

Sixth Edition

Primer of  
**DIAGNOSTIC  
IMAGING**

Mukesh G. Harisinghani  
John W. Chen  
Ralph Weissleder

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SIXTH EDITION

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knowledge, research, and wisdom  
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# Preface

The sixth edition of *Primer of Diagnostic Imaging* will continue to function as an integral learning source for residents and fellows, as well as a refresher text for faculty and practicing physicians. This book serves not only as the core curriculum for our fast-evolving specialty but also as a current reference text for practitioners. We have sought to update and include material to reflect current imaging algorithms, while at the same time retaining older material that is pertinent to a variety of practice patterns. Since the preparation of the last edition, we have incorporated further advances in the various imaging modalities and have to the best of our knowledge corrected any

inaccurate information. Furthermore, by continuing to have our successful graduates evaluate the content, we have ensured that the subject matter covers the information assessed by the current American Board of Radiology examination. We are particularly indebted to our reviewers for their feedback. It is our hope that *Primer of Diagnostic Imaging* will continue to serve the next generation of radiologists, helping them navigate the stream of continuously emerging new information.

Mukesh G. Harisinghani  
John W. Chen  
Ralph Weissleder

# Abbreviations

<b>2D</b>	two-dimensional	<b>ANCA</b>	antineutrophil cytoplasmic antibody
<b>3D</b>	three-dimensional	<b>AP</b>	anteroposterior
<b>4D</b>	four-dimensional	<b>APKD</b>	adult polycystic kidney disease
<b>5-HIAA</b>	5-hydroxyindoleacetic acid	<b>APS</b>	anterior pararenal space
<b>AA</b>	aortic arch	<b>APUD</b>	amine precursor uptake and decarboxylation
<b>A-a</b>	alveolar-arterial Po <sub>2</sub> difference	<b>APW</b>	absolute percentage washout
<b>AAA</b>	abdominal aortic aneurysm	<b>AR</b>	autosomal recessive
<b>ABC</b>	aneurysmal bone cyst	<b>ARDS</b>	acute respiratory distress syndrome
<b>ABPA</b>	allergic bronchopulmonary aspergillosis	<b>ARF</b>	anterior renal fascia
<b>ABS</b>	amniotic band syndrome	<b>ARKD</b>	autosomal recessive kidney disease
<b>AC</b>	abdominal circumference; acromioclavicular; alternating current	<b>ARPKD</b>	autosomal recessive polycystic kidney disease
<b>ACA</b>	anterior cerebral artery	<b>ARVD</b>	arrhythmogenic right ventricular dysplasia
<b>ACC</b>	agenesis of corpus callosum; adenoid cystic carcinoma	<b>AS</b>	ankylosing spondylitis; aortic stenosis
<b>ACL</b>	anterior cruciate ligament	<b>ASA</b>	anterior spinal artery
<b>ACLS</b>	advanced cardiac life support	<b>ASD</b>	airspace disease; atrial septal defect
<b>ACOM</b>	anterior communicating (artery)	<b>a-Se</b>	amorphous selenium
<b>ACR</b>	American College of Radiology	<b>ASNR</b>	American Society of Neuroradiology
<b>ACS</b>	anterior cervical space	<b>ATA</b>	American Thyroid Association Guidelines
<b>ACT</b>	activated clotting time	<b>ATN</b>	acute tubular necrosis
<b>ACTH</b>	adrenocorticotrophic hormone	<b>ATP</b>	adenosine triphosphate
<b>AD</b>	adrenal diameter; autosomal dominant; average distance	<b>AV</b>	arteriovenous; atrioventricular
<b>ADC</b>	apparent diffusion coefficient	<b>AVF</b>	arteriovenous fistula
<b>ADEM</b>	acute disseminated encephalomyelitis	<b>AVM</b>	arteriovenous malformation
<b>ADH</b>	antidiuretic hormone	<b>AVN</b>	avascular necrosis
<b>ADPKD</b>	adult dominant polycystic kidney disease	<b>AZV</b>	azygos vein
<b>AFB</b>	aortofemoral bypass	<b>Ba</b>	barium
<b>AFI</b>	amniotic fluid index	<b>BBOT</b>	2,5-bis(5-ter-butyl-2-benzoxasolyl)thiophene
<b>AFL</b>	air-fluid level	<b>BI</b>	Billroth I
<b>AFP</b>	alpha-fetoprotein	<b>BII</b>	Billroth II
<b>AFV</b>	amniotic fluid volume	<b>BAC</b>	bronchoalveolar carcinoma
<b>Ag</b>	silver	<b>BAI</b>	basion-axial interval
<b>AHA</b>	American Heart Association	<b>BBB</b>	blood-brain barrier
<b>AHD</b>	acquired heart disease	<b>BBBD</b>	blood-brain barrier disruption
<b>AI</b>	aortic insufficiency; aluminum	<b>BCDDP</b>	Breast Cancer Detection Demonstration Program
<b>AICA</b>	anterior inferior cerebellar artery	<b>BCNU</b>	1,3-bis(2-chloroethyl)-1-nitrosourea
<b>AICD</b>	automatic implantable cardioverter-defibrillator	<b>BCP</b>	basic calcium phosphate
<b>AICV</b>	anterior intercostal vein	<b>BCS</b>	Budd-Chiari syndrome
<b>AIDS</b>	acquired immunodeficiency syndrome	<b>BE</b>	barium enema; binding energy
<b>AIP</b>	acute interstitial pneumonia	<b>BEIR</b>	Biological Effects of Ionizing Radiation
<b>AJCC</b>	American Joint Committee on Cancer	<b>BF</b>	Bucky factor
<b>ALD</b>	adrenoleukodystrophy	<b>BFM</b>	bronchopulmonary foregut malformation
<b>ALS</b>	amyotrophic lateral sclerosis	<b>BGO</b>	bismuth germanium oxide
<b>AM</b>	abnormal motility	<b>β-HCG</b>	beta-human chorionic gonadotropin
<b>AMI</b>	acute myocardial infarction	<b>BIP</b>	bronchiolitis obliterans interstitial pneumonitis
<b>AML</b>	angiomyolipoma; anterior mitral leaflet	<b>BI-RADS</b>	Breast Imaging Reporting and Data System
<b>amu</b>	atomic mass unit		
<b>ANC</b>	acute necrotic collections		



<b>BLC</b>	benign lymphoepithelial cyst	<b>CLC</b>	corpus luteum cyst
<b>BOOP</b>	bronchiolitis obliterans and organizing pneumonia	<b>CMC</b>	carpometacarpal (joint)
<b>BP</b>	blood pressure	<b>CMD</b>	corticomedullary differentiation
<b>BPD</b>	biparietal diameter; bronchopulmonary dysplasia	<b>CMS</b>	Centers for Medicare and Medicaid Services
<b>BPE</b>	background parenchymal enhancement	<b>CMV</b>	cytomegalovirus
<b>BPF</b>	bronchopleural fistula	<b>CN</b>	cranial nerve
<b>BPH</b>	benign prostatic hyperplasia	<b>CNS</b>	central nervous system
<b>BPM</b>	beats per minute	<b>CO</b>	carbon monoxide
<b>BPOP</b>	bizarre parosteal osteochondromatous proliferation	<b>Co</b>	cobalt
<b>BPP</b>	biophysical profile	<b>COP</b>	cryptogenic organizing pneumonia
<b>Bq</b>	becquerel	<b>COPD</b>	chronic obstructive pulmonary disease
<b>BRBPR</b>	bright red blood per rectum	<b>CP</b>	cerebellopontine; choroid plexus
<b>BRTO</b>	balloon-occluded retrograde transvenous obliteration	<b>CPA</b>	cerebellopontine angle
<b>BS</b>	buccal space	<b>CPAM</b>	congenital pulmonary airway malformation
<b>C</b>	caudate; coulomb	<b>CPAP</b>	continuous positive airway pressure
<b>CA</b>	carcinoma	<b>CPC</b>	choroid plexus cysts
<b>CABG</b>	coronary artery bypass graft	<b>CPM</b>	central pontine myelinosis
<b>CAD</b>	coronary artery disease	<b>cpm</b>	counts per minute
<b>CAH</b>	chronic active hepatitis	<b>CPPD</b>	calcium pyrophosphate dihydrate
<b>CAPD</b>	chronic ambulatory peritoneal dialysis	<b>cps</b>	counts per second
<b>CaWO<sub>4</sub></b>	calcium tungstate	<b>CR</b>	computed radiography
<b>CBD</b>	common bile duct	<b>Cr</b>	creatinine/phosphocreatine
<b>CBF</b>	cerebral blood flow	<b>CREST</b>	calcinosis, Raynaud's, esophageal dysmotility, sclerodactyly, telangiectasia (syndrome)
<b>CBV</b>	cerebral blood volume	<b>CRL</b>	crown-rump length
<b>CC</b>	corneal clouding; craniocaudal; craniocaudal	<b>CRMO</b>	chronic recurrent multifocal osteomyelitis
<b>CCA</b>	common carotid artery	<b>CRPS</b>	complex regional pain syndrome
<b>CCAM</b>	congenital cystic adenoid malformation	<b>C-section</b>	cesarean section
<b>CCF</b>	carotid-cavernous sinus fistula	<b>C-spine</b>	cervical spine
<b>CCK</b>	cholecystokinin	<b>CS</b>	central sulcus; carotid space
<b>CCU</b>	coronary care unit	<b>Cs</b>	cesium
<b>CD</b>	cystic duct	<b>CSF</b>	cerebrospinal fluid
<b>CD4</b>	cluster designation 4 antigen	<b>CsI</b>	cesium iodide
<b>CDH</b>	congenital diaphragmatic hernia; congenital dislocation of the hip	<b>CSP</b>	corrected sinusoidal pressure
<b>CDI</b>	color Doppler imaging	<b>CT</b>	computed tomography
<b>cd/m<sup>2</sup></b>	candela per square meter	<b>CTA</b>	computed tomographic angiography
<b>CEA</b>	carcinoembryonic antigen	<b>CTAP</b>	computed tomographic arterial portography
<b>CECT</b>	contrast-enhanced computed tomography	<b>CTC</b>	computed tomography colonography
<b>CF</b>	cystic fibrosis	<b>CTDI</b>	CT dose index
<b>CFA</b>	common femoral artery; cryptogenic fibrosing alveolitis	<b>CTP</b>	computed tomographic perfusion
<b>CHA</b>	calcium hydroxyapatite; common hepatic artery	<b>CTPA</b>	CT pulmonary angiography
<b>CHAOS</b>	congenital high airway obstruction	<b>CTV</b>	computed tomographic venography
<b>CHD</b>	common hepatic duct; congenital heart disease	<b>CU</b>	clinical unit
<b>CHF</b>	congestive heart failure	<b>Cu</b>	copper
<b>Cho</b>	choline	<b>CVA</b>	cerebrovascular accident
<b>CHP</b>	chronic hypersensitivity pneumonitis	<b>CVR</b>	CPAM volume ratio
<b>CI</b>	cardiothoracic index	<b>CVS</b>	calcium volume score; chorionic villus sampling
<b>Ci</b>	Curie	<b>CWP</b>	coal workers' pneumoconiosis
<b>CIDP</b>	chronic inflammatory demyelinating polyneuropathy	<b>CXR</b>	chest radiograph
<b>CIN</b>	contrast-induced nephropathy	<b>D</b>	dilatation
<b>CJD</b>	Creutzfeldt-Jakob disease	<b>DA</b>	double arch
		<b>DAI</b>	diffuse axonal injury
		<b>dB</b>	decibel
		<b>DC</b>	direct current
		<b>DCIS</b>	ductal carcinoma in situ

<b>DDH</b>	developmental dysplasia of the hip	<b>ESR</b>	erythrocyte sedimentation rate
<b>DDx</b>	differential diagnosis	<b>ESV</b>	end-systolic volume
<b>DE-CMRI</b>	delayed-enhancement cardiac magnetic resonance imaging	<b>ESWL</b>	extracorporeal shock wave lithotripsy
<b>DECT</b>	dual-energy CT	<b>ET</b>	endotracheal tube
<b>DES</b>	diethylstilbestrol; diffuse esophageal spasm	<b>ETL</b>	echo train length
<b>DFTN</b>	diffuse fold thickening with fine nodularity	<b>eV</b>	electron volt
<b>DIC</b>	disseminated intravascular coagulation	<b>EVLt</b>	endovenous laser treatment
<b>DIP</b>	desquamative interstitial pneumonitis; distal interphalangeal (joint)	<b>EXP</b>	exponential
<b>DIPS</b>	direct intrahepatic portocaval shunt	<b>FAPS</b>	familial adenomatous polyposis syndrome
<b>DISH</b>	diffuse idiopathic skeletal hyperostosis	<b>FBP</b>	filtered back projection
<b>DISI</b>	dorsal intercalated segment instability	<b>FCD</b>	fibrous cortical defect
<b>DJD</b>	degenerative joint disease	<b>FD</b>	filling defect
<b>DLBCL</b>	diffuse large B-cell lymphoma	<b>FDA</b>	U.S. Food and Drug Administration
<b>DLP</b>	dose length product	<b>FDG</b>	fluorodeoxyglucose
<b>DM</b>	diabetes mellitus	<b>Fe</b>	iron
<b>DMSA</b>	dimercaptosuccinic acid	<b>FESS</b>	functional endoscopic sinus surgery
<b>DNA</b>	deoxyribonucleic acid	<b>FEV</b>	forced expiratory volume
<b>DNET</b>	dysembryoplastic neuroepithelial tumor	<b>FFDM</b>	full-field digital mammography
<b>DORV</b>	double-outlet right ventricle	<b>FGT</b>	fibroglandular tissue
<b>DPS</b>	dorsal pleural sinus	<b>FIGO</b>	International Federation of Gynecology and Obstetrics
<b>DR</b>	digital radiography	<b>FL</b>	femur length
<b>DRE</b>	digital rectal examination	<b>FLAIR</b>	fluid-attenuated inversion recovery
<b>DSA</b>	digital subtraction angiography	<b>FMC</b>	focal myometrial contraction
<b>D-TGA</b>	complete transposition of great arteries	<b>FMD</b>	fibromuscular dysplasia
<b>DTPA</b>	diethylenetriaminepentaacetic acid	<b>fMRI</b>	functional magnetic resonance imaging
<b>DU</b>	deep ulcer(s)	<b>FN</b>	false negative
<b>DVT</b>	deep vein thrombosis	<b>FNA</b>	fine-needle aspiration
<b>DW</b>	Dandy-Walker	<b>FNH</b>	focal nodular hyperplasia
<b>DWI</b>	diffusion-weighted imaging	<b>FOD</b>	focal spot–object distance
<b>E</b>	exposure	<b>FOV</b>	field of view
<b>E<sub>aver</sub></b>	average electron energy	<b>FP</b>	false positive
<b>E<sub>max</sub></b>	maximum energy	<b>FRC</b>	functional residual capacity
<b>EA</b>	esophageal atresia	<b>FS</b>	focal spot; fractional shortening
<b>EAC</b>	external auditory canal	<b>FSE</b>	fast spin echo
<b>EBV</b>	Epstein-Barr virus	<b>FSH</b>	follicle-stimulating hormone
<b>ECA</b>	external carotid artery	<b>FTA-ABS</b>	fluorescent treponemal antibody absorption (test)
<b>ECD</b>	endocardial cushion defect; ethyl cysteinyl dimer	<b>FUO</b>	fever of unknown origin
<b>ECF</b>	extracellular fluid	<b>FWHM</b>	full width at half maximum
<b>ECG</b>	electrocardiogram	<b>g</b>	gram
<b>ECMO</b>	extracorporeal membrane oxygenation	<b>GA</b>	gestational age
<b>EDH</b>	epidural hematoma	<b>Ga</b>	gallium
<b>EDV</b>	end-diastolic volume	<b>GB</b>	gallbladder
<b>EEG</b>	electroencephalogram	<b>GBCA</b>	Gd-based contrast agents
<b>EF</b>	ejection fraction	<b>GBM</b>	glioblastoma multiforme
<b>EFW</b>	estimated fetal weight	<b>GBPS</b>	gated blood pool study
<b>EG</b>	eosinophilic granuloma	<b>G-CSF</b>	granulocyte colony-stimulating factor
<b>EGA</b>	estimated gestational age	<b>GCT</b>	giant cell tumor
<b>EMS</b>	endometrial stripe	<b>Gd</b>	gadolinium
<b>ENT</b>	ear, nose, throat	<b>GDA</b>	gastroduodenal artery
<b>EPA</b>	Environmental Protection Agency	<b>GE</b>	gastroesophageal
<b>EPO</b>	erythropoietin	<b>GEJ</b>	gastroesophageal junction
<b>ERCP</b>	endoscopic retrograde cholangiopancreatography	<b>GFR</b>	glomerular filtration rate
<b>ERPF</b>	effective renal plasma flow	<b>GH</b>	growth hormone
<b>ERV</b>	expiratory reserve volume	<b>GI</b>	gastrointestinal
		<b>GIP</b>	giant cell interstitial pneumonia
		<b>GIST</b>	gastrointestinal stromal tumor
		<b>GLAD</b>	glenolabral degenerative joint disease

<b>glut</b>	glucose transporter	<b>ICV</b>	internal cerebral vein
<b>GLUT1</b>	glucose transporter 1	<b>ID</b>	information density; inner diameter
<b>GM</b>	gray matter	<b>IDA</b>	iminodiacetic acid
<b>GnRH</b>	gonadotropin-releasing hormone	<b>IDH</b>	isocitrate dehydrogenase
<b>GRE</b>	gradient-recalled echo	<b>IG</b>	immunoglobulin
<b>GSD</b>	genetically significant dose	<b>IgA</b>	immunoglobulin A
<b>GSO</b>	gadolinium oxyorthosilicate	<b>IgE</b>	immunoglobulin E
<b>GTD</b>	gestational trophoblastic disease	<b>IgG</b>	immunoglobulin G
<b>GU</b>	genitourinary	<b>IHF</b>	immune hydrops fetalis
<b>GVH</b>	graft-versus-host (disease)	<b>IHN</b>	infrahyoid
<b>GWM</b>	gray-white matter	<b>IHSS</b>	idiopathic hypertrophic subaortic stenosis
<b>Gy</b>	gray (unit of radiation)	<b>IJV</b>	internal jugular vein
<b>H</b>	height	<b>IL-2</b>	interleukin-2
<b>HA</b>	hepatic artery	<b>ILO</b>	International Labor Organization
<b>HAZV</b>	hemiazygos vein	<b>ILT</b>	inferolateral trunk
<b>Hb</b>	hemoglobin	<b>IM</b>	intramuscular
<b>HbAS</b>	sickle cell trait	<b>IMA</b>	inferior mesenteric artery
<b>HbSS</b>	sickle cell disease	<b>IMV</b>	internal mammary vein
<b>HC</b>	head circumference	<b>In</b>	indium
<b>HCC</b>	hepatocellular carcinoma	<b>INF</b>	inferior
<b>HCG</b>	human chorionic gonadotropin	<b>INH</b>	isoniazid
<b>HD</b>	Hurter and Driffeld (curve)	<b>INR</b>	international normalized ratio
<b>HGH</b>	human growth hormone	<b>INSS</b>	International Neuroblastoma Staging System
<b>HIDA</b>	hepatic iminodiacetic acid derivative	<b>IPF</b>	idiopathic pulmonary fibrosis
<b>HIP</b>	health insurance plan	<b>IPH</b>	idiopathic pulmonary hemorrhage
<b>HIV</b>	human immunodeficiency virus	<b>IPKD</b>	infantile polycystic kidney disease
<b>HLA</b>	human leukocyte antigen	<b>IPMN</b>	intraductal papillary mucinous neoplasm
<b>HLHS</b>	hypoplastic left heart syndrome	<b>IPMT</b>	intraductal papillary mucinous tumor
<b>HMD</b>	hyaline membrane disease	<b>IQ</b>	intelligence quotient
<b>HMDP</b>	hydroxymethylene diphosphonate	<b>IRV</b>	inspiratory reserve volume
<b>HMPAO</b>	hexamethylpropyleneamine oxime	<b>ITB</b>	iliotibial band
<b>HOCA</b>	high-osmolar contrast agent	<b>IUD</b>	intrauterine device
<b>HPF</b>	high-power field	<b>IUGR</b>	intrauterine growth retardation
<b>HPO</b>	hypertrophic pulmonary osteoarthropathy	<b>IUP</b>	intrauterine pregnancy
<b>HPS</b>	hypertrophic pyloric stenosis	<b>IV</b>	intravenous
<b>HPT</b>	hyperparathyroidism	<b>IVC</b>	inferior vena cava
<b>HPV</b>	human papilloma virus	<b>IVDA</b>	intravenous drug abuse(r)
<b>HQ</b>	high-quality	<b>IVP</b>	intravenous pyelogram
<b>HR</b>	heart rate	<b>IVS</b>	interventricular septum
<b>hr</b>	hour	<b>JRA</b>	juvenile rheumatoid arthritis
<b>HRCT</b>	high-resolution computed tomography	<b>keV</b>	kiloelectron volt
<b>HS</b>	hepatosplenomegaly; high-speed	<b>Kr</b>	krypton
<b>HSA</b>	human serum albumin	<b>KS</b>	Kaposi sarcoma
<b>HSG</b>	hysterosalpingogram	<b>KUB</b>	kidney, urethra, bladder
<b>HSV</b>	herpes simplex virus	<b>kV</b>	kilovoltage
<b>HTLV</b>	human T-cell lymphotropic virus	<b>kVp</b>	peak kilovoltage
<b>HTN</b>	hypertension	<b>L</b>	left; length
<b>HU</b>	heat unit; Hounsfield unit	<b>LA</b>	left atrium
<b>HVA</b>	homovanillic acid	<b>La</b>	lanthanum
<b>HVL</b>	half-value layer	<b>LAD</b>	left anterior descending (artery)
<b>IA</b>	intraarterial	<b>LAE</b>	left atrial enlargement
<b>IAA</b>	interruption of aortic arch	<b>LAM</b>	lymphangiioleiomyomatosis
<b>IABP</b>	intraaortic balloon pump	<b>LAO</b>	left anterior oblique
<b>IAC</b>	internal auditory canal	<b>LATS</b>	long-acting thyroid-stimulating (factor)
<b>IBD</b>	inflammatory bowel disease	<b>LBBS</b>	left bundle branch block
<b>ICA</b>	internal carotid artery	<b>LBWC</b>	limb/body wall complex
<b>ICRP</b>	International Commission on Radiological Protection		
<b>ICU</b>	intensive care unit		

<b>LCA</b>	left carotid artery; left coronary artery	<b>MA</b>	meconium aspiration; mesenteric adenopathy
<b>LCF</b>	lateroconal fascia	<b>mA</b>	milliampere
<b>LCIS</b>	lobular carcinoma in situ	<b>MAA</b>	macroaggregated albumin
<b>LCL</b>	lateral collateral ligament	<b>MAb</b>	monoclonal antibody
<b>LCNEC</b>	large cell neuroendocrine carcinoma	<b>MAG</b>	methyl-acetyl-gly
<b>LCP</b>	Legg-Calvé-Perthes (disease)	<b>MAG3</b>	methyl-acetyl-gly-gly-gly
<b>LCx</b>	left circumflex (artery)	<b>MAI</b>	<i>Mycobacterium avium-intracellulare</i>
<b>LD</b>	lymphocyte depleted (Hodgkin lymphoma)	<b>MALT</b>	mucosa-associated lymphoid tissue
<b>LD<sub>50</sub></b>	lethal dose, 50%	<b>MAOI</b>	monoamine oxidase inhibitor
<b>LDH</b>	lactate dehydrogenase	<b>MAP</b>	maximum-a-posteriori
<b>LEJV</b>	left external jugular vein	<b>mAs</b>	milliampere second
<b>LES</b>	lower esophageal sphincter	<b>MBq</b>	megabecquerel
<b>LET</b>	linear energy transfer	<b>MC</b>	mixed cellularity (Hodgkin lymphoma)
<b>LFT</b>	liver function test	<b>MCA</b>	middle cerebral artery
<b>LGA</b>	large for gestational age; left gastric artery	<b>MCD</b>	medullary cystic disease
<b>LH</b>	luteinizing hormone	<b>MCDK</b>	multicystic dysplastic kidney
<b>LHA</b>	left hepatic artery	<b>mCi</b>	millicurie
<b>LHD</b>	left hepatic duct	<b>μCi</b>	microcurie
<b>LIJV</b>	left internal jugular vein	<b>MCL</b>	medial collateral ligament
<b>LIMA</b>	left internal mammary artery	<b>MCP</b>	metacarpophalangeal
<b>LIMV</b>	left internal mammary vein	<b>MCTD</b>	mixed connective tissue disease
<b>LIP</b>	lymphocytic interstitial pneumonia	<b>MCV</b>	middle cerebral vein
<b>LIQ</b>	low intelligence quotient	<b>MD</b>	monochorionic, diamniotic (twins)
<b>LL</b>	lower lobe	<b>MDA</b>	metaphyseal-diaphyseal angle
<b>LLI</b>	left lateral inferior	<b>MDCT</b>	multidetector computed tomography
<b>LLL</b>	left lower lobe	<b>MDP</b>	methylene diphosphonate
<b>LLS</b>	left lateral superior	<b>MELAS</b>	mitochondrial myopathy, encephalopathy, lactic acidosis, stroke like episodes (syndrome)
<b>LM</b>	lateromedial	<b>MEN</b>	multiple endocrine neoplasia
<b>LMB</b>	left mainstem bronchus	<b>MERRF</b>	myoclonic epilepsy with ragged red fibers (syndrome)
<b>LMI</b>	left medial inferior	<b>MeV</b>	megaelectron volt
<b>LMP</b>	last menstrual period	<b>MFH</b>	malignant fibrous histiocytoma
<b>LMS</b>	left medial superior	<b>MGH</b>	Massachusetts General Hospital
<b>LN</b>	lymph node	<b>MHz</b>	megahertz
<b>LOCA</b>	low-osmolar contrast agent	<b>MI</b>	myocardial infarction
<b>LP</b>	lymphocyte predominant (Hodgkin lymphoma)	<b>MIBG</b>	metaiodobenzylguanidine
<b>LPA</b>	left pulmonary artery	<b>MIBI</b>	methoxyisobutyl isonitrile
<b>LPM</b>	anterolateral papillary muscle	<b>MIP</b>	maximum-intensity projection
<b>LPO</b>	left posterior oblique	<b>ML</b>	mediolateral
<b>LPV</b>	left portal vein	<b>MLCN</b>	multilocular cystic nephroma
<b>LR</b>	likelihood ratio	<b>MLD</b>	maximum transverse diameter to the left from midline
<b>L-R shunt</b>	left-to-right shunt	<b>MLEM</b>	maximum likelihood expectation maximization
<b>LSA</b>	left subclavian artery	<b>MLO</b>	mediolateral oblique
<b>LSCV</b>	left subclavian vein	<b>MM</b>	monoamniotic, monochorionic (twins)
<b>LSICV</b>	left superior intercostal vein	<b>MNG</b>	multinodular goiter
<b>LSMFT</b>	liposclerosing myxofibrous tumor	<b>Mo</b>	molybdenum
<b>LSO</b>	lutetium oxyorthosilicate	<b>mo</b>	month
<b>L-TGA</b>	corrected transposition of great arteries	<b>MOCE</b>	multiple osteocartilaginous exostoses
<b>LTV</b>	lateral thoracic vein	<b>MOM</b>	multiples of median
<b>LUCL</b>	lateral ulnar collateral ligament	<b>mOsm</b>	milliosmole
<b>LUL</b>	left upper lobe	<b>MPA</b>	main pulmonary artery
<b>LUQ</b>	left upper quadrant	<b>MPD</b>	maximum permissible dose
<b>LUS</b>	lower uterine segment	<b>MPM</b>	posteromedial papillary muscle
<b>LV</b>	left ventricle	<b>MPV</b>	main portal vein
<b>LVA</b>	left vertebral artery	<b>MR</b>	magnetic resonance
<b>LVE</b>	left ventricular enlargement	<b>mR</b>	milliroentgen
<b>LVEF</b>	left ventricular ejection fraction		
<b>L VH</b>	left ventricular hypertrophy		
<b>LYSO</b>	lutetium yttrium oxyorthosilicate		

<b>MRA</b>	magnetic resonance angiography	<b>NTD</b>	neural tube defect
<b>MRCF</b>	magnetic resonance cholangiopancreatography	<b>NTMB</b>	nontuberculous mycobacteria
<b>MRD</b>	maximum transverse diameter to the right from midline	<b>OA</b>	osteoarthritis
<b>MRE</b>	magnetic resonance enterography	<b>OC</b>	oral contraceptive; optical colonoscopy; oral cavity
<b>MRI</b>	magnetic resonance imaging	<b>OCH</b>	Oriental cholangiohepatitis
<b>MRS</b>	magnetic resonance spectroscopy	<b>OD</b>	once daily; optical density; outer diameter
<b>MRSA</b>	methicillin-resistant <i>Staphylococcus aureus</i>	<b>ODD</b>	object-detector distance
<b>MRV</b>	magnetic resonance venography	<b>ODS</b>	osmotic demyelination syndrome
<b>MS</b>	multiple sclerosis	<b>OEIS</b>	omphalocele, exstrophy, imperforate anus, special anomaly
<b>MSA</b>	multisystem atrophy	<b>OFD</b>	occipitofrontal diameter
<b>MSAFP</b>	maternal serum alpha-fetoprotein	<b>OI</b>	osteogenesis imperfecta
<b>MSD</b>	mean sac diameter	<b>OIC</b>	osteogenesis imperfecta congenita
<b>mSv</b>	millisievert	<b>OIT</b>	osteogenesis imperfecta tarda
<b>MT</b>	magnetization transfer	<b>OMC</b>	osteomeatal complex
<b>MTB</b>	<i>Mycobacterium tuberculosis</i>	<b>OP</b>	oropharynx
<b>MTF</b>	modulation transfer function	<b>OPLL</b>	ossification of the posterior longitudinal ligament
<b>MTP</b>	metatarsal phalangeal (joint)	<b>OPSCC</b>	oropharyngeal squamous cell carcinoma
<b>MTT</b>	mean transit time	<b>ORIF</b>	open reduction and internal fixation
<b>MV</b>	mitral valve	<b>OSA</b>	osteosarcoma
<b>MVA</b>	motor vehicle accident	<b>OSEM</b>	ordered set expectation maximization
<b>MVP</b>	mitral valve prolapse	<b>Osm</b>	osmoles
<b>MW</b>	molecular weight		
<b>NAA</b>	<i>N</i> -acetyl aspartate	<b>PA</b>	posteroanterior; pulmonary artery
<b>NB</b>	nasal bone length	<b>PAC</b>	premature atrial contraction
<b>nCi</b>	nanocurie	<b>PAG</b>	perineural arachnoid gliomatosis
<b>NCRP</b>	National Council on Radiation Protection	<b>PAH</b>	pulmonary arterial hypertension
<b>NEC</b>	necrotizing enterocolitis	<b>PAN</b>	polyarteritis nodosa
<b>NEMA</b>	National Electrical Manufacturers Association	<b>PAPVC</b>	partial anomalous pulmonary venous connection
<b>NEMD</b>	nonspecific esophageal motility disorder(s)	<b>PAVM</b>	pulmonary arteriovenous malformation
<b>NEX</b>	number of excitations	<b>Pb</b>	lead
<b>NF</b>	neurofibromatosis	<b>PC</b>	phase contrast
<b>NF1</b>	neurofibromatosis type 1	<b>PCA</b>	posterior cerebral artery
<b>NF2</b>	neurofibromatosis type 2	<b>PCDK</b>	polycystic dysplastic kidney
<b>NG</b>	nasogastric	<b>PCL</b>	posterior cruciate ligament
<b>NH</b>	nonhereditary	<b>PCN</b>	percutaneous nephrostomy
<b>NHL</b>	non-Hodgkin lymphoma	<b>PCNSL</b>	primary central nervous system lymphoma
<b>Ni</b>	nickel	<b>PCO</b>	polycystic ovary
<b>NIDDM</b>	non-insulin-dependent diabetes mellitus	<b>PCOM</b>	posterior communicating (artery)
<b>NIH</b>	National Institutes of Health	<b>PCP</b>	<i>Pneumocystis</i> pneumonia
<b>NIHF</b>	nonimmune hydrops fetalis	<b>PCS</b>	posterior cervical space
<b>NME</b>	nonmass enhancement	<b>PD</b>	pancreatic duct
<b>NOF</b>	nonossifying fibroma	<b>PDA</b>	patent ductus arteriosus
<b>NOS</b>	not otherwise specified	<b>PDAC</b>	pancreatic ductal adenocarcinoma
<b>NP</b>	neonatal pneumonia	<b>PDW</b>	proton density weighted
<b>NPC</b>	nasopharyngeal carcinoma	<b>PE</b>	photoelectric effect; pulmonary embolism
<b>NPH</b>	normal-pressure hydrocephalus	<b>PEEP</b>	positive end-expiratory pressure
<b>NPO</b>	nil per os (fasting)	<b>PEM</b>	positron emission mammography
<b>NPV</b>	negative predictive value	<b>PET</b>	positron emission tomography
<b>NR</b>	net count rate	<b>PFA</b>	profunda femoral artery
<b>NRC</b>	Nuclear Regulatory Commission	<b>PFC</b>	persistent fetal circulation
<b>NS</b>	nodular sclerosing (Hodgkin lymphoma)	<b>PGE<sub>1</sub></b>	prostaglandin E-1
<b>NSA</b>	number of signals averaged	<b>PHA</b>	pulse height analyzer
<b>NSAID</b>	nonsteroidal antiinflammatory drug	<b>PHPV</b>	persistent hyperplastic primary vitreous
<b>NSF</b>	nephrogenic systemic fibrosis	<b>PHS</b>	pulse height selector
<b>NSIP</b>	nonspecific interstitial pneumonia	<b>PI</b>	pulsatility index
<b>NT</b>	nuchal translucency	<b>PICA</b>	posterior inferior cerebellar artery

<b>PICV</b>	posterior intercostal vein	<b>PUD</b>	peptic ulcer disease
<b>PID</b>	pelvic inflammatory disease	<b>PUL</b>	percutaneous ureterolithotomy
<b>PIE</b>	pulmonary infiltrates with eosinophilia; pulmonary interstitial emphysema	<b>PUV</b>	posterior urethral valve
<b>PIOPED</b>	prospective investigation of pulmonary embolus detection	<b>PV</b>	portal vein
<b>PIP</b>	postinflammatory polyp; proximal interphalangeal (joint)	<b>PVA</b>	polyvinyl alcohol
<b>PJP</b>	<i>Pneumocystis jiroveci</i> pneumonia	<b>PVC</b>	premature ventricular contraction; polyvinyl chloride
<b>PKU</b>	phenylketonuria	<b>PVH</b>	pulmonary venous hypertension
<b>PLN</b>	projected length of needle	<b>PVNS</b>	pigmented villonodular synovitis
<b>PLPN</b>	projected length to pull back needle	<b>PVOD</b>	pulmonary venoocclusive disease
<b>PM</b>	photomultiplier (tube)	<b>PVP</b>	portal venous phase
<b>PMC</b>	pseudomembranous colitis	<b>PVS</b>	perivertebral space
<b>PMF</b>	progressive massive fibrosis	<b>PWI</b>	perfusion-weighted imaging
<b>PMHR</b>	predicted maximum heart rate	<b>PWMA</b>	periventricular white matter abnormality
<b>PML</b>	posterior mitral leaflet; progressive multifocal leukoencephalopathy	<b>PZT</b>	lead zirconium titanate
<b>PMMA</b>	polymethylmethacrylate	<b>QA</b>	quality assurance
<b>PMS</b>	pharyngeal mucosal space	<b>qid</b>	four times daily
<b>PMT</b>	photomultiplier tube	<b>R</b>	range; right; roentgen
<b>PNET</b>	primitive neuroectodermal tumor	<b>Ra</b>	radium
<b>PO</b>	orally (per os)	<b>RA</b>	right atrium; rheumatoid arthritis
<b>Po<sub>2</sub></b>	partial pressure of oxygen	<b>RAI</b>	right anterior inferior
<b>post.</b>	posterior	<b>RAIU</b>	radioactive iodine uptake
<b>PP</b>	parietal peritoneum	<b>RAO</b>	right anterior oblique
<b>PPF</b>	pterygopalatine fossa	<b>RAS</b>	renal artery stenosis; right anterior superior
<b>PPHN</b>	persistent pulmonary hypertension of the newborn	<b>RB-ILD</b>	respiratory bronchiolitis–associated interstitial lung disease
<b>ppm</b>	parts per million	<b>RBBB</b>	right bundle branch block
<b>PPO</b>	2,5-ciphenyloxazole	<b>RBC</b>	red blood cell(s) (count)
<b>PPS</b>	posterior pararenal space; parapharyngeal space	<b>RBE</b>	relative biologic effectiveness
<b>PPV</b>	positive predictive value	<b>RCA</b>	right carotid artery; right coronary artery
<b>PRES</b>	posterior reversible encephalopathy syndrome	<b>RCC</b>	renal cell carcinoma
<b>PRF</b>	pulse repetition frequency; posterior renal fascia	<b>RCV</b>	red cell volume
<b>PRL</b>	prolactin	<b>RCVS</b>	reversible cerebral vasoconstriction syndrome
<b>PROM</b>	premature rupture of membranes	<b>RDS</b>	respiratory distress syndrome
<b>PRS</b>	perinephric space	<b>REJV</b>	right external jugular vein
<b>PS</b>	parotid space	<b>RES</b>	reticuloendothelial system
<b>PSA</b>	prostate-specific antigen	<b>RF</b>	radiofrequency; rheumatoid factor
<b>PSE</b>	partial splenic embolization	<b>RGA</b>	right gastric artery
<b>PSMA</b>	prostate-specific membrane antigen	<b>Rh</b>	rhesus (factor)
<b>PSP</b>	progressive supranuclear palsy	<b>RHA</b>	right hepatic artery
<b>PSPMT</b>	pulse spray pharmacomechanical thrombolysis	<b>RHD</b>	right hepatic duct
<b>PSS</b>	progressive systemic sclerosis	<b>RI</b>	resistive index
<b>PT</b>	prothrombin time	<b>RIJV</b>	right internal jugular vein
<b>PTA</b>	percutaneous transluminal angioplasty	<b>RIMA</b>	right internal mammary artery
<b>PTCA</b>	percutaneous transluminal coronary angioplasty	<b>RIMV</b>	right internal mammary vein
<b>PTD</b>	posttransplantation lymphoproliferative disorder	<b>RIND</b>	reversible ischemic neurologic deficit
<b>PTFE</b>	polytetrafluoroethylene	<b>R-L shunt</b>	right-to-left shunt
<b>PTH</b>	parathormone	<b>RLL</b>	right lower lobe
<b>PTLD</b>	posttransplantation lymphoproliferative disorder	<b>RLQ</b>	right lower quadrant
<b>PTT</b>	partial thromboplastin time	<b>RMB</b>	right mainstem bronchus
<b>PTU</b>	propylthiouracil	<b>RML</b>	right middle lobe
		<b>RMS</b>	retromesenteric anterior interfascial space
		<b>Rn</b>	radon
		<b>RNA</b>	ribonucleic acid
		<b>ROI</b>	range of interest
		<b>rPA</b>	ratio of pulmonary artery diameter to aortic diameter

<b>RPI</b>	right posterior inferior	<b>SPIO</b>	superparamagnetic iron oxide
<b>RPN</b>	renal papillary necrosis	<b>SSFP</b>	steady-state free precession
<b>RPO</b>	right posterior oblique	<b>SSFSE</b>	single-shot fast spin echo
<b>RPS</b>	right posterior superior; retropharyngeal space	<b>ST</b>	ST complex on ECG
<b>RPV</b>	right portal vein	<b>STIR</b>	short tau inversion recovery
<b>RPW</b>	relative percentage washout	<b>STT</b>	scaphotrapeziotrapezoid
<b>RRS</b>	retrorenal posterior interfascial space	<b>SU</b>	superficial ulcer(s)
<b>RSA</b>	right subclavian artery	<b>sup.</b>	superior
<b>RSCV</b>	right subclavian vein	<b>SUV</b>	standardized uptake value
<b>RSV</b>	respiratory syncytial virus	<b>SV</b>	seminal vesicle
<b>RT</b>	radiotherapy	<b>SVC</b>	superior vena cava
<b>RTA</b>	renal tubular acidosis	<b>SWI</b>	susceptibility-weighted imaging
<b>r-tPA</b>	recombinant tissue plasminogen activator	<b>T</b>	tesla; thalamus; time
<b>RTV</b>	right thoracic vein	<b>T1W</b>	T1-weighted (images)
<b>RUG</b>	retrograde urethrogram	<b>T2W</b>	T2-weighted (images)
<b>RUL</b>	right upper lobe	<b>T3</b>	triiodothyronine
<b>RUQ</b>	right upper quadrant	<b>T4</b>	thyroxine
<b>RV</b>	reserve volume; right ventricle	<b>T18</b>	trisomy 18
<b>RVA</b>	right vertebral artery	<b>T21</b>	trisomy 21
<b>RVEF</b>	right ventricular ejection fraction	<b>TA</b>	truncus arteriosus
<b>RVH</b>	right ventricular hypertrophy	<b>TAPVC</b>	total anomalous pulmonary venous connection
<b>RVT</b>	renal vein thrombosis	<b>TAPVR</b>	total anomalous pulmonary venous return
<b>s</b>	second	<b>TAR</b>	thrombocytopenia-absent radius (syndrome)
<b>S/P</b>	status post	<b>TAS</b>	transabdominal ultrasound
<b>SA</b>	sinoatrial; subclavian artery; specific activity	<b>TB</b>	tuberculosis
<b>SAH</b>	subarachnoid hemorrhage	<b>TBI</b>	traumatic brain injury
<b>SB</b>	small bowel	<b>TC</b>	thyroid cartilage
<b>SBFT</b>	small bowel follow-through	<b>Tc</b>	technetium
<b>SBO</b>	small bowel obstruction	<b>TCC</b>	transitional cell cancer
<b>SC</b>	subcutaneous	<b>TCD</b>	transcranial Doppler
<b>SCA</b>	superior cerebellar artery	<b>TD</b>	tolerance dose
<b>SCC</b>	squamous cell carcinoma	<b>TDL</b>	true depth of lesion
<b>SCFE</b>	slipped capital femoral epiphysis	<b>TDLU</b>	terminal duct lobular unit
<b>SCLS</b>	small cell lung cancer	<b>TE</b>	echo time
<b>SD</b>	standard deviation	<b>TEE</b>	transesophageal echocardiography
<b>SDAT</b>	senile dementia, Alzheimer type	<b>TEF</b>	tracheoesophageal fistula
<b>SDH</b>	subdural hematoma	<b>TF</b>	thickened folds; transversalis fascia
<b>SE</b>	spin echo	<b>TFA</b>	tibiofemoral angle
<b>seg.</b>	segment	<b>TFCC</b>	triangular fibrocartilage complex
<b>SFA</b>	superficial femoral artery	<b>TFN</b>	thickened folds with nodularity
<b>SGA</b>	small for gestational age	<b>TGA</b>	transposition of great arteries
<b>SGOT</b>	serum glutamic-oxaloacetic transaminase	<b>TGC</b>	time-gain compensator
<b>SHN</b>	suprahyoid	<b>THR</b>	total hip replacement
<b>SI</b>	sacroiliac; signal intensity	<b>THY</b>	thyroid gland
<b>SIN</b>	salpingitis isthmica nodosa	<b>TI</b>	terminal ileum; thallium; time of inversion
<b>SiO<sub>2</sub></b>	silicone dioxide	<b>TIA</b>	transient ischemic attack
<b>SK</b>	streptokinase	<b>TiO<sub>2</sub></b>	titanium dioxide
<b>SL</b>	sublingual	<b>TIPS</b>	transjugular intrahepatic portosystemic shunt
<b>SLAC</b>	scapholunate advanced collapse	<b>TIRADS</b>	Thyroid Image Reporting and Data System
<b>SLE</b>	systemic lupus erythematosus	<b>TKR</b>	total knee replacement
<b>SMA</b>	superior mesenteric artery	<b>TLA</b>	translumbar approach
<b>SMV</b>	superior mesenteric vein	<b>TLC</b>	total lung capacity
<b>Sn</b>	tin	<b>TLN</b>	true length of needle
<b>SNR</b>	signal-to-noise ratio	<b>TLPN</b>	true length to pull back needle
<b>SPECT</b>	single photon emission computed tomography	<b>TM</b>	tympanic membrane; time motion
<b>SPEN</b>	solid pseudopapillary epithelial neoplasm	<b>TMC</b>	toxic megacolon
<b>SPGR</b>	spoiled gradient-echo	<b>TMJ</b>	temporomandibular joint

<b>TN</b>	true negative	<b>VC</b>	vital capacity
<b>TNM</b>	tumor-node-metastases	<b>VCUG</b>	voiding cystourethrogram
<b>TOA</b>	tuboovarian abscess	<b>VD</b>	vas deferens
<b>TOF</b>	time of flight	<b>VDRL</b>	Venereal Disease Research Laboratory
<b>TORCH</b>	toxoplasmosis, rubella, cytomegalovirus, herpes simplex virus (syndrome)	<b>VHL</b>	von Hippel-Lindau (disease)
<b>TP</b>	true positive	<b>VISI</b>	volar intercalated segment instability
<b>tPA</b>	tissue plasminogen activator	<b>VMA</b>	vanillylmandelic acid
<b>TPN</b>	total parenteral nutrition	<b>VP</b>	ventriculoperitoneal
<b>TPO</b>	tracheopathia osteoplastica	<b>Ṽ/Ḙ</b>	ventilation/perfusion
<b>TR</b>	repetition interval	<b>VR</b>	Virchow-Robin (space)
<b>TRAM</b>	transverse rectus abdominis musculocutaneous	<b>VRE</b>	vancomycin-resistant enterococcus
<b>TRAPS</b>	twin reversal arterial perfusion sequence	<b>VS</b>	visceral space
<b>TRUS</b>	transrectal ultrasound	<b>VSD</b>	ventricular septal defect
<b>TSH</b>	thyroid-stimulating hormone	<b>VUR</b>	vesicoureteral reflux
<b>TSI</b>	thyroid stimulating immunoglobulin	<b>VZ</b>	varicella zoster
<b>TTN</b>	transient tachypnea of the newborn	<b>W</b>	width; tungsten
<b>TURP</b>	transurethral resection of prostate	<b>WBC</b>	white blood cell(s) (count)
<b>TV</b>	tidal volume; transvaginal	<b>WES</b>	wall-echo-shadow (triad)
<b>TVS</b>	transvaginal sonography	<b>WHO</b>	World Health Organization
<b>U</b>	uranium	<b>WM</b>	white matter
<b>UA</b>	umbilical artery	<b>WPW</b>	Wolf-Parkinson-White (syndrome)
<b>UBC</b>	unicameral bone cyst	<b>w/w</b>	weight (of solute) per weight (of total solvent)
<b>UC</b>	ulcerative colitis	<b>XCCL</b>	exaggerated craniocaudal
<b>UCD</b>	uremic cystic disease	<b>Xe</b>	xenon
<b>UCL</b>	ulnar collateral ligament	<b>XGP</b>	xanthogranulomatous pyelonephritis
<b>UGI</b>	upper gastrointestinal	<b>yr</b>	year
<b>UIP</b>	usual interstitial pneumonia	<b>Z</b>	atomic number
<b>UK</b>	urokinase	<b>Symbols</b>	
<b>UL</b>	upper lobe	<	less (common) than
<b>UPJ</b>	ureteropelvic junction	≪	much less (common) than
<b>US</b>	ultrasound	≤	less than or equal to
<b>U.S.</b>	United States	>	more (common) than
<b>USPIO</b>	ultrasmall superparamagnetic iron oxide	≫	much more (common) than
<b>UTI</b>	urinary tract infection	≥	greater than or equal to
<b>UV</b>	ultraviolet; umbilical vein	→	leads to
<b>UVJ</b>	ureterovesical junction	∅	normal, unchanged
<b>VA</b>	vertebral artery	↑	increased
<b>VACTERL</b>	vertebral body, anal, cardiovascular, tracheoesophageal, renal, limb anomalies (association)	↓	decreased
<b>VATS</b>	video-assisted thorascopic surgery		



# Chest Imaging

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## Imaging Anatomy

### GROSS LUNG ANATOMY

#### SEGMENTAL ANATOMY (Figs. 1.1–1.2)

#### Right Lung

Upper lobe	Apical	B1
	Anterior	B2
	Posterior	B3
Middle lobe	Lateral	B4
	Medial	B5

Lower lobe

Superior	B6
Medial basal	B7
Anterior basal	B8
Lateral basal	B9
Posterior basal	B10

#### Left Lung

Upper lobe	
Upper	Apicoposterior B1, B3
	Anterior B2
Lingula	Superior B4
	Inferior B5

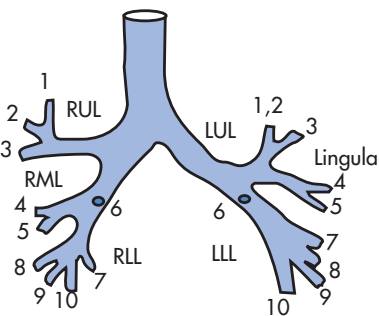


FIG. 1.1

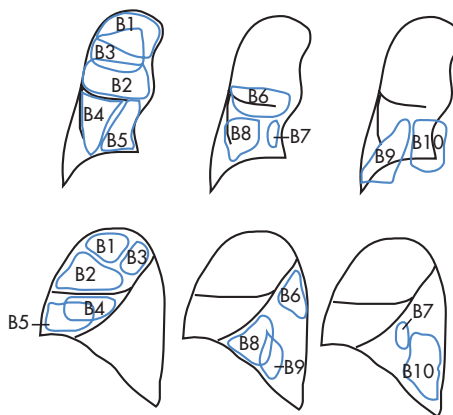


FIG. 1.2

Lower lobe	Superior	B6
	Medial basal	B7
	Anterior basal	B8
	Lateral basal	B9
	Posterior basal	B10

**SEGMENTAL COMPUTED TOMOGRAPHY (CT) ANATOMY (Fig. 1.3)**

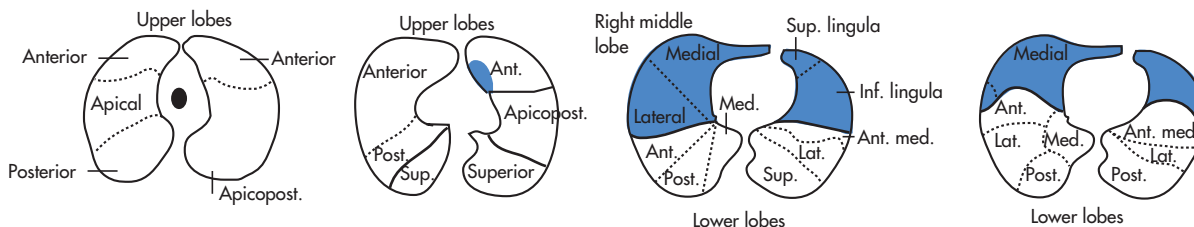


FIG. 1.3

**BRONCHIAL CT ANATOMY (Fig. 1.4)**

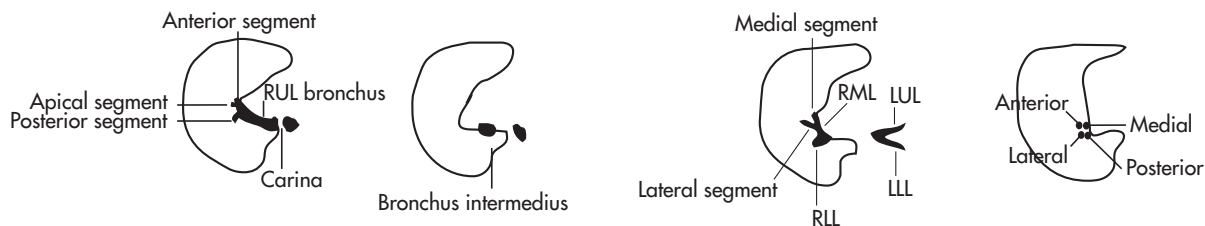


FIG. 1.4

**PLAIN RADIOGRAPH ANATOMIC LANDMARKS (Figs. 1.5–1.9)**

**Thoracic Inlet**

The thoracic inlet represents the junction between structures at the base of the neck and those of the thorax. It parallels the first rib and is higher posteriorly than anteriorly.

**Lines**

- Anterior junction line: 2-mm linear line that projects over the trachea. Represents the

approximation of the visceral and parietal pleura of the right and left lungs anterior to the mediastinum (composed of four layers of pleura)

- Posterior junction line (four layers of pleura): extends above clavicles and can often be seen on a frontal radiograph as a vertical line traversing the tracheal air column
- Posterior tracheal stripe (normally measures <4 mm in diameter): thickening or presence of a focal opacity in the region of the posterior tracheal stripe should raise the possibility of esophageal carcinoma

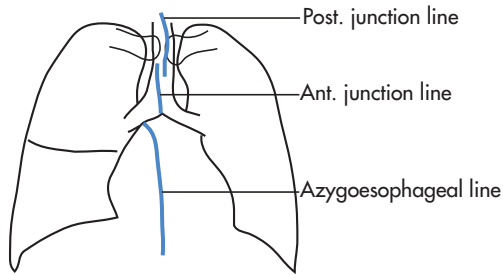


FIG. 1.5

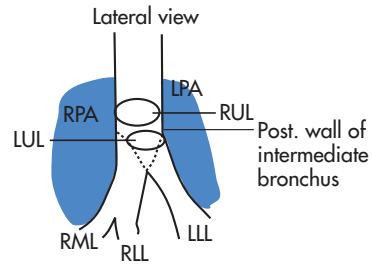


FIG. 1.9

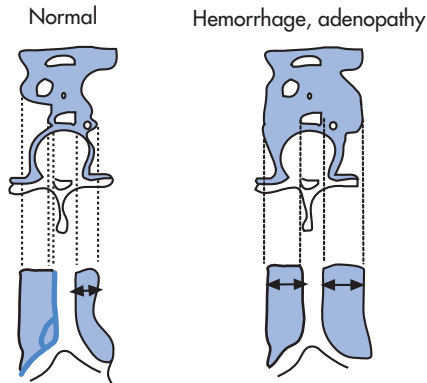


FIG. 1.6

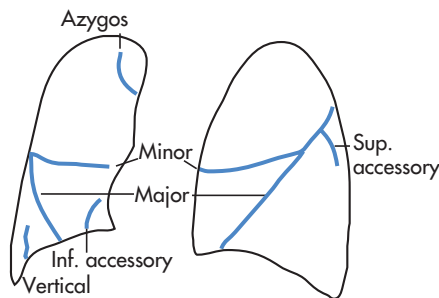


FIG. 1.7

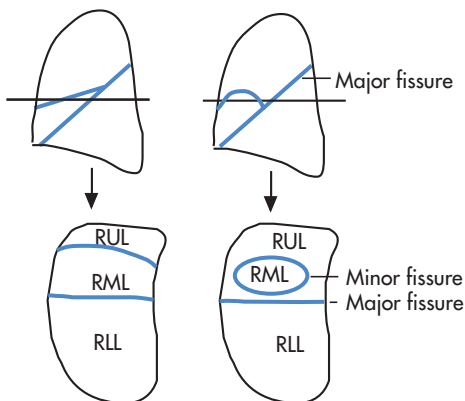


FIG. 1.8

- Azygoesophageal line: interface between RLL air and mediastinum
- Left paraspinal line: extends from aortic arch to diaphragm
- Right paraspinal line

**Paratracheal Stripe**

- Abnormal if >4 mm
- Never extends below right bronchus

**Fissures**

The normal major fissures are seldom seen on a posteroanterior radiograph.

The top of the left lower lobe (LLL) is usually higher than the top of the right lower lobe (RLL).

- Minor (horizontal) fissure
- Major (oblique) fissure
- Azygos fissure
- Other fissures
  - Superior accessory fissure
  - Inferior accessory fissure
  - Left minor fissure

**Pulmonary Ligament**

- Consists of a double layer of pleura that connects the medial aspect of the lower lobe (LL) to the adjacent mediastinum and diaphragm
- Not seen on posteroanterior or lateral chest radiographs (CXRs)
- Determines the shape of the collapsed LL in patients with atelectasis and the shape of the collapsed lung in patients with pneumothorax

**Trachea**

- The trachea is a midline structure
- The aorta commonly causes a smooth indentation on the left side
- The trachea measures 10–12 cm in length
- 16–20 U-shaped cartilage rings on its lateral and anterior aspects
- Calcification of the cartilage rings is a common normal finding in patients older than 40 years, particularly women, but it is seldom evident on radiographs

- Divides into the left and right main bronchi at the carina (approximately at the level of the fifth thoracic vertebra)

### Upper Lobe (UL) Bronchi (Figs. 1.10–1.11)

The right main bronchus divides into the RUL bronchus and the bronchus intermedius.

- RUL bronchus is always higher than LUL bronchus on lateral view
- Posterior wall of bronchus intermedius (right) is normally less than 2 mm thick and bifurcates into middle and LLs bronchi
- Tracheal bronchus (bronchus suis): 0.1% of population, arises from right wall of trachea (left much less common), supplies apical segment or occasionally entire RUL
- The left main bronchus is approximately 5 cm in length and divides into the LUL and LLL bronchi.
- Accessory cardiac bronchus: 0.1% of population, extends inferomedially from medial wall of bronchus intermedius or RLL bronchus toward mediastinum; may be blind ending

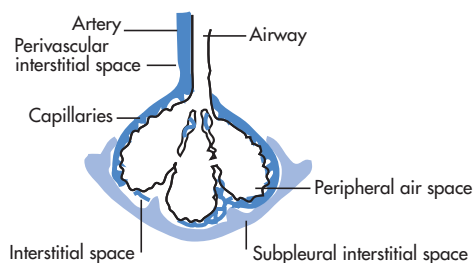


FIG. 1.10

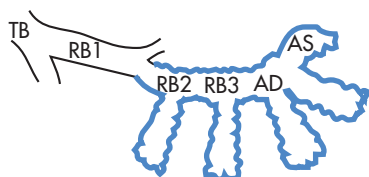


FIG. 1.11

## PARENCHYMAL ANATOMY

### ACINUS

- Includes all structures distal to one terminal bronchiole. The terminal bronchiole is the last purely air-conducting structure.
- Acinus measures 7 mm
- Acinus contains about 400 alveoli

### SECONDARY PULMONARY LOBULE

- Smallest anatomic unit of the lung visible on high-resolution CT (HRCT)
- Polygonal structure bounded by interlobular septa, 1.5–2 cm in diameter
- Three to five acini per secondary lobule
- Supplied by several terminal bronchioles

### EPITHELIUM

The alveolar epithelium is made up of two cell types:

- Type 1 pneumocytes
- Type 2 pneumocytes: produce surfactant, have phagocytic ability, and regenerate

### HIGH-RESOLUTION COMPUTED TOMOGRAPHY (HRCT) (Fig. 1.12)

#### Technique

- 1–1.5-mm thin collimation
- High spatial frequency reconstruction
  - This helps to improve spatial resolution, thereby improving the ability to detect subtle abnormalities—thick interlobular septa, cyst walls, small nodules, ground glass opacities and bronchiectasis.
- Optional
  - Increase in kVp or mA (140 kVp, 170 mA)
  - Targeted image reconstruction (one lung rather than both to increase spatial resolution)

#### HRCT Anatomy

The basic anatomic unit of pulmonary structure and function visible by HRCT is the secondary pulmonary lobule:

- Polyhedral 1.5-cm structure surrounded by connective tissue (interlobular septa) and made up of 5–15 pulmonary acini, which contain the alveoli for gas exchange
- Central artery and bronchiole
- Peripheral pulmonary veins and lymphatics in septum

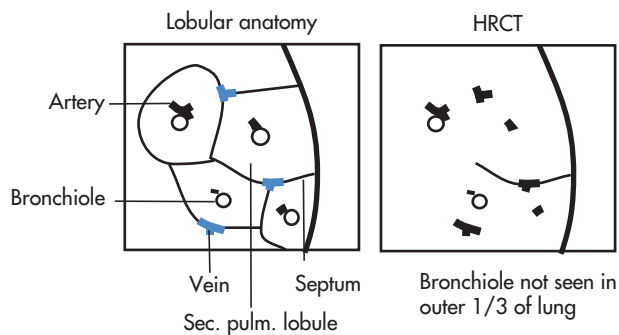


FIG. 1.12

Dominant high-resolution pattern:

- Reticular
- Nodular
- High attenuation (ground glass, consolidation)
- Low attenuation (emphysema, cystic)

Questions:

- Location within the secondary lobule
- Upper versus lower zone or a central versus peripheral predominance
- Presence of additional findings (pleural fluid, lymphadenopathy, traction bronchiectasis)

This protocol produces high-definition images of the lung alveoli, airways, interstitium, and pulmonary vasculature. Air trapping is identified on expiratory images.

## PULMONARY FUNCTION (Fig. 1.13)

### LUNG VOLUMES, CAPACITIES, AND FLOW RATES

- Tidal volume (TV): normal respiratory cycle
- Vital capacity (VC): amount of air that can be expired with force after maximal inspiration
- Functional residual capacity (FRC): volume remaining in lung after quiet expiration
- Total lung capacity (TLC): volume contained in lung at maximum inspiration
- Forced expiratory volume ( $FEV_1$ ): amount of air expired in 1 second

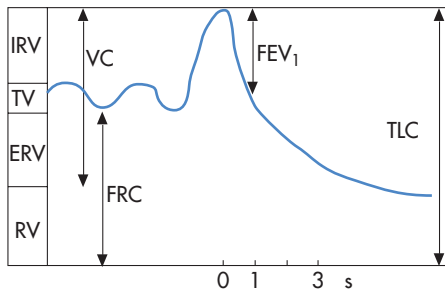


FIG. 1.13

## MEDIASTINUM (Fig. 1.14)

- Superior mediastinum: plane above aortic arch; thoracic inlet structures
- Anterior mediastinum: contains thymus, lymph nodes, mesenchymal tissue; some classifications include the heart and fat
- Middle mediastinum: contains heart, major vessels, trachea and main bronchi, lymph nodes, phrenic nerve, and left recurrent laryngeal nerve

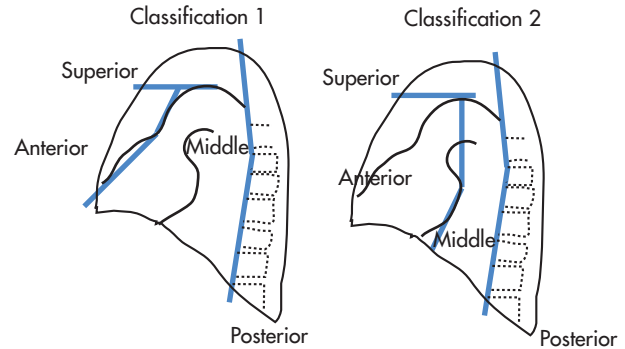


FIG. 1.14

- Posterior mediastinum: starts at anterior margin of vertebral bodies; contains descending thoracic aorta, esophagus, thoracic duct, azygos and hemiazygos veins, lymph nodes, autonomic nerves, paravertebral areas, and fat

## IMAGING PROTOCOLS

### STANDARD CHEST CT PROTOCOL

Supine position. Scan in suspended inspiration at total lung capacity. Scan setup:

- 5 × 5-mm sections from apex of the lungs to the adrenals
- Six 1.25-mm high-resolution cuts throughout lung at 2.5-cm intervals
- 1-mm reconstructions through pulmonary nodules
- Number of different combinations of pitch and section thickness

In interstitial lung disease the six cuts are repeated with the patient in the prone position. Reconstruction is done with a high-resolution bone algorithm.

Use of IV contrast medium:

- Evaluation of vascular structures, arteriovenous malformation, aortic dissection
- Evaluation of mediastinal tumors, enlarged lymph nodes
- Hilar masses
- Neck masses

### PULMONARY EMBOLISM (PE) CT PROTOCOL

- Patient in supine position
- Scan range: adrenals to lung apex
- Injection of 140 mL of nonionic iodinated contrast at 3 mL/second, with delay of 25–30 seconds. Scanning is performed with suspended respiration.
- Scans are retrospectively reconstructed from the dome of the diaphragm as 2.5-mm-thick slices with 1-mm spacing.

## DIAGNOSTIC RADIOLOGY REPORT (AMERICAN COLLEGE OF RADIOLOGY [ACR])

An authenticated written interpretation should be performed on all radiologic procedures. The report should include:

1. Name of patient and other identifier (e.g., birth date, Social Security number, or hospital or office identification number)
2. Name of the referring physician to provide more accurate routing of the report to one or more locations specified by the referring physician (e.g., hospital, office, clinic)
3. History
4. Name or type of examination
5. Dates of the examination and transcription
6. Time of the examination (for ICU/CCU patients) to identify multiple examinations (e.g., chest) that may be performed on a single day
7. Body of the report:
  - Procedures and materials
 

Include in the report a description of the procedures performed and any contrast media (agent, concentration, volume, and reaction, if any), medications, catheters, and devices.
  - Findings
 

Use precise anatomic and radiologic terminology to accurately describe findings.
  - Limitations
 

Where appropriate, identify factors that can limit the sensitivity and specificity of the examination. Such factors might include technical factors, patient anatomy, limitations of the technique, incomplete bowel preparation, and wrist examination for carpal scaphoid.
  - Clinical issues
 

The report should address or answer any pertinent clinical issues raised in the request for the imaging examination. For example, to rule out pneumothorax state: "There is no evidence of pneumothorax." To rule out fracture state: "There is no evidence of fracture." It is not advisable to use such universal disclaimers as "The mammography examination does not exclude the possibility of cancer."
  - Comparative data
 

Comparisons with previous examinations and reports when possible are a part of the radiologic consultation and report and optionally may be part of the "impression" section.

8. Impression (conclusion or diagnosis):
  - Each examination should contain an "impression" section.
  - Give a precise diagnosis whenever possible.
  - Give a differential diagnosis when appropriate.
  - Recommend, only when appropriate, follow-up and additional diagnostic radiologic studies to clarify or confirm the impression.

In normal CXR section the only structures visible in normal lungs are the fissures and the pulmonary vessels.

Lung parenchymal abnormalities are divided into five basic patterns:

1. Mass
2. Consolidative
3. Interstitial
4. Vascular
5. Airway

## Infection

### GENERAL

#### PATHOGENS

Bacterial pneumonia

- *Streptococcus pneumoniae* (pneumococcus)
- *Staphylococcus*
- *Pseudomonas*
- *Klebsiella*
- *Nocardia*
- *Chlamydia*
- *Neisseria meningitides*
- *Haemophilus influenzae*
- Anaerobes
- *Legionella*
- *Mycoplasma pneumoniae*
- *Actinomyces israelii*
- *Mycobacterium tuberculosis*

Viral pneumonia (25% of community-acquired pneumonias)

- Influenza
- Varicella, herpes zoster
- Rubella
- Cytomegalovirus
- Coxsackievirus, parainfluenza virus, adenovirus, respiratory syncytial virus (RSV)

Fungal pneumonia

- Histoplasmosis
- Coccidioidomycosis
- Blastomycosis
- Aspergillosis
- Cryptococcosis
- Candidiasis
- Zygomycoses

## Parasitic pneumonias

- *Pneumocystis jiroveci* Frenkel 1999 (formerly *Pneumocystis carinii*)
- *Toxoplasma gondii*

## ACQUISITION OF PNEUMONIA

## Community-acquired pneumonia

- *S. pneumoniae*, *Haemophilus*
- *Mycoplasma*

## Hospital-acquired pneumonia (incidence 1%, mortality 35%): nosocomial infection

- Gram-negative bacteria: *Pseudomonas*, *Proteus*, *Escherichia coli*, *Enterobacter*, *Klebsiella*
- Methicillin-resistant *Staphylococcus aureus* (MRSA)
- Vancomycin-resistant enterococcus (VRE)

## Pneumonia in immunosuppressed patients

- Bacterial pneumonia (gram negative) still most common
- Tuberculosis
- Fungal
- *Pneumocystis* pneumonia (PCP)

## Endemic pneumonias

- Fungal: histoplasmosis, coccidioidomycosis, blastomycosis
- Viral

## Aspiration-associated pneumonia (important)

## RISK FACTORS

The radiographic appearance of pulmonary infections is variable depending on the pathogen, underlying lung disease, risk factors, and previous or partial treatment.

## COMMUNITY-ACQUIRED INFECTIONS

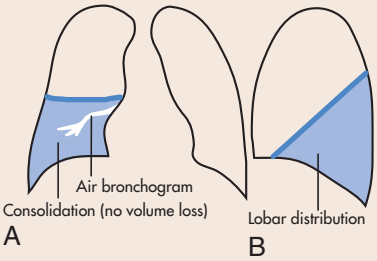
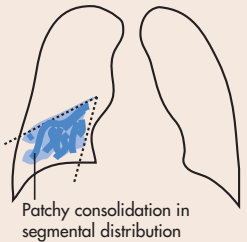
Risk Factor	Common Pathogens
Alcoholism	Gram-negative bacteria, <i>Streptococcus pneumoniae</i> , <i>Mycobacterium tuberculosis</i> , aspiration (mouth flora)
Old age	<i>S. pneumoniae</i> , <i>Staphylococcus aureus</i> , aspiration
Aspiration	Mouth flora (anaerobes)
Cystic fibrosis	<i>Pseudomonas</i> , <i>S. aureus</i> , <i>Aspergillus</i>
Chronic bronchitis	<i>S. pneumoniae</i> , <i>Haemophilus influenzae</i>

## Other risk factors for developing pneumonia:

- Bronchiectasis
- Coma, anesthesia, seizures (aspiration)
- Tracheotomy
- Antibiotic treatment
- Immunosuppression (renal failure, diabetes, cancer, steroids, AIDS)
- Chronic furunculosis (*Staphylococcus*)

## RADIOGRAPHIC SPECTRUM OF PULMONARY INFECTIONS

## SUMMARY

Type	Pathogen	Imaging
<p><b>Lobar Pneumonia</b></p> <p>Infection primarily involves alveoli</p> <p>Spread through pores of Kohn and canals of Lambert throughout a segment and ultimately an entire lobe</p> <p>Bronchi are not primarily affected and remain air filled; therefore:</p> <p>Air bronchograms</p> <p>No volume loss because airways are open</p> <p>Nowadays uncommon because of early treatment</p> <p>Round pneumonia (more common in children)</p>	<p><i>Streptococcus pneumoniae</i></p> <p><i>Klebsiella pneumoniae</i></p> <p>Others</p> <p><i>Staphylococcus aureus</i></p> <p><i>Haemophilus influenzae</i></p> <p>Fungal</p>	 <p>Air bronchogram</p> <p>Consolidation (no volume loss)</p> <p>Lobar distribution</p> <p>A</p> <p>B</p>
<p><b>Bronchopneumonia</b></p> <p>Primarily affects the bronchi and adjacent alveoli</p> <p>Volume loss may be present as bronchi filled with exudates</p> <p>Bronchial spread results in multifocal patchy opacities</p>	<p><i>S. aureus</i></p> <p>Gram-negative bacteria</p> <p>Others</p> <p><i>H. influenzae</i></p> <p><i>Mycoplasma</i></p>	 <p>Patchy consolidation in segmental distribution</p>

Continued

## SUMMARY—cont'd

Type	Pathogen	Imaging
<b>Nodules</b> Variable in size Indistinct margins	Fungal <i>Histoplasma</i> <i>Aspergillus</i> <i>Cryptococcus</i> <i>Coccidioides</i> Bacterial <i>Legionella</i> <i>Nocardia</i> Septic emboli <i>S. aureus</i>	
<b>Cavitary Lesions (Infectious)</b> Abscess: necrosis of lung parenchyma ± bronchial communication Fungus ball (air crescent/monad sign) Postprimary TB (favor apical and posterior segments of the upper lobes) Pneumatoceles caused by air leak into pulmonary interstitium	Anaerobic bacteria <i>Aspergillus</i> <i>M. tuberculosis</i> <i>S. aureus</i>	
<b>Diffuse Opacities</b> Reticulonodular pattern: interstitial peribronchial areas of inflammation (viral) Alveolar location (PCP) Miliary pattern: hematogenous spread (TB)	Viral <i>Mycoplasma</i> PCP	

PCP, *Pneumocystis* pneumonia; TB, tuberculosis.

## Complications of Pneumonia

- Parapneumonic effusion
  - Stage 1: exudation: free flowing
  - Stage 2: fibropurulent: loculated
  - Stage 3: organization, erosion into lung or chest wall
- Empyema
- Bronchopleural fistula (BPF; fistula between bronchus and pleural space) with eroding pleural-based fluid collections
- Bronchiectasis
- Pulmonary fibrosis, especially after necrotizing pneumonia or acute respiratory distress syndrome (ARDS)
- Adenopathy

## RESOLUTION OF PNEUMONIA

- 80%–90% of cases resolve within 4 weeks.
- 5%–10% resolve within 4–8 weeks (usually in older or diabetic patients). Subsequent radiographs

should always show interval improvement compared with the previous radiographs.

- Nonclearance
  - Antibiotic resistance
  - Consider other pathogen (e.g., *M. tuberculosis*)
  - Recurrent infection
  - Obstruction pneumonitis due to tumor

## BACTERIAL INFECTIONS

## GENERAL

## Common Pathogens

- *S. pneumoniae*, 50% (40–60 years)
- *Mycoplasma*, 30%
- Anaerobes, 10%
- Gram-negative bacteria, 5%
- *Staphylococcus*, 5%



- *Haemophilus*, 3% (especially in infants and patients with chronic obstructive pulmonary disease [COPD])

### Clinical Findings

#### Pneumonic syndrome

- Fever
- Cough
- Pleuritic pain
- Sputum

#### Ancillary findings

- Headache, arthralgia, myalgia
- Diarrhea
- Hemoptysis

## STREPTOCOCCAL PNEUMONIA

### Radiographic Features

- Lobar or segmental pneumonia pattern
- Bronchopneumonia pattern
- Round pneumonia (in children)

## STAPHYLOCOCCAL PNEUMONIA (Fig. 1.15)

### Radiographic Features

- Bronchopneumonia pattern
- Bilateral, >60%
- Abscess cavities, 25%–75%
- Pleural effusion, empyema, 50%
- Pneumatoceles, 50% (check valve obstruction), particularly in children
- Central lines
- Signs of endocarditis

## PSEUDOMONAS PNEUMONIA

### Typical Clinical Setting

- Hospital-acquired infection
- Ventilated patient
- Reduced host resistance
- Patients with cystic fibrosis

### Radiographic Features

#### Three presentations:

- Extensive bilateral parenchymal consolidation (predilection for both LLs)
- Abscess formation

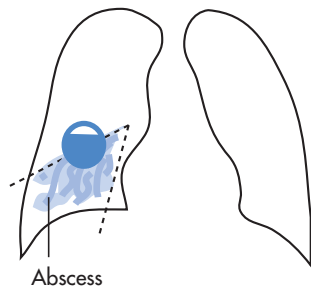


FIG. 1.15

- Diffuse nodular disease (bacteremia with hematogenous spread; rare)

## LEGIONNAIRES DISEASE

Severe pulmonary infection caused by *Legionella pneumophila*; 35% of patients require ventilation, 20% mortality. Most infections are community acquired. Patients have hyponatremia. Seroconversion for diagnosis takes 2 weeks.

### Radiographic Features

#### Common features

- Initial presentation of peripheral patchy consolidation
- Bilateral severe disease
- Rapidly progressive
- Pleural effusions, <50%
- LL predilection

#### Uncommon features

- Abscess formation
- Lymph node enlargement

## HAEMOPHILUS PNEUMONIA

Caused by *H. influenzae*. Occurs most commonly in children, immunocompromised adults, or patients with COPD. Often there is concomitant meningitis, epiglottitis, and bronchitis.

### Radiographic Features

- Bronchopneumonia pattern
- LL predilection, often diffuse
- Empyema

## MYCOPLASMA PNEUMONIA

Most common nonbacterial pneumonia (atypical pneumonia). Mild course. Age 5–20 years. Positive for cold agglutinins, 60%.

### Radiographic Features

- Reticular pattern
- LL predominance, often diffuse
- Consolidation, 50%

### Complications

- Autoimmune hemolytic anemia
- Erythema nodosum, erythema multiforme
- Stevens-Johnson syndrome
- Meningoencephalitis

## KLEBSIELLA (FRIEDLÄNDER) PNEUMONIA

Gram-negative organism. Often in debilitated patients and/or alcoholics.

### Radiographic Features

- Consolidation appears similar to that of infection with *S. pneumoniae*

- Lobar expansion
- Cavitation, 30%–50%, typically multiple
- Massive necrosis (pulmonary gangrene)
- Pleural effusion uncommon

### TUBERCULOSIS (TB) (Fig. 1.16)

Transmitted by inhalation of infected droplets of *M. tuberculosis* or *M. bovis*. TB acquisition usually requires constant or repeated contact with sputum-positive patients because the tubercle does not easily grow in the immunocompetent human host. Target population includes:

- Patients of low socioeconomic status (homeless)
- Alcoholics

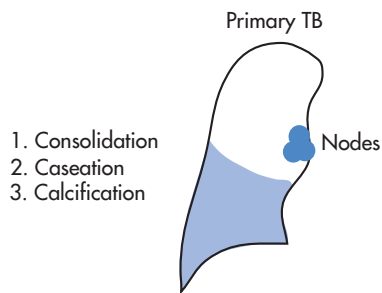


FIG. 1.16

- Immigrants: from Mexico, Philippines, Indochina, Haiti
- Elderly patients
- AIDS patients
- Prisoners

### Primary Infection (Fig. 1.17)

Usually heals without complications. Sequence of events includes:

- Pulmonary consolidation (1–7 cm); cavitation is rare; LL (60%) > UL
- Caseous necrosis 2–10 weeks after infection
- Lymphadenopathy (hilar and paratracheal), 95%
- Pleural effusion, 10%
- Spread of a primary focus occurs primarily in children or immunosuppressed patients.

### Secondary Infection (Fig. 1.18)

Active disease in adults most commonly represents reactivation of a primary focus. However, primary disease is now also common in adults in developed countries because there is no exposure in childhood. Distribution is as follows:

- Typically limited to apical and posterior segments of ULs or superior segments of LLs (because of high  $PO_2$ )
- Rarely in anterior segments of ULs (in contradistinction to histoplasmosis)

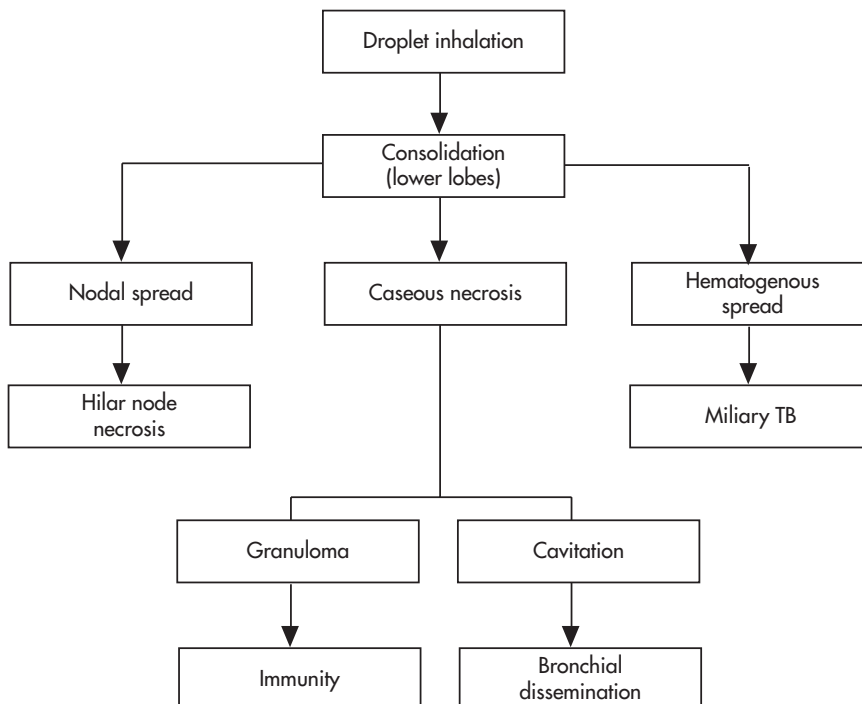


FIG. 1.17

**Radiographic Features**

- Exudative TB
  - Patchy or confluent air space disease
  - Adenopathy uncommon
- Fibrocalcific TB
  - Sharply circumscribed linear densities radiating to hilum
- Cavitation, 40%

**Complications (Fig. 1.19)**

- Miliary TB may occur after primary or secondary hematogenous spread.
- Bronchogenic spread occurs after communication of the necrotic area with a bronchus; it produces

an acinar pattern (irregular nodules approximately 5 mm in diameter).

- Tuberculoma (1–7 cm): nodule during primary or secondary TB; may contain calcification
- Effusions are often loculated.
- Bronchopleural fistula
- Pneumothorax

**COMPARISON**

	Primary TB	Reinfection TB
Location	Usually bases	Upper lobes, superior segment Lower lobes
Appearance	Focal	Patchy
Cavitation	No	Frequent
Adenopathy as only finding	Common	No
Effusion	Common	Uncommon
Miliary pattern	Yes	Yes

TB, Tuberculosis.

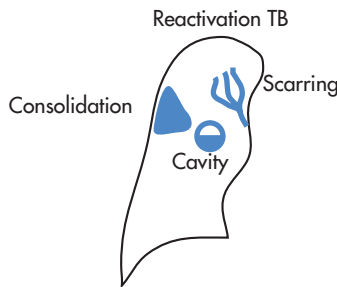


FIG. 1.18

**NONTUBERCULOUS MYCOBACTERIAL (NTMB) INFECTIONS**

The two most common NTMB pathogens are *M. avium-intracellulare* and *M. kansasii* (less common: *M. xenopi*, *M. chelonae*, *M. goodii*, *M. fortuitum*, “fast grower”). Unlike TB, NTMB infections are not

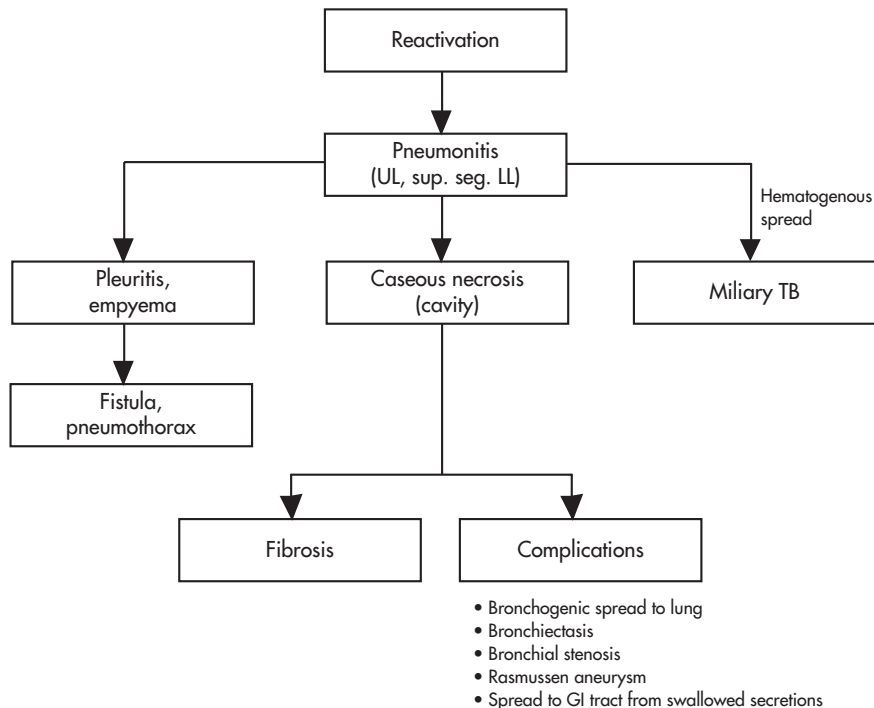


FIG. 1.19

acquired by human-human transmission but are a direct infection from soil or water. There is also no pattern of primary disease or reactivation: the infection is primary, although some infections may become chronic. The infection often occurs in elderly patients with COPD, older women in good health, and AIDS patients.

### Radiographic Features

- NTMB infections may be indistinguishable from classic TB.
- Atypical features such as bronchiectasis and bronchial wall thickening are common.
- Nodules are common in older women.

### COMPUTED TOMOGRAPHY FINDINGS

Findings	TB (%)	MAI Infection (%)
Nodules <1 cm	80	95
Nodules 1–3 cm	40	30
Mass >3 cm	10	10
Consolidation	50	50
Cavity	30	30
Bronchiectasis	30	95
Bronchial wall thickening	40	95
Septal thickening	50	15
Emphysema	20	20
Calcified granuloma	15	5

MAI, *Mycobacterium avium-intracellulare*; TB, tuberculosis.

### NOCARDIA PNEUMONIA

Caused by *Nocardia asteroides*, worldwide distribution. Common opportunistic invader in:

- Lymphoma
- Steroid therapy; especially transplant patients
- Pulmonary alveolar proteinosis (common)

### Radiographic Features

- Focal consolidation (more common)
- Cavitation
- Irregular nodules

### ACTINOMYCOSIS

Actinomycosis is caused by *Actinomyces israelii*, a gram-positive normal saprophyte in the oral cavity. Pulmonary disease develops from aspiration of the organism (poor dentition) or from direct penetration into the thorax.

### Radiographic Features

- Focal consolidation > cavitating mass
- Lymphadenopathy uncommon
- Extension into the chest wall and pleural thickening is less common today but still occurs and is an important differential feature.

### PULMONARY ABSCESS

The spectrum of anaerobic pulmonary infections includes:

- Abscess: single or multiple cavities >2 cm, usually with AFL
- Necrotizing pneumonia: analogous to abscess but more diffuse and cavities <2 cm
- Empyema: suppurative infection of the pleural space, most commonly as a result of pneumonia

### Predisposing Conditions

- Aspiration (e.g., alcoholism, neurologic disease, coma)
- Intubation
- Bronchiectasis, bronchial obstruction

### Treatment

- Antibiotics, postural drainage
- Percutaneous drainage of empyema
- Drainage/resection of lung abscess only if medical therapy fails

### SICKLE CELL ANEMIA

- Patients with sickle cell disease are at increased risk of pneumonia and infarction. These entities are difficult to differentiate, and hence are called *acute chest syndrome*.
- Pneumonias were originally due to pneumococci but now are due to viruses or *Mycoplasma*. Differential diagnosis includes atelectasis and infarct.
- Infarcts are more frequent in adults than in children. Rare in children younger than 12 years.
- Consolidation is seen on CXRs; resolves more slowly than in the general population and tends to recur.

### VIRAL PNEUMONIA

#### GENERAL

#### Classification

DNA viruses

Unenveloped

- Parvoviruses
- Papovaviruses
- Adenoviruses
- Hepatitis viruses (hepatitis B)

Enveloped

- Herpesviruses (herpes simplex virus [HSV], Epstein-Barr virus [EBV], varicella-zoster virus [VZV], cytomegalovirus [CMV])
- Poxviruses (variola virus, molluscum contagiosum virus)

## RNA viruses

## Unenveloped

- Picornaviruses (hepatitis A virus, coxsackievirus)
- Caliciviruses
- Reoviruses

## Enveloped

- Retroviruses (HIV)
- Arenaviruses
- Coronaviruses
- Togaviruses
- Bunyaviruses
- Orthomyxoviruses (influenza virus)
- Paramyxoviruses (mumps virus, measles virus, RSV, parainfluenza virus)

**Occurrence**

## Immunocompetent hosts

Influenza  
Hantavirus  
EBV  
Adenovirus

## Immunocompromised hosts

HSV  
VZ  
CMV  
Measles virus  
Adenovirus

**Spectrum of Disease**

- Acute interstitial pneumonia (AIP): diffuse or patchy interstitial pattern, thickening of bronchi, thickened interlobar septa
- Lobular inflammatory reaction: multiple nodular opacities 5–6 mm (varicella; late calcification)
- Hemorrhagic pulmonary edema: mimics bacterial lobar pneumonia
- Pleural effusion: usually absent or small
- Chronic interstitial fibrosis (bronchiolitis obliterans)

**INFLUENZA PNEUMONIA**

Influenza is very contagious and thus occurs in epidemics. Pneumonia, however, is uncommon.

Involves the upper respiratory tract, including the trachea and major bronchi.

**Radiographic Features**

- Acute phase: multiple acinar densities
- Coalescence of acinar densities to diffuse patchy airspace disease (ASD; bronchopneumonia type)

**VARICELLA-ZOSTER PNEUMONIA**

Fifteen percent of infected patients have pneumonias; 90% are older than 20 years.

**Radiographic Features**

- Acute phase: multiple acinar opacities
- Coalescence of acinar opacities to diffuse patchy ASD
- 1–2-mm calcifications throughout lungs after healing
- HRCT usually shows 1–10-mm well-defined and ill-defined nodules diffusely throughout both lungs.

**MEASLES VIRUS PNEUMONIA**

Two forms:

- Primary measles virus pneumonia and secondary bacterial pneumonia
- Atypical measles virus pneumonia

**Radiographic Features**

Primary measles virus:

- Mixed reticular opacities and air space consolidation.
- Lymph node enlargement in the hilum.
- CT findings include ground-glass attenuation, air space consolidation, and small centrilobular nodules.

Virus	Centrilobular Nodules	Lobar Ground Glass	Diffuse Ground Glass	Thickened Interlobular Septa	Consolidation
Influenza virus	+++	+++	+		+
EBV	+	+	+		+
CMV	++	++	++	+	+
VZ	+++	+	+		
HSV	+	+++	+		+++
Measles virus	++	+	+		+
Hantavirus			+++	+	++
Adenovirus	++	+			+++

CMV, Cytomegalovirus; EBV, Epstein-Barr virus; HSV, herpes simplex virus; VZ, varicella-zoster virus.

Atypical measles virus:

- Spherical or segmental consolidation, which clears rapidly
- Hilar lymph node enlargement and pleural effusion are frequently present.

### CYTOMEGALOVIRUS (CMV) PNEUMONIA

Occurs most commonly in neonates or immunosuppressed patients.

#### Radiographic Features

- Predominantly interstitial infection, multiple small nodules (common)
- Adenopathy may be present

### SWINE-ORIGIN INFLUENZA A (H1N1) VIRUS INFECTION

Epidemiologic data to date suggest that the newly emerged H1N1 virus, although transmissible from person to person, is of relatively low virulence. CXRs are normal in more than half of patients. However, the disease can progress to bilateral extensive ASD in severely ill patients. These patients are also at high risk of PE, which should be sought carefully on contrast-enhanced CT scans.

### SEVERE ACUTE RESPIRATORY SYNDROME

Emerging highly contagious infection caused by a coronavirus; first outbreak reported in southern China in 2002. The disease has two clinical stages: viral replicative stage and immunopathologic stage. The incubation period for the virus ranges from 2 to 12 days.

#### Radiographic Features

- During viral replication stage, well-defined areas of ground-glass opacities seen in the LLs and periphery of the lungs. The LLs and peripheral areas of the lungs are most commonly involved.
- During the immunopathologic phase, patients show the appearance of new lesions that are poorly defined and usually localized to the LLs and posterior or dependent regions of the lungs. Following the acute phase, there is a decrease in the extent of ground-glass opacity and consolidation. Some patients may develop spontaneous pneumomediastinum.

## FUNGAL INFECTIONS

### GENERAL

Two broad categories:

Endemic human mycoses (prevalent only in certain geographic areas):

- Histoplasmosis (Ohio, Mississippi, St. Lawrence river valleys)
- Coccidioidomycosis (San Joaquin Valley)
- Blastomycosis

Opportunistic mycoses (worldwide in distribution) occur primarily in immunocompromised patients (aspergillosis and cryptococcosis may also occur in immunocompetent hosts):

- Aspergillosis
- Candidiasis
- Cryptococcosis
- Mucormycosis

#### Radiographic Features

- Acute phase: pneumonic type of opacity (may be segmental, nonsegmental, or patchy); miliary (hematogenous) distribution in immunosuppressed patients
- Reparative phase: nodular lesions with or without cavitations and crescent sign
- Chronic phase: calcified lymph nodes or pulmonary focus with fungus (e.g., histoplasmosis)
- Disseminated disease (spread to other organs) occurs primarily in immunocompromised patients

### HISTOPLASMOSIS (Fig. 1.20): PULMONARY AND MEDIASTINAL

*Histoplasma capsulatum* is particularly prevalent in the Ohio, Mississippi, and St. Lawrence river valleys, although the agent has a worldwide distribution. The organism is most prevalent in soil that contains excrement of bats and birds (bat caves, chicken houses, old attics, or buildings).

#### Clinical Findings

Most patients are asymptomatic or have nonspecific respiratory symptoms, increased complement fixation titer, and *H. capsulatum* antigen positivity.

#### Radiographic Features

Consolidation (primary histoplasmosis)

- Parenchymal consolidation
- Adenopathy is very common and may calcify heavily later on.

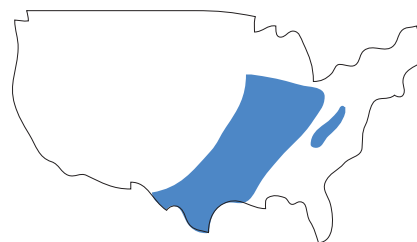


FIG. 1.20

Nodular form (chronic histoplasmosis, reinfection):

- Histoplasmoma: usually solitary, sharply circumscribed nodule, most commonly in LLs
- Fibrocavitary disease in ULs indistinguishable from postprimary TB
- Cavitory nodules

Disseminated form (immunocompromised patients)

- Miliary nodules
- Calcifications in liver and spleen

### Mediastinal Histoplasmosis

Mediastinal histoplasmosis may follow pulmonary histoplasmosis. There are two distinct entities (which may not always be separable from each other):

Mediastinal granuloma

- Results from spread of *H. capsulatum* to lymph nodes
- Granulomas usually calcified
- Displacement of the superior vena cava or esophagus

Mediastinal fibrosis (fibrosing or sclerosing mediastinitis)

- May cause superior vena cava syndrome, airway compression, PA occlusion, pericarditis
- Diffuse infiltration of mediastinum
- Multiple densely calcified nodes (CT is more useful than magnetic resonance imaging [MRI] in making this diagnosis)

### COCCIDIOIDOMYCOSIS (Fig. 1.21)

*Coccidioides immitis* is endemic in the southwest United States (San Joaquin Valley, “valley fever”) and in Central America and South America. Infection occurs by inhalation of spores in soil. Human-to-human infection does not occur.

#### Clinical Findings

Cutaneous manifestations common; 70% are asymptomatic.

#### Radiographic Features

Consolidation (primary form)

- “Fleeting” parenchymal consolidation, most commonly LLs
- Adenopathy in 20%

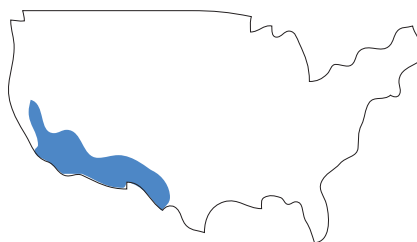


FIG. 1.21

Nodular form (chronic form, 5%)

- 15% cavitate
  - 50% have a thin-walled cavity (suggestive of diagnosis)
  - 50% have a thick-walled cavity (i.e., nonspecific)

May present with pneumothorax

- Nodules rarely calcify
- Hilar or paratracheal adenopathy

Disseminated form (immunocompromised patients; rare: 0.5% of all forms)

- Miliary nodules
- Extrapulmonary spread

### NORTH AMERICAN BLASTOMYCOSIS (Fig. 1.22)

- Caused by *Blastomyces dermatitidis*, uncommon infection. Most infections are self-limited.
- CXR is nonspecific: ASD > nodule (15% cavitate) or solitary mass > miliary spread.
- Focal or diffuse air space consolidation is the most common radiologic finding.
- Focal blastomycosis typically occurs in paramediastinal location and has an air bronchogram, findings that may suggest the diagnosis.
- Satellite nodules around primary focus are common.
- Chronic blastomycosis may mimic lung cancer because it can manifest itself as a focal mass. An air bronchogram or presence of satellite nodules is suggestive of correct diagnosis.
- Adenopathy, pleural effusions, and calcifications are very uncommon.
- Bone lesions, 25%
- Skin lesions are common.

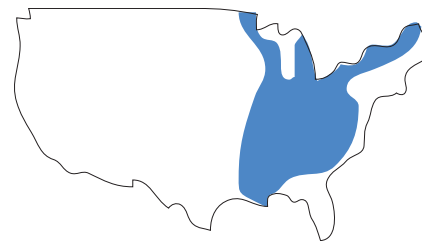


FIG. 1.22

### ASPERGILLOSIS (Fig. 1.23)

*Aspergillus* is a ubiquitous fungus that, when inhaled, leads to significant lung damage. The fungus grows in soil, water, decaying vegetation, and hospital air vents. Infection with *A. fumigatus* > *A. flavus*, *A. niger*, or *A. glaucus*. There are four unique forms of pulmonary aspergillosis, each associated with a specific immune status.

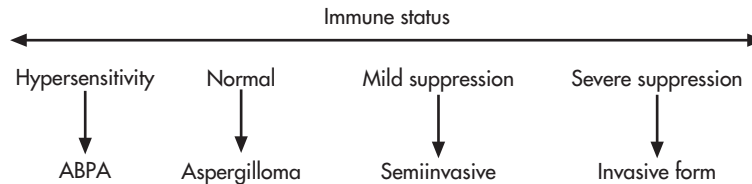


FIG. 1.23

## TYPES OF ASPERGILLOSIS

Type	Lung Structure	Immune Status	Pathology
Allergic (ABPA)	Normal	Hypersensitivity	Hypersensitivity → bronchiectasis, mucus plugging
Aspergilloma	Preexisting cavity	Normal	Saprophytic growth in preexisting cavity
Invasive	Normal	Severely impaired	Vascular invasion, parenchymal necrosis
Semiinvasive	Normal	Normal or impaired	Chronic local growth, local cavity formation

ABPA, Allergic bronchopulmonary aspergillosis.

## ALLERGIC BRONCHOPULMONARY ASPERGILLOSIS (ABPA)

ABPA is a complex type I (IgE-mediated) and type III (IgG-mediated) hypersensitivity reaction to *A. fumigatus*, occurring primarily in individuals with asthma and occasionally in individuals with cystic fibrosis. The hypersensitivity initially causes bronchospasm, mucus production, and bronchial wall edema (IgE mediated); ultimately there is bronchial wall damage due to the type III IgG-mediated response, with resultant cystic bronchiectasis.

### Clinical Findings

Elevated levels of specific serum IgE and IgG antibodies to *A. fumigatus*, asthma, peripheral eosinophilia, elevated serum IgE levels ( $\geq 1000$  IU/mL), positive skin test for *Aspergillus* antigen. Treatment is with oral corticosteroids, antifungal agents, and omalizumab, which is a humanized monoclonal antibody targeted against IgE.

### Radiographic Features

- Fleeting pulmonary parenchymal opacities (common manifestation)
- Central, UL saccular bronchiectasis (hallmark) (Fig. 1.24A)

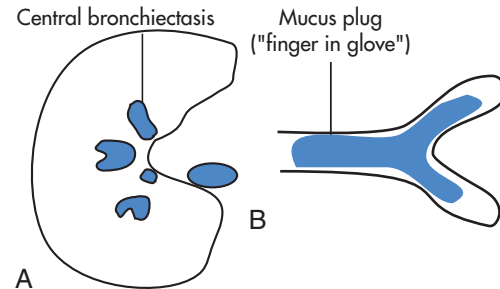


FIG. 1.24

- Mucus plugging (“finger-in-glove” appearance) (Fig. 1.24B) and bronchial wall thickening (common); 25% of patients will demonstrate high-attenuation mucus plugging.
- Tree-in-bud nodularity
- Cavitation, 10%

## ASPERGILLOMA (MYCETOMA, FUNGUS BALL)

This is a saprophytic infection that occurs in the setting of structural lung disease (from TB, sarcoid, emphysema). Commonly in ULs, solitary lesions. The fungus grows into the preexisting cavity (e.g., cyst, bulla, bronchiectasis), creating a “fungus ball” consisting of fungus, mucus, and inflammatory cells. Individuals with mycetomas are often asymptomatic but may develop recurrent hemoptysis, which in rare cases can be massive. In these cases, bronchial artery embolization is indicated. The other treatment options include surgical resection, intracavity administration of amphotericin B, and systemic antifungal therapy.

### Radiographic Features

- Focal intracavitary mass (3–6 cm), typically in ULs.
- Air may surround the aspergilloma (Monod sign), mimicking the appearance of cavitation seen with invasive aspergillosis.
- Small area of consolidation around cavity is typical.
- Adjacent pleural thickening is common.
- Fungus ball moves with changing position.



## INVASIVE ASPERGILLOSIS

Invasive aspergillosis has a high mortality rate (70%–90%) and occurs mainly in severely immunocompromised patients (bone marrow transplants, leukemia). The infection starts with endobronchial fungal proliferation and then leads to vascular invasion with thrombosis and infarction of the lung (“angioinvasive infection”). Additional sites of infection (in 30%) are the brain, liver, kidney, and GI tract. Treatment is with systemic and/or intracavitary administration of amphotericin.

### Radiographic Features (Fig. 1.25)

- Multiple pulmonary nodules, 40%
- Nodules have a characteristic halo of ground-glass appearance (represents pulmonary hemorrhage)
- Within 2 weeks, 50% of nodules undergo cavitation, which results in the air crescent sign. The appearance of the air crescent sign indicates the recovery phase (increased granulocytic response). The air crescent sign may also be seen in TB, actinomycosis, mucormycosis, septic emboli, and tumors. Do not confuse the air crescent sign with the Monod sign (clinical history helps to differentiate the two).
- Other manifestations:
  - Peribronchial opacities
  - Focal areas of consolidation

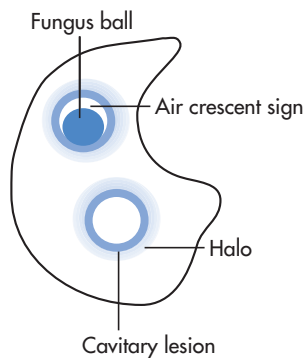


FIG. 1.25

## SEMIINVASIVE ASPERGILLOSIS

This form of aspergillosis occurs in mildly immunocompromised patients and has a pathophysiology similar to that of invasive aspergillosis except that the disease progresses more chronically over months (mortality rate 30%). Risk factors include diabetes, alcoholism, pneumoconiosis, malnutrition, and COPD. Treatment is with systemic and/or intracavitary administration of amphotericin.

### Radiographic Features

- Appearance similar to that of invasive aspergillosis
- Cavitation occurs at 6 months after infection

## CRYPTOCOCCOSIS

Caused by *Cryptococcus neoformans*, which has a worldwide distribution and is ubiquitous in soil and pigeon excreta. Infection occurs through inhalation of contaminated dust.

### Clinical Findings

Common in patients with lymphoma, diabetes, or AIDS and in patients receiving steroid therapy.

### Radiographic Features

- Most common findings in the lung are pulmonary mass, multiple nodules, or segmental or lobar consolidation.
- Cavitation, adenopathy, and effusions are rare.
- Disseminated form: CNS, other organs

## CANDIDIASIS

Caused by *Candida albicans* more frequently than other *Candida* species.

### Clinical Findings

Typically in patients with lymphoreticular malignancy; suspect pulmonary disease if associated with oral disease. Often there is disseminated fungemia.

### Radiographic Features

- Plain radiograph is nonspecific: opacities (LL) > nodules.
- Nodular disease in disseminated form
- Pleural effusion, 25%
- Cavitation and adenopathy are rare.

## ZYGOMYCOSSES

Group of severe opportunistic mycoses caused by fungi of the *Zygomycetes* class:

- Mucormycosis (*Mucor*)
- *Rhizopus*
- *Absidia*

Zygomycoses usually have two major clinical manifestations:

- Pulmonary mucormycosis
- Rhinocerebral mucormycosis

Zygomycoses are uncommon infections and occur primarily in immunocompromised patients (leukemia, AIDS, chronic steroid use, diabetes).

### Radiographic Features

- Radiographic features are similar to those of invasive aspergillosis because of angioinvasive behavior of fungi.

## Acquired Immunodeficiency Syndrome

### GENERAL

AIDS is caused by HTLV type III (human T-cell lymphotropic virus = HIV [human immunodeficiency virus]). HIV-1 and HIV-2 are single-stranded RNA viruses that bind to CD4 present on T lymphocytes (other cells: glial cells, lung monocytes, dendritic cells in lymph nodes). The viral RNA genome is copied into DNA with the help of reverse transcriptase and integrated into the host cellular DNA.

Known routes of HIV transmission:

- Blood and blood products
- Sexual activity
- In utero transmission
- During delivery

### CLINICAL FINDINGS

- Lymphadenopathy
- Opportunistic infections
- Tumors: lymphoma—usually B-cell non-Hodgkin's lymphoma (NHL), Kaposi sarcoma (KS)
- Other manifestations:

Associated with lymphocytic interstitial pneumonia (LIP), usually in childhood

Spontaneous pneumothorax (development of cystic spaces, interstitial fibrosis related to PCP)

Septic emboli

- Clinical findings supportive of AIDS diagnosis (Fig. 1.26):

CD4 cell count  $<200/\text{mm}^3$ ; the dysfunction of the immune system is inversely related to the CD4 cell count; PCP, CD4 cell count  $<200/\text{mm}^3$ ; MAI infection, CD4 cell count  $<50/\text{mm}^3$

Less than one case of bacterial pneumonia per year

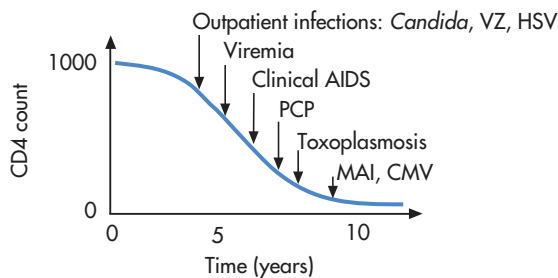


FIG. 1.26

### Opportunistic Infections

- *P. jiroveci* Frenkel 1999, 70%
- Mycobacterial infection, 20%; CD4 cell counts often  $<50/\text{mm}^3$
- Bacterial infection, 10% (*S. pneumoniae*, *Haemophilus*)
- Fungal infection ( $<5\%$  of AIDS patients)
- Nocardia,  $<5\%$ : cavitating pneumonia
- CMV pneumonia (common at autopsy)

### CHEST

#### GENERAL

- 50% of all AIDS patients have pulmonary manifestations of infection or tumor.
- A normal CXR does not exclude the diagnosis of PCP.
- CMV infection is common at autopsy but does not cause significant morbidity or death; CMV antibody titers are present in virtually all patients with AIDS.

- Use of chest CT in AIDS patients:

Symptomatic patient with normal CXR; however, patients will commonly first undergo induced sputum or bronchoscopy or be given empirical therapy for PCP.

To clarify confusing CXR findings

Workup of focal opacities, adenopathy, nodules

### SPECTRUM OF CHEST MANIFESTATIONS

(Fig. 1.27)

#### Nodules

- KS (usually associated with skin lesions)
- Septic infarcts (rapid size increase)
- Fungal: *Cryptococcus*, *Aspergillus*

#### Large opacity: consolidation, mass

- Hemorrhage
- NHL
- Pneumonia
- Linear or interstitial opacities
- PCP
- Atypical mycobacteria
- KS

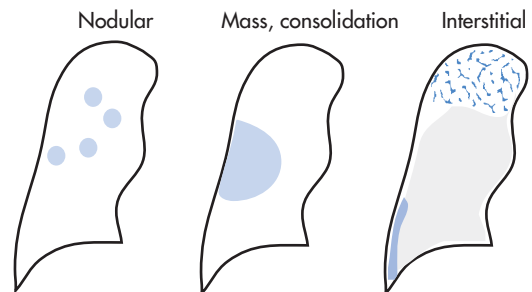


FIG. 1.27

## Lymphadenopathy

- Mycobacterial infections
- KS
- Lymphoma
- Reactive hyperplasia, rare in thorax

## Pleural effusion

- KS
- Mycobacterial, fungal infection
- Pyogenic empyema

## PNEUMOCYSTIS JIROVECI PNEUMONIA (PJP) (Figs. 1.28–1.30)

### General

*P. jiroveci* is an atypical fungus that can result in pneumonia in immunocompromised individuals. PJP affects individuals with AIDS, transplant recipients, and patients receiving long-term corticosteroid therapy. When PJP occurs in HIV-infected individuals, it is usually only after the CD4 count has decreased to less

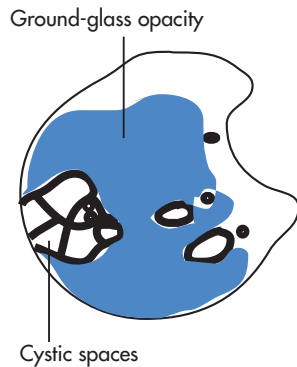


FIG. 1.28

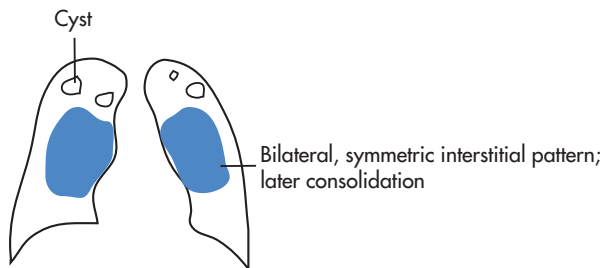


FIG. 1.29

### Apical pattern



FIG. 1.30

than  $200/\text{mm}^3$ . The diagnosis of PJP can be confirmed by bronchoalveolar lavage or presence of the organism in a sputum sample.

### Radiographic Features

- Interstitial pattern, 80%
  - CXR: bilateral perihilar ground-glass opacities or thickened interstitium
  - HRCT: ground-glass opacities, interlobular septal thickening, and in some cases multifocal areas of consolidation
- Up to one-third of patients with PJP will have a normal CXR.
- Multiple cysts of various sizes are seen in one-third of patients with PJP and may cause spontaneous pneumothorax.
- UL *P. jiroveci* involvement is common, because aerosolized pentamidine may not get to ULs; UL disease may mimic TB, but the latter may have pleural effusions or lymphadenopathy, both of which are uncommon in PJP.
- Atypical patterns, 5%
  - Unilateral disease
  - Granulomatous inflammation resulting in focal nodules or masses
- PJP as a presenting manifestation of AIDS is decreasing in frequency because of trimethoprim-sulfamethoxazole prophylaxis.

### MYCOBACTERIAL INFECTION

*M. tuberculosis* > *M. avium-intracellulare* (MAI) (this pathogen usually causes extrathoracic disease). CD4 cell count usually  $<50/\text{mm}^3$ .

### Radiographic Features

- Hilar and mediastinal adenopathy common
  - Necrotic lymph nodes (TB) have a low attenuation center and only the rim is enhanced with contrast medium.
  - M. tuberculosis* is more commonly associated with necrosis from MAI.
  - Adenopathy in KS or lymphoma is enhanced uniformly.
- Pleural effusion
- Other findings are similar to those of non-AIDS TB (UL consolidations, cavitations).

### FUNGAL INFECTIONS

Fungal infections in AIDS are uncommon ( $<5\%$  of patients):

- Cryptococcosis (most common); 90% have CNS involvement.
- Histoplasmosis: nodular or miliary pattern most common; 35% have a normal CXR.
- Coccidioidomycosis: diffuse interstitial pattern, thin-walled cavities