obtained from several representative areas within the lesion.

Caveat: In women younger than age 30 who have a palpable mass, many radiologists prefer US as the initial imaging modality (because of the low incidence of breast cancer in this age group and the increased risk of breast cancer in women of this age who have received radiation). If US is negative, a limited mammographic examination may then be performed to search for suspicious microcalcifications suggesting malignancy (which may not be detected by US).

Recurrent Breast Cancer after Mastectomy

Common Causes

- Residual foci of glandular tissue or malignancy

Approach to Diagnostic Imaging

Caveat: There is no consensus on the need for routine imaging of the postmastectomy breast, whether or not reconstruction has been performed. Any palpated lump is generally biopsied, and superficial

recurrence typically can be easily palpated. One study indicated that mammography of the unreconstructed mastectomy site does not increase the detection of local recurrences.

1. **Mammography**
   - Best imaging technique for screening the breast for nonpalpable recurrences, since the autogenous reconstruction is primarily lucent fatty tissue (unlike silicone or saline implants)
   - Can show that a palpable lump represents normal residual fatty tissue or oil cyst(s) of fat necrosis, or has features suggestive of recurrent tumor
2. **Magnetic resonance imaging**
   - Indicated if mammography is equivocal
   - Can differentiate implant rupture (free silicone droplets) or herniation (bulging areas) from findings that suggest local recurrence of tumor
3. **Computed tomography**
   - May aid in evaluating the extent of recurrent disease and visualizing tissue posterior to an implant
4. **Core biopsy**
   - Provides material for definitive histologic examination

Note: Routine mammographic screening of the contralateral breast is essential.

Breast Implant Assessment for Rupture

Presenting Signs and Symptoms

- Pain, lump(s), abrupt or gradual contour change, or volume decrease
- Often asymptomatic

Approach to Diagnostic Imaging

1. **Mammography**
   - Detects all cases of saline implant rupture by demonstrating collapse of the implant shell (saline is resorbed)
   - Detects many cases of extracapsular silicone implant rupture by demonstrating free silicone in the breast or axilla
   - Cannot detect intracapsular silicone implant rupture
   - Detects malignancy, either clinically occult or associated with a palpable lump

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Note: Since mammography cannot reliably exclude silicone implant rupture, proceed to additional imaging despite normal mammography if clinical signs or symptoms suggest rupture.

2. **Magnetic resonance imaging**
   - Preferred technique because of its ability to image in multiple planes and posterior to the implant
   - More sensitive and specific than breast US or mammography for detecting a ruptured implant
3. **Ultrasound**
   - May be used if MRI not available, although it is more operator-dependent and may not visualize posterior to the implant
4. **Computed tomography**
   - Less frequently used because of its relatively high radiation dose to the breast and difficulty in accurately detecting free silicone in breast tissues

CHAPTER 9. REPRODUCTIVE

Hedvig Hricak

SIGNS AND SYMPTOMS

Female

Abnormal Uterine Bleeding

Presenting Signs and Symptoms

- Excessive menstrual bleeding (menorrhagia)
- Nonmenstrual or intermenstrual bleeding (metrorrhagia)
- Postmenopausal bleeding

Common Causes

PREMENOPAUSAL

- Ovulation (functional ovarian cysts)
- Cervicitis
- Birth control pills
- Anovulatory cycle
- Pregnancy
- Malignancy
- Leiomyoma
- Adenomyosis

POSTMENOPAUSAL

- Endometrial atrophy
- Endometrial polyp

HORMONAL

- Vaginal atrophy
- Endometrial cancer (about 20% of patients with postmenopausal bleeding)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred initial imaging procedure for detecting abnormalities of the female genital tract

Note: See individual sections for recommended workup of specific disorders.

Dysmenorrhea

Presenting Sign and Symptom

- Pain associated with menses during ovulatory cycles

Common Causes

PRIMARY

- No demonstrable lesion affecting the reproductive structures

SECONDARY

- Endometriosis
- Chronic pelvic inflammatory disease
- Cervical stenosis, infection, or neoplasm

Approach to Diagnostic Imaging

1. **Ultrasound**

- Imaging procedure of choice for detecting or excluding lesions of the female genital tract

Infertility

Common Causes

MALE FACTORS (40%)

- Deficient spermatogenesis
- Varicocele
- Cryptorchidism
- Retrograde ejaculation into the bladder
- Congenital anomalies

FEMALE FACTORS (60%)

- Ovulatory dysfunction (20%)
- Tubal dysfunction (30%)
- Cervical mucus dysfunction (5%)
- Other uterine abnormalities (5%)

Approach to Diagnostic Imaging

1. **Hysterosalpingography**
   - Preferred imaging study for demonstrating obstruction of the fallopian tubes (usually secondary to scarring from pelvic inflammatory disease) and uterine synechia (adhesions)
2. **Ultrasound or magnetic resonance imaging**
   - Indicated if the hysterosalpingogram is normal, to detect congenital anomalies of the female genital tract that are seen in up to 10% of women evaluated for infertility or repeated abortion

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Note: Role of sonohysterography for the evaluation of the fallopian tubes is under investigation

Missing Intrauterine Device (IUD)

Presenting Sign and Symptom

- Patient unable to feel the attached string (and did not notice that the device was expelled)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred initial imaging technique if an intrauterine position of the device cannot be confirmed by pelvic examination, uterine sound, or biopsy instrument
2. **Computed tomography**
   - Indicated if US is equivocal

Note: A plain frontal view is not sufficient because it can misdiagnose an extrauterine IUD located in the cul-de-sac.

Male

Scrotal Pain (Acute)

Common Causes

- Testicular torsion (usually in patients younger than age 20; characterized by more acute onset)
- Acute epididymo-orchitis (most common after age 20; more gradual onset, often with pyuria)
- Vasculitis (e.g., Henoch-Schönlein purpura in children, polyarteritis nodosa in adults)
- Trauma
- Strangulated, incarcerated hernia
- Testicular cancer (10% of testicular cancers present with acute pain)

Approach to Diagnostic Imaging

1. **Ultrasound with color Doppler**
   - Torsion: decreased or absent flow on the symptomatic side
   - Epididymo-orchitis: diffuse increase in blood flow on the affected side
2. **Radionuclide flow study**
   - Torsion: a rounded cold area surrounded by a rim of increased radionuclide activity reflecting hyperemia (doughnut sign)

- Epididymo-orchitis: a generalized increase in vascular flow to the affected side

Caveat: The choice of imaging technique is made on an individualized basis. To rule out torsion, the general preferences are to use US in adults and radionuclide studies in children.

Undescended Testis (Cryptorchidism)

Presenting Signs and Symptoms

- Incomplete or improper prenatal descent of one or both testes (occurs in about 3% of newborns; most spontaneously descend, so that by age 1 the incidence is only 1%)

Long-term Complications (Requiring Orchiopexy)

- Infertility due to progressive failure of spermatogenesis
- Increased risk of a malignant testicular neoplasm developing (in both the undescended and in the contralateral, normally descended testis)

Approach to Diagnostic Imaging

Note: The use of diagnostic imaging for nonpalpable undescended testes is controversial, with some surgeons preferring to go directly to laparoscopy or operative exploration.

1. **Ultrasound**
   - Sensitive for demonstrating the often atrophic undescended testis if it is located beyond the internal inguinal ring (inguinal canal and spermatic cord)

Note: Identification of the mediastinum testis is important to distinguish an undescended testis from an enlarged lymph node in the area of the cord.

Caveat: US is of no value if the testis is located in the pelvis or abdomen.

2. **Computed tomography**
   - Most valuable for detecting the undescended abdominal testis
   - May be useful in postpubertal males or for suspected neoplastic degeneration

Caveat: CT involves radiation (a consideration in this generally younger age group) and cannot detect an undescended testis smaller than 1 cm.

3. **Magnetic resonance imaging**
   - Preferred approach for detecting undescended testes located at or beyond the internal ring of the inguinal canal, and for demonstrating all complications (especially inflammatory or neoplastic)

Screening for Prostate Carcinoma

Indications

- Screening prostate-specific antigen (PSA) studies and digital rectal examination are recommended for all men annually after age 50 (earlier if positive family history or genetic screening)
- If either the screening PSA study or the digital rectal examination is abnormal, proceed directly to US

Clinical Guidelines for Elevated Serum Levels of PSA

- >4 ng/mL: suggestive of prostate cancer (but can be seen in men with benign prostatic hyperplasia, especially if gland is very large)

Note: Some prostate cancers do not secrete PSA, and thus patients with these tumors do not have elevated PSA levels.

Common Causes

- Prostate cancer
- Benign prostatic hypertrophy

Approach to Diagnostic Imaging

1. **Ultrasound (transrectal)**
   - Preferred imaging technique for asymptomatic men with an elevated PSA level or abnormal digital rectal examination
   - Signs suspicious but nonspecific for malignancy include hypoechoic nodule in the peripheral zone, asymmetric enlargement of the gland with deformation of its contour, and areas of increased vascularity on Doppler study

Note: PSA density (ratio of PSA to gland volume) is a helpful indicator of malignancy and can be determined by using US-obtained volume measurements of the gland.

- Excellent for guiding needle biopsy, which is often recommended if no focal abnormality is detected based on PSA, digital rectal examination, PSA density, or other clinical indications

Caveat: Up to 25% of prostate cancers are isoechoic and indistinguishable from normal parenchyma. In addition, it is difficult for any imaging modality to detect cancer in the midst of benign prostatic hypertrophy (central gland).

Note: Additional imaging studies are not routinely used at present until a diagnosis of prostate cancer is established by biopsy. Combined magnetic resonance imaging (MRI) and MR spectroscopic imaging show promise in localizing prostate cancer for patients with elevated PSA and repeated negative biopsies.

Disorders

Female

Mass

Cancer of the Cervix

Presenting Signs and Symptoms

- Usually detected by screening Papanicolaou (Pap) test
- Vaginal discharge and bleeding

Risk Factors

- History of early, frequent coitus and multiple partners
- Possible relationship to venereal transmission of human papilloma virus

Staging

1. **Magnetic resonance imaging**
   - Preferred study for:
     - Demonstrating the tumor
     - Measuring its size
     - Showing direct tumor extension to the vagina, paracervical and parametrial tissues, bladder, and rectum
   - MRI is superior to CT, which even with contrast enhancement cannot consistently differentiate tumor from adjacent normal tissue
2. **Computed tomography**
   - Valuable in advanced disease and in the search for lymph node metastases

     Caveat: Cervical cancer frequently metastasizes to pelvic, inguinal, and retroperitoneal lymph nodes but may not enlarge them. However, both MRI and CT use lymph node enlargement as primary criterion for detecting metastatic involvement.
3. **Ultrasound (endovaginal)**
   - Can assess tumor size (but is inferior to MRI)

     Caveat: There is no indication for the routine use of excretory urography or barium enema examination (the diagnostic mainstays before cross-sectional imaging).

Cancer of the Endometrium

Presenting Signs and Symptoms

- Inappropriate uterine bleeding (postmenopausal or recurrent metrorrhagia in a premenopausal woman)
- Mucoid or watery discharge

Predisposing Factors

- Delayed menopause
- Abnormal menstrual history or infertility
- Estrogen-producing ovarian tumor

Possible Implicated Factors

- Obesity
- Hypertension
- Diabetes mellitus

- Breast cancer
- Absence of ovulation
- Family history of breast or ovarian cancer

Approach to Diagnostic Imaging

1. **Ultrasound (endovaginal approach preferred)**
   - Used by some physicians to measure endometrial thickness in postmenopausal women to select patients suspected of having endometrial carcinoma for dilation and curettage

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Note: In a postmenopausal woman not on hormone replacement therapy, an endometrial stripe >5 mm is an indication for endometrial biopsy.

Staging

1. **Magnetic resonance imaging**
   - Procedure of choice for demonstrating:
     - Depth of myometrial invasion
     - Extension into the cervix, broad ligaments, parametrium, and ovaries
     - Lymphatic spread to pelvic and retroperitoneal lymph nodes
   - Use of contrast material is recommended

Note: Staging with MRI is superior to that obtained with clinical evaluation and CT.

2. **Computed tomography**
   - Indicated only in advanced cases to search for adjacent organ and pelvic side wall invasion or lymph node metastases

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Note: Endovaginal US has been advocated for the assessment of myometrial invasion. However, this method has not been widely accepted because it is subjective, operator-dependent, and significantly inferior to contrast-enhanced MRI.

Cancer of the Ovary

Presenting Signs and Symptoms

- Asymptomatic (until very large)
- Vague lower abdominal discomfort
- Mild digestive complaints
- Inappropriate vaginal bleeding
- Late findings include abdominal swelling due to ascites and a lobulated or fixed solid mass associated with nodular implants in the cul-de-sac

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred initial imaging procedure for demonstrating the adnexal lesion that varies in appearance from a multilocular cyst with vegetations to a complex mass with prominent solid elements

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Note: The value of endovaginal US using color flow Doppler to detect neovascularity in the ovary in the hope of earlier detection of ovarian cancer is controversial; however, combined gray-scale US and Doppler provide the best lesion characterization.

Caveat: An unequivocal diagnosis of malignancy requires the demonstration of metastases. Nevertheless, even in the absence of metastatic disease, imaging findings can be highly suggestive of malignancy. For example, MRI has a positive predictive value of 92% for determining whether an ovarian tumor is benign or malignant.

2. **Magnetic resonance imaging or computed tomography**
   - Indicated when the US findings are inconclusive in determining whether a lesion is benign or malignant

Staging

1. **Computed tomography**
   - Preferred study for demonstrating:
     - Direct extension of tumor to adjacent structures
     - Peritoneal and omental spread
     - Lymphatic metastases to pelvic and retroperitoneal nodes
     - Malignant ascites
     - Late hematogenous spread to the liver and lungs
   - Currently considered superior to MRI because with MRI there has been difficulty in differentiating tumor from

bowel, longer examination time, and higher cost

Caveat: Ovarian carcinoma spreads primarily by peritoneal seeding, with small tumor nodules implanting on the peritoneum, mesentery, and omentum. The role of imaging is to assist surgical planning, determine the surgical expertise required, and diagnose tumor nonresectability.

Note: MRI is indicated only if there is a contraindication to the use of iodinated contrast material (e.g., renal failure or allergy) or if the CT findings are inconclusive.

Endometriosis

Presenting Signs and Symptoms

- Pelvic pain associated with menses (dysmenorrhea)
- Dyspareunia
- Pelvic mass
- Effect of implants on other organs (e.g., lesions involving large bowel or bladder may cause pain with defecation, abdominal bloating, rectal bleeding with menses, or hematuria and suprapubic pain during urination)

Common Causes

- Unknown mechanism for presence of endometrial tissue at ectopic sites outside the uterus (retrograde flow of menstrual bleeding is a hypothesis)

Predisposing Factors

- Family history
- Delay in childbearing
- Müllerian duct anomalies
- Asian race

Approach to Diagnostic Imaging

Caveat: Ectopic implants of endometrial tissue generally are too small to be visualized by any imaging method, and laparoscopy is essential to detect and stage endometriosis.

1. **Ultrasound**
   - May demonstrate one or more cystic masses filled with old blood (endometrioma)

Note: Although US can identify the presence of an adnexal lesion, it may be unable to definitively differentiate an endometrioma from other adnexal masses.

2. **Magnetic resonance imaging**
   - Most sensitive modality for diagnosing endometriosis and for differentiating an endometrioma from other adnexal masses

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Notes: MRI cannot reliably visualize adhesions or intraperitoneal implants.

Other imaging modalities (barium enema, excretory urography, CT) may demonstrate the extent of disease (secondary involvement of other organs) and response to therapy but are not sufficiently specific to provide a precise diagnosis.

Leiomyoma (Fibroid) of the Uterus

Presenting Signs and Symptoms

Note: Signs and symptoms depend on the location and size of the lesion.

- Asymptomatic (detected incidentally on routine pelvic examination or on an imaging study performed for another reason)
- Inappropriate vaginal bleeding
- Pressure symptoms caused by increasing size of the uterus
- Acute abdomen (when torsed or undergoing “red” degeneration)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred initial imaging technique for diagnosing this benign uterine tumor

- Endovaginal studies are helpful for small and submucosal leiomyomas

Caveat: The use of sonohysterography in the evaluation of submucosal leiomyoma or endometrial polyp, or for the measurement of endometrial thickness, is controversial.

Note: There is no longer any indication for hysterosalpingography in the diagnosis of submucosal leiomyomas.

2. **Magnetic resonance imaging**
   - Indicated if US is negative or inconclusive in differentiating between uterine and adnexal masses or between leiomyoma and adenomyosis, and in searching for submucosal leiomyomas in unexplained bleeding or an infertility workup

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Note: MRI is more sensitive than US or hysterosalpingography.

Caveat: Neither US nor MRI can reliably differentiate benign leiomyoma from the rare malignant leiomyosarcoma.

Note: Although not indicated for imaging of clinically suspected leiomyoma, plain abdominal radiographs may fortuitously detect the lesion by demonstrating the virtually pathognomonic “popcorn” pattern of pelvic calcification.

Pelvic Mass (Unspecified)

Presenting Sign and Symptom

- Palpable or clinically suspected mass

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred imaging procedure for evaluating patients with a clinically suspected pelvic mass
   - Can confirm the presence of a mass, establish its organ of origin, and demonstrate its internal consistency (cystic, complex, or solid)

Caveat: US is less accurate than CT or MRI for demonstrating tumor extension of a malignant neoplasm or lymph node metastases.

2. **Computed tomography or magnetic resonance imaging**
   - Preferred imaging methods for further evaluating pelvic tumors and for staging pelvic masses suspected of being malignant
   - Superior to US for demonstrating tumor spread to adjacent and distant structures

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Note: The role of excretory urography has been limited to assessing patients who have a pelvic mass and hematuria. If a patient presents with renal failure, hydronephrosis can be established by US. If a malignant lesion is suspected, contrast CT can adequately evaluate the kidneys and the path of the ureters.

Caveat: There is no indication for plain abdominal radiographs (too insensitive and nonspecific).

Other

Adenomyosis

Presenting Signs and Symptoms

- Menorrhagia and intermenstrual bleeding
- Smooth enlargement of the uterus
- Nonspecific pelvic pain and bladder and rectal pressure

Histology

- Benign invasion of endometrium (basalis layer) into the myometrium (unknown cause)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Endovaginal sonography is the recommended initial imaging procedure for demonstrating the heterogeneous texture of an enlarged uterus

Caveat: Many patients with a leiomyomatous uterus have a similar pattern on US of a diffusely abnormal uterine texture without evidence of discrete leiomyomas. When surgery is planned, distinguishing between leiomyoma and adenomyosis is crucial in patients who wish to preserve the uterus. Adenomyosis requires hysterectomy for definitive therapy, whereas leiomyomas can be treated by selective myomectomy with preservation of the uterus.

2. **Magnetic resonance imaging**
   - Highly sensitive for detecting adenomyosis and accurate in making the critical distinction from leiomyoma

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Note: CT is not applicable in this clinical situation.

Pelvic Inflammatory Disease

Presenting Signs and Symptoms

ACUTE

- Lower abdominal pain, fever, and purulent vaginal discharge that usually begins shortly after menses

CHRONIC

- Chronic pain
- Menstrual irregularities
- Infertility (due to mucosal destruction and tubal obstruction)

Common Sources of Infection

- Sexual intercourse
- Childbirth (puerperal fever)
- Abortion

Note: Patients who use IUDs are particularly susceptible.

Approach to Diagnostic Imaging

Note: In uncomplicated cases that respond well to antibiotic therapy, there is no need for imaging studies.

1. **Ultrasound**
   - Demonstrates pyosalpinx or tubo-ovarian abscess complicating pelvic inflammatory disease
   - Assesses response to therapy
2. **Computed tomography**
   - May be performed after US to visualize the full extent of disease in severe cases
   - Indicated if clinical symptoms mimic appendicitis

Note: MRI is used only if CT is indicated and the patient is allergic to iodinated contrast material.

Male

Benign Prostatic Hyperplasia (BPH)

Presenting Signs and Symptoms

- Varying degrees of bladder outlet obstruction (progressive urinary frequency, urgency, and nocturia due to incomplete emptying and refilling of the bladder)
- Decreased size and force of the urinary stream (associated with hesitancy and intermittency)
- May have terminal dribbling, almost continuous overflow incontinence, or complete urinary retention

Common Causes

- Unknown (may involve hormonal imbalance associated with aging)

Approach to Diagnostic Imaging

Note: BPH is a clinical diagnosis. Imaging is indicated to measure the volume of the gland as a determinant in deciding the surgical approach, to follow changes in gland size during medical therapy, and (if needed) to assess the degree of urinary obstruction (residual urine volume). The size of the gland does not correlate with the symptoms.

1. **Ultrasound**
   - *Transrectal*
     - Demonstrates enlargement and heterogeneity of the gland (specifically the transitional zone [central gland])
     - Often shows a circumferential surgical pseudocapsule
     - May visualize discrete nodules, as well as nodular thickening of the bladder wall (a sign of long-standing urinary outlet obstruction)
   - *Transabdominal*
     - Can be used to measure the residual urine volume
     - Can evaluate the kidney for the presence of hydronephrosis
2. **Excretory urography**
   - Demonstrates a filling defect at the base of the bladder associated with upward displacement of the terminal portions of the ureters (fishhooking)
   - Can assess the degree of urinary obstruction

Cancer of the Prostate

Presenting Signs and Symptoms

- Asymptomatic
- May be symptoms of bladder outlet obstruction, ureteral obstruction, hematuria, pyuria (indistinguishable from benign prostatic hyperplasia)
- Elevated prostate-specific antigen (PSA)
- Localized bone pain (from skeletal metastases)
- Elevated serum acid phosphatase (indicating local extension or metastases)

Common Causes

- Probably hormone-related
- Genetic factors

Approach to Diagnostic Imaging

1. **Ultrasound (transrectal)**
   - Preferred imaging technique once prostate cancer has been suspected by digital rectal examination or an elevated PSA level
   - Signs suspicious but not specific for malignancy include hypoechoic nodule (especially in the peripheral zone), mass effect on surrounding tissues, and asymmetric enlargement of the gland with deformation of its contour
   - Hypervascularity of tumor on color Doppler
   - Permits gland volume measurements necessary for calculating the PSA density (gland volume to PSA ratio)
   - Excellent for guiding needle biopsy

Caveat: Up to 25% of prostate cancers are isoechoic and indistinguishable from normal parenchyma. In addition, it is difficult for any imaging modality to detect cancer in the midst of benign prostatic hyperplasia (central gland).

Notes: There is no indication for excretory urography in the evaluation of a patient with suspected prostate cancer.

There is no indication for MRI in the pre-biopsy investigation for prostate cancer. MRI can detect many tumors, but there is an overlap in the MRI appearance of malignant and benign prostate nodules, and a precise diagnosis requires biopsy and histologic examination.

Staging

1. **Magnetic resonance imaging**
   - The use of phased-array coils, endorectal coils, or a combination, represents the state-of-the-art and most effective imaging technique for assessing local spread (extracapsular extension, seminal vesicle invasion) and metastatic involvement of lymph nodes
2. **Computed tomography**
   - Once considered the “gold standard” for the staging of prostate cancer, but no longer used routinely

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Note: CT staging is recommended only if the presence of lymph node metastases is suggested on clinical grounds (markedly abnormal digital rectal examination, PSA >20 ng/mL, Gleason score > 8).

3. **Radionuclide bone scan**
   - Single best modality for detecting skeletal metastases (high frequency with prostate cancer)

Caveat: Radionuclide bone scan is no longer routinely recommended. It should be ordered only if the PSA exceeds 10 ng/mL or if there are skeletal symptoms.

Testicular Malignancy

Presenting Signs and Symptoms

- Scrotal mass (progressively increasing in size)
- Generally painless (pain may be exquisite if hemorrhage into a rapidly expanding tumor occurs; 10% of testicular cancers present with pain)
- Often attributed to minor trauma (indicating the time when the mass was first discovered)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Primary imaging adjunct to physical examination, that localizes a mass to the testis and characterizes its internal composition
   - Should be obtained if symptoms persist after 10 days of antibiotic therapy
2. **Magnetic resonance imaging**
   - Problem-solving modality performed if US is equivocal, if there is a discrepancy between the physical examination and the US study, if bilateral disease is likely (e.g., lymphoma, leukemia), or as follow-up if a patient has a unilateral testis and an equivocal US study

Staging

1. **Computed tomography (abdomen and pelvis)**
   - Most effective staging procedure for demonstrating the presence and extent of extratesticular spread of tumor (most commonly through the lymphatic system along the gonadal vessels, following the testicular veins to renal hilar nodes on the left or the aortocaval chain on the right, or along the external iliac chain)

Note: Thin-section CT of the lungs is also recommended for early detection of frequent pulmonary metastases. If helical CT is available, scans of the abdomen and pelvis are also often obtained.

2. **Magnetic resonance imaging**
   - Comparable to CT for detecting retroperitoneal lymphadenopathy
   - Possible advantages include the ability to distinguish lymph nodes from blood vessels without the use of intravenous contrast material
   - Recommended in patients with elevated creatinine, allergy to iodinated contrast material, or retroperitoneal surgical clips (which would degrade the CT image)

Note: If the primary diagnosis is testicular choriocarcinoma, brain MRI should be performed because of the high rate of metastases.

CHAPTER 10. OBSTETRICS

Peter W. Callen and Nina S. Vincoff

Ectopic Pregnancy

Presenting Signs and Symptoms

- Cramping pelvic pain
- Spotting (occasionally rapid bleeding leading to shock)
- Enlarged uterus but smaller than expected for dates
- Possibly, tender mass in one adnexa
- Lower than expected b-hCG level

Predisposing Factors

- Pelvic inflammatory disease
- Tubal surgery
- Endometriosis
- Ovulation induction
- Previous ectopic pregnancy
- Exposure to diethylstilbestrol (DES)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Procedure of choice for demonstrating the extrauterine gestational sac, empty uterus, and secondary signs of ectopic pregnancy
   - If US is normal, there is still as much as a 20% risk of an ectopic pregnancy (even if transvaginal technique is used)

Note: When an intrauterine pregnancy is demonstrated by US, the risk of a coexisting ectopic pregnancy is extremely low (about 1 in 17,000 to 30,000). Nevertheless, concurrent intrauterine and ectopic pregnancies do occur, especially in women taking ovulation-inducing drugs.

Early Pregnancy Failure and Embryonic Demise

Presenting Signs and Symptoms

- Vaginal bleeding and cramping
- Failure of the uterus to grow
- Absence of fetal heart tones
- Decreasing b-hCG levels

Common Causes

- Fetal chromosomal abnormality
- Cervical abnormality (incompetent, amputated, lacerated)
- Uterine abnormality (leiomyoma, congenital anomaly)
- Impaired corpus luteum function
- Hypothyroidism
- Diabetes mellitus
- Chronic renal disease
- Infection (especially viruses such as cytomegalovirus, rubella, and herpes)

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Procedure of choice for demonstrating an abnormal gestational sac and/or absence of embryonic cardiac activity
   - Commonly used criteria for normal early pregnancy (transvaginal technique):
     - Mean sac diameter 8 mm (38 days since LMP): yolk sac visible
     - Mean sac diameter 16 mm (46 days since LMP): embryo visible
     - Embryo length 5 mm (approximately 46 days since LMP): cardiac activity
   - Can demonstrate an underlying structural abnormality involving the uterus

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Note: With endovaginal technique, the absence of cardiac activity in an embryo larger than 5 mm is considered diagnostic of embryonic demise. Embryos smaller than 5 mm without cardiac activity should be rescanned in a few days to confirm demise.

Fetal Anomalies

- Predisposing Factors
- Family history of congenital anomalies or genetic illness
- Maternal illness or exposure during pregnancy
- Substance abuse
- Preconceptional maternal diabetes

Approach to Diagnostic Imaging

1. **Level I ultrasound (basic)**
   - Commonly performed between 18 and 20 weeks gestational age
   - In addition to fetal measurements and estimates of fetal weight and gestational age , the basic sonogram includes imaging of the brain, heart, spine, stomach, kidneys, urinary bladder, and umbilical cord
   - Detects unsuspected fetal anomalies, prompting amniocentesis or further imaging
2. **Level II ultrasound (targeted or survey)**
   - Performed when an abnormality is detected during basic US, when there are predisposing factors for fetal anomalies, or when the maternal serum a-fetoprotein is abnormal
   - A detailed evaluation of fetal anatomy, targeted as indicated by the patient's history, is performed by a physician
3. **Magnetic resonance imaging (fast-sequence)**
   - Although US remains the primary modality for imaging fetal anomalies, fast-sequence MR imaging can provide additional information in selected cases, particularly if fetal surgery or intervention is planned
   - Especially useful in obese patients or those with severe oligohydramnios, when US may be difficult
   - Current indications include anomalies of the nervous system, abdominal wall, and genitourinary tract, as well as congenital diaphragmatic hernia

Fetal Presentation and Fetopelvic Disproportion

Presenting Sign and Symptom

- Failure of the fetal head to properly descend into the pelvis

Common Causes

- Malpositioned fetal head (e.g., breech presentation, hyperextended fetal head, transverse lie)
- Inadequate maternal pelvis

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Procedure of choice for determining fetal presentation (fetal part closest to the cervix) and fetal lie (relationship of the long axis of the uterus to the fetus)
   - Can distinguish among types of breech presentation when vaginal delivery or version is being considered
     Frank breech: hips flexed, knees extended (65%)
     Complete breech: hips flexed, knees flexed (10%)
     Footling breech: may be associated with umbilical cord prolapse (25%)
2. **Computed tomography**
   - Procedure of choice for pelvimetry (usually performed when vaginal delivery is being considered for breech presentation)

Note: Sagittal and coronal digital images and one transverse axial section are obtained. These provide an accurate measurement of the pelvis and a much lower radiation exposure to the fetus than conventional pelvimetry (approximately 0.23 rad).

3. **Magnetic resonance imaging**
   - May be used as an alternative to CT for pelvimetry

Intrauterine Growth Retardation (IUGR)

Presenting Sign and Symptom

- Estimated fetal weight below the 10th percentile for gestational age

Common Causes

- Uteroplacental insufficiency
- Fetal chromosomal abnormalities

- Intrauterine infection (cytomegalovirus, rubella, toxoplasmosis)
- Maternal disease (hypertension, preeclampsia, diabetes mellitus, renal disease, malnutrition)
- Smoking, alcohol, drug abuse

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred initial imaging study for estimating gestational age and assessing whether fetal growth is proceeding normally
   - Can distinguish symmetric from asymmetric IUGR
   - *Symmetric* IUGR (the head, abdomen, and femur measurements are all proportionally small) usually occurs early in pregnancy and is commonly associated with chromosome abnormalities or infection
   - *Asymmetric* IUGR (the fetal abdomen is disproportionally small relative to the head and femur) usually occurs later in pregnancy and is most often secondary to uteroplacental insufficiency
   - Oligohydramnios (markedly decreased amniotic fluid) may be seen in the presence of severe IUGR

Multiple Pregnancy

Presenting Sign and Symptom

- Large uterine size for dates

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Demonstrates the presence of multiple embryos or fetuses
   - Permits characterization of multiple pregnancies according to the number of amniotic sacs and whether or not the fetuses share a single placenta

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Note: The relative risk of twin morbidity (prematurity, polyhydramnios, increased incidence of congenital anomalies, discordant growth, cord accidents) is substantially higher if the fetuses share a placenta (monochorionic) and a single amniotic cavity (monoamniotic).

Placental Abruption

Presenting Signs and Symptoms

- Vary depending on the degree of placental separation and the extent of blood loss
- Third-trimester bleeding (retroplacental hemorrhage that may pass through the cervix and produce vaginal bleeding or be retained behind the placenta)
- Severe bleeding may lead to fetal cardiac distress or death and maternal shock
- Complications include disseminated intravascular coagulation, acute renal failure, and uteroplacental apoplexy

Risk Factors

- Maternal hypertension
- Smoking
- Cocaine abuse
- Autoimmune disorders
- Previous history of placental abruption

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Major value is its ability to exclude a placenta previa as the cause of vaginal bleeding
   - May often miss the diagnosis of placental abruption due to (1) complete egress of retroplacental blood or (2) isoechogenicity of blood compared with the placenta

Placenta Previa

Presenting Signs and Symptoms

- Painless third-trimester vaginal bleeding (may become massive, bright-red bleeding)

Risk Factors

- Previous cesarean section
- Uterine abnormality inhibiting normal implantation (fibroid)
- Multiple previous pregnancies
- Previous placenta previa

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Procedure of choice for demonstrating that part or all of the placenta covers the internal cervical os in a woman in the *third* trimester (most cases of “apparent” placenta previa in the second trimester will “resolve” by the third trimester)

Note: Transperineal (translabial) and transvaginal US may greatly enhance visualization of the cervix, lower uterine segment, and placental edge. However, the transvaginal technique should not be performed in a patient experiencing vaginal bleeding to avoid precipitating greater hemorrhage.

Unknown Gestational Age

Common Causes

- Inability to recall last menstrual period
- Irregular menstrual cycles
- Oral contraceptive use

Approach to Diagnostic Imaging

1. **Ultrasound**
   - Preferred imaging technique for estimating gestational age
   - Indicated when historical dates are in question or there is a discrepancy between fundal height and dates
   - In the *first* trimester, the crown-rump length of the embryo is used to calculate the approximate gestational age
   - In the *second* and *third* trimesters, the gestational age and fetal weight are calculated by using measurements of the biparietal diameter of the head, head circumference, abdominal circumference, and femur length
   - Nomograms using individual measurements and equations are available to calculate gestational age on the basis of fetal biometry

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Note: Gestational age calculations are very accurate in the first trimester and become increasingly unreliable closer to term. Therefore, measurements in the third trimester are more appropriately made to assess fetal growth rather than to establish gestational age.

APPENDIX I

DIGITAL RADIOGRAPHY (COMPUTED RADIOGRAPHY)

There is currently an increasing trend toward the use of Picture Archiving and Communications Systems (PACS) that utilize digital images rather than traditional x-ray films. Although this approach is ideally suited to the newer, digital imaging modalities–ultrasound (US), computed tomography (CT), magnetic resonance imaging (MRI), and radionuclide studies–conventional radiography presents a significant obstacle. Whether obtained in the main radiology department of a hospital, in the operating suite, or as portable examinations of extremely ill patients, plain radiographs of the chest, abdomen, and skeletal structures are generally obtained in an analog mode. The following systems are currently the main approaches now being used to digitize these analog images and make them PACS-compatible.

DIGITAL CONVERSION OF CONVENTIONAL RADIOGRAPHIC IMAGES (AFTER EXPOSURE AND DEVELOPMENT) Among the many disadvantages of this approach are the high cost (requires twice the number of films for each examination) and the relatively long time required for digital conversion (only a small number of films can be handled). Automatic loading is expensive and complicated because of the many different sizes of films. Manual loading presents even more problems. Because of these drawbacks, digital conversion of conventional radiographic images is not generally used.

PHOTO-STIMULABLE PHOSPHOR RADIOGRAPHY (“FUJI APPROACH”). First introduced in 1981, this technique is based on the storing of two-dimensional information created by x-rays on a photo-stimulable plate the same size as the object. After the plate is illuminated with laser beams, the information it contains is released as photo-stimulated luminescence that is converted into an analog electronic readout by a photo-multiplier. The analog signal obtained is then converted into a digital image. The photo-stimulable plate is reusable, since the image is erased once the laser light releases the stored electrons.

The photo-stimulable phosphor method has been licensed by Fuji to many companies and is currently in wide use. Its major disadvantage is the great expense of the photo-stimulable plates, as well as the rest of the system.

IMAGE INTENSIFICATION. With the use of an image intensifier of sufficient size to capture the image of the subject, the luminescent image created by photo-multiplication can then be digitized. The disadvantage of this approach is the difficulty encountered in manufacturing the required 17" × 17" high-resolution, artifact-free, uniform-surface image intensifiers at an acceptable cost.

DIGITAL DETECTORS. In the near future, large-area, flat-panel digital detectors will replace film and other approaches used to obtain digital images (including image intensifiers). At present, equipment companies are pursuing two main approaches to convert x-rays into electrons: (1) direct conversion in selenium panels and (2) primary absorption in a scintillator with conversion of light in photodiodes. Both of these approaches utilize an array composed of hydrogenated amorphous silicon (a-Si:H) deposited on a glass or ceramic substrate for readout.

For selenium detectors, absorbed x-rays produce a charge that is stored in a capacitor formed in the a-Si:H layer. Each capacitor represents a single pixel, and the charge can be read out independently for each pixel.

For light conversion detectors, cesium iodide scintillators initially absorb x-rays and convert them into visible light. This light is absorbed by low-noise photodiodes formed in the a-Si:H layer and converted into electronic charges. Each photodiode represents a pixel. Charges from each pixel are read out by low-noise electronics, turned into digital data, and sent to a digital processor.

SPECIAL APPROACHES. CT scanners can directly create digital radiographs. This technique is primarily used for pelvimetry, in which sagittal and coronal scout digital radiographs of the pelvis are obtained along with a single-plane transverse image. However, this method of obtaining digital images is far too costly for general use. In addition, it would not provide adequate detail, since the CT matrix is too coarse to produce high-resolution radiographs.

ULTRASOUND

US is the most popular and widely accepted cross-sectional imaging technique. It combines relatively low cost with wide distribution, immediate accessibility, high spatial resolution, and the ability to image in any plane. In this noninvasive modality, high-frequency sound waves produced by electrical stimulation of a specialized crystal are passed through the body (reduced in intensity) in relation to the acoustic properties of the tissues through which they travel. The crystal is mounted in a transducer, which also acts as a receiver to record echoes reflected back from the body whenever sound waves strike an interface between two tissues that have different acoustic impedance. A water-tissue interface produces strong reflections (echoes), whereas a solid-tissue mass that contains only small differences in composition causes weak reflections. Display of the US image on a television monitor shows both the intensity level of the echoes and the position in the body from which they arose. US images may be displayed as static gray-scale images or as multiple images that permit movement to be viewed in real time. In general, fluid-filled structures have intense echoes at their borders, no

internal echoes, and good through-transmission of the sound waves. Solid structures produce internal echoes of variable intensity.

An additional, more recent US technology is the color flow duplex system. In this technique, conventional real-time imaging is combined with Doppler imaging to produce quantitative data, and color to depict motion and the direction and velocity of blood flow. The color and intensity represent the direction of flow and the magnitude of the velocity, respectively.

The major advantage of US is its safety. To date, there is no evidence of adverse effects on human tissues at the intensity level currently used for diagnostic procedures. Therefore, US is the modality of choice for examining children and pregnant women, in whom there is potential danger from the radiation exposure of most other imaging studies. It is by far the best technique for evaluating fetal age, congenital anomalies, and complications of pregnancy.

The major limitation of US is the presence of acoustic barriers, such as air, bone, and barium. For example, air reflects essentially all of the US beam, so that structures beneath it cannot be imaged. This is a special problem in a patient with adynamic ileus and is the major factor precluding US examination of the thorax. For a US study of the pelvis, the patient is usually given large amounts of fluid to fill the bladder, thus displacing the air-filled bowel from the region of interest. In postoperative patients, US may be difficult to perform because of overlying dressings, retention sutures, drains, and open wounds that may prevent the transducer from coming into direct contact with the skin. US is also highly operator-dependent. Extensive technologist (sonographer) and physician (sonologist) training is necessary to produce high-quality images suitable for interpretation.

COMPUTED TOMOGRAPHY

In this technique, cross-sectional tomographic images are obtained by first scanning a “slice” of tissue from multiple angles with a narrow x-ray beam. Then, a relative linear attenuation coefficient (amount of radiation absorbed in tissue for the various tissue elements in the section) is calculated. Finally, the computed reconstruction of hundreds of thousands of bits of data is displayed as a gray-scale image on a television monitor. The CT number reflects the attenuation of a specific tissue relative to that of water, which is arbitrarily given a CT number of 0. The highest CT number is that of bone, the lowest that of air. Fat has a CT number of less than 0, whereas soft tissues have CT numbers greater than 0.

The major advantages of CT (especially when enhanced with oral and intravenous iodinated contrast material) over conventional and digital radiography are its superb contrast resolution, speed, and the ability to display exquisite anatomic detail in tomographic form.

The newest technology in CT is spiral (helical) scanning. In this technique, continual CT scanning is performed as the patient is moved through the gantry (unlike the multiple single scans in conventional CT). This permits much faster scanning with substantial reduction of artifacts due to respiratory motion. Spiral scanning provides data that can be reformatted in coronal and sagittal planes and offers the potential of demonstrating vascular lesions without the need for arteriography.

Because of its many advantages, CT is now competing with US as the screening modality of choice in the industrialized world. The only real disadvantages of CT are its relatively high cost and the use of ionizing radiation.

MAGNETIC RESONANCE IMAGING

This rapidly developing imaging technique basically consists of inducing transitions between energy states by causing certain hydrogen atoms within a powerful static magnetic field to absorb and transfer energy when impacted by a radio pulse of a specific frequency. Various measures of the time required for the material to return to a baseline energy state (relaxation time) can be translated by a complex computer program to a visual image on a television monitor. The parameters of the MR image are set by selection of a pulse sequence. Most magnets used for MRI are superconducting (cryogenic). However, to reduce cost, some equipment uses permanent or resistive magnets.

Although the signal intensity of various substances on MR scans is complex and depends on multiple factors, some generalizations can be made:

T1-weighted imaging: Substances causing high (bright) signal intensity include fat, subacute hemorrhage, highly proteinaceous material (e.g., mucus), and slow-flowing blood. Water, as in cerebrospinal fluid or simple cysts, has a relatively low signal intensity and appears dark. Soft tissue has an intermediate level of signal.
T2-weighted imaging: Water has a high (bright) signal intensity, whereas muscle and other soft tissues (including fat) tend to have a low signal intensity and appear dark.

Bone, calcium, and air appear very dark on all imaging sequences.

MRI has many of the advantages offered by other imaging modalities, without the associated disadvantages. Like US, MRI does not use ionizing radiation and is capable of directly imaging in multiple planes. Unlike US, MRI depends less on the operator's skill and can penetrate bone and air without a significant decrease in intensity so that the underlying tissue can be clearly imaged. Major advantages of MRI over CT are the far higher soft-tissue contrast resolution, the ability to directly image in any plane, the capacity to depict patent blood vessels as signal voids without the need for iodinated contrast material, and the use of innumerable different sequences to improve soft-tissue contrast and reduce artifacts.

Although MRI has improved the sensitivity of detecting abnormal tissue, it has had much less effect on specificity. In the

head, for example, infarction, edema, tumor, infection, and demyelinating disease all produce identical high signal intensity on T2-weighted images. Other disadvantages of MRI are its high cost, the possibility of patient claustrophobia, and the contraindication to imaging in patients with pacemakers (may prevent proper operation) or intracranial ferromagnetic aneurysm clips (may slip and result in hemorrhage). New approaches to motion suppression are constantly being developed. Ultrafast techniques for MRI scanning are now available that can provide high spatial resolution images.

MR angiography (MRA) is a technique that provides high-quality images of the arterial and venous systems with contrast material. Further technical refinements and clinical experience will expand the role of this modality and allow MRA to eventually supplant conventional angiography in the diagnosis of vascular disease.

MRI has emerged as the imaging modality of choice for evaluating the central nervous system (brain and spinal cord), musculoskeletal system (including joints and spine), pelvis, retroperitoneum, mediastinum, and large vessels. It is equivalent to contrast-enhanced CT for studying focal liver disease, lymphadenopathy, and disorders of the spleen, pancreas, and kidneys. In specific clinical situations (e.g., most disease processes involving the central nervous system), it is more cost-effective to perform MRI as the initial imaging procedure to achieve a precise diagnosis, rather than obtaining numerous other imaging studies and then having to order an MRI scan anyway.

MAGNETIC RESONANCE SPECTROSCOPIC IMAGING. MR proton spectroscopic imaging now has two major clinical applications. This modality can be used to stage carcinoma of the prostate by superimposing on the MR image voxels containing data of ratios of normally occurring citrate and choline, which are found in higher concentrations in cancer. Computer software can assign a color to each voxel where the choline-to-citrate ratio is high. In the posttreatment follow-up of patients with brain tumors, proton spectroscopic imaging can differentiate among recurrent tumor, necrosis, and postirradiation changes. This approach takes advantage of the fact that normal brain contains N-acetylaspartate. Tumor has a high concentrations of choline, and necrosis gives no signal.

MAGNETIC SOURCE IMAGING. Magnetic source imaging machines detect tiny magnetic fields created by normally occurring electrical currents in the brain or heart, and amplify them using superconducting circuits (SQUIDs), localizing the activity via a mathematical model. The anatomic source of activity is then shown superimposed on a high-resolution MR image, yielding a composite image showing morphology and function. The temporal resolution is real-time. Applications of this technology include localization of seizure activity in patients with epilepsy and identification and localization of focal functional areas in the brain to enable neurosurgeons to avoid these regions during surgical procedures. This modality is also of great value in identifying foci in the heart that are producing life-threatening arrhythmias. Though still under development, magnetic source imaging shows great promise.

CONTRAST MEDIA

Various oral and intravenous agents are employed in medical imaging to

Increase the contrast between different tissues,
Depict the hollow viscera,
Study blood vessels and the flow within them,
Assess organ function,
Facilitate interventional procedures.

Contrast media are widely used with all imaging modalities except US (although even in this area vascular applications are now being developed and tested prior to approval by the U.S. Food and Drug Administration [FDA]).

BARIUM SULFATE. This inert material is used as a suspension in water primarily to study the gastrointestinal tract. Suspension agents are employed to prevent sedimentation and flocculation. Double-contrast techniques using air (or methylcellulose in enteroclysis) provide superb depiction of mucosal-surface detail.

WATER-SOLUBLE, IODINATED CONTRAST MEDIA. These chemicals can directly visualize the blood vessels (arteriography, venography) or opacify the urinary tract after being excreted by the kidneys. Use of newer, relatively expensive, low osmolar or nonionic contrast materials can reduce the minor complications and the painful and unpleasant symptoms that may commonly follow the injection of hypertonic iodine-containing contrast media. It is unclear whether these newer substances can also reduce the mortality rate of 1 in 100,000 administrations associated with conventional hypertonic iodinated contrast materials.

The American College of Radiology recommends the use of nonionic contrast media in patients with

History of adverse reaction to iodinated contrast material
History of asthma or allergy
Known cardiac dysfunction
Generalized debilitation

Nonionic contrast media are also recommended whenever the radiologist believes that they are indicated.

Water-soluble contrast media are now most frequently used to increase contrast resolution in CT scanning. They can indicate whether an area of abnormality has increased or decreased vascularity, compared with adjacent normal tissue. In the brain, contrast enhancement implies that there has been a break in the blood-brain barrier. Low-osmolar and nonionic iodinated contrast media have recently decreased in price, due to expiration of patents and competition, and their use has increased.

Water-soluble contrast materials are used in routine radiography to demonstrate fistulas, sinuses, and perforations. As an enema, they are used to evaluate suspected colonic perforation or to soften hard stool in patients with severe constipation

ULTRASOUND CONTRAST AGENTS. Contrast agents are now available to increase the sensitivity of both US and Doppler studies, as well as enhancing the signal intensity and widening the applications of these procedures. Most US contrast agents are based on stabilized gas microbubbles. Intravenously injected stabilized gas bubbles must be less than 5 µm in diameter to pass through the pulmonary capillaries. For some contrast media, high-frequency harmonic waves are reflected from the surface of the microbubbles, and if the instrument is tuned to only receive harmonic frequencies, signals from tissues surrounding the vessels can be eliminated.

Another approach for US contrast media is the use of perfluorochemicals, which are inert, dense fluids that can be used in emulsions and are highly US reflective. They are eliminated from the blood stream by phagocytosis, making the liver and spleen visible, or by evaporation through the lungs.

US contrast media are used to enhance visualization of vessels in tumors, demonstrate vessel stenoses, study heart disease, and even perform US hysterosalpingography.

MAGNETIC RESONANCE CONTRAST AGENTS. At present, intravascular, extracellular chelates of gadolinium are used as tissue-enhancing agents to produce effects similar to those of iodinated contrast media in CT. They permit diagnoses that otherwise would require long T2-weighted images to be made on shorter T1-weighted sequences, thus reducing motion artifact. MR contrast agents are far safer than even the nonionic iodinated compounds used in conventional radiography and CT. Their major disadvantage is high cost, especially when added to the already steep price of MRI.

Specific contrast agents for the liver, using minute iron oxide particles that are captured by the reticuloendothelial system and give an extremely low-intensity signal, have been approved by the FDA and are slowly receiving acceptance despite their high cost.

There is a substantial need for an orally administered MR contrast medium to outline the gastrointestinal tract. Currently, only one very costly agent containing bromine (no protons and thus no signal) has been FDA-approved for MRI.

NUCLEAR MEDICINE INSTRUMENTATION

SCINTILLATION CAMERA (ANGER CAMERA) This instrument consists of one, two, or three large, flat, sodium iodide crystals up to 50 cm in diameter. Photons from the radioactive tracer produce luminescence in the crystal, which is then augmented many times by a large number of arrayed photo-multiplier tubes. The two-dimensional location of the source of the signal, which is determined by computing the relative intensity of luminescence emitted by the multiple photo tubes, is displayed on an oscilloscope and then recorded on film.

SINGLE PHOTON EMISSION TOMOGRAPHY (SPECT). In this technique, the detector system rotates around the patient. The signal from the radioactive sources within the body is acquired from multiple projections and integrated using a computer algorithm somewhat similar to but more complicated than that used for CT.

POSITRON EMISSION TOMOGRAPHY (PET). Positron-emitting materials such as radioactive carbon (^{10}C, ^{15}C) or oxygen (^{15}O) have fewer neutrons than protons. They are produced in generators or cyclotrons by bombardment of atoms with protons or deuterons. Many are extremely short-lived. When a positron-emitting isotope is introduced into the body, it enters into annihilation reactions with electrons to produce a pair of gamma photons (each with an energy of 511 keV). These gamma photons radiate linearly in opposite directions at an angle of 180°. When they excite a circle of detectors, the signals are transformed into an image using an algorithm similar to that used in CT.

Today, PET is primarily employed in the search for metastases when CT or MRI is inconclusive. Clinical scanning is predominantly performed with fluorodeoxyglucose tagged with fluorine 18 (^{18}F-FDG). Studies to determine the viability of myocardium following heart attacks are also performed, but not as frequently. PET is also used in functional imaging to identify foci initiating epileptic seizures and to aid in diagnosing Alzheimer's disease.

The disadvantages of PET are its relatively poor spatial resolution (which is improving) and its high cost (which is dropping with increasing use of this modality).

APPENDIX II

With the ever-escalating cost of medicine, it is important to be constantly aware of the patient charges for different tests and procedures ordered. Knowing the price of these studies could lead to a reduction in unwarranted examinations and serve as an impetus to decreasing health care costs through a well reasoned approach to diagnostic imaging.

Although less-expensive procedures sometimes yield approximately the same results as more costly studies, it is important to realize that adding the expense of a more elaborate and expensive test to a relatively inexpensive one will cost the patient (payor) more than if the more sophisticated procedure had simply been ordered and performed initially.

Because charges vary widely among various institutions and in different geographic regions, the relative costs (technical and professional) listed below are expressed as multiples of the plain frontal and lateral examination of the chest, which is designated as “×”.

Barium enema	2.5×
Upper gastrointestinal series	3×
Excretory urogram	3×
Hysterosalpingogram	3×
Ultrasound	3×
Radionuclide scan (lung, bone)	3-4×
Echocardiogram	4-5×
CT	7-10×
MRI	8-12×
MR spectroscopic imaging	10-14×
Angiography	8-12×
CTAP	22×
Surgery	>40×