DIAGNOSTIC AND SURGICAL
IMAGING ANATOMY
CHEST • ABDOMEN • PELVIS

Michael P. Federle, MD, FACR

Professor of Radiology
Chief, Abdominal Imaging
University of Pittsburgh Medical Center
Pittsburgh, PA

Melissa L. Rosado-de-Christenson, MD

Clinical Professor of Radiology
The Ohio State University College of Medicine
Columbus, OH

Adjunct Professor of Radiology
The Uniformed Services University of the Health Sciences
Bethesda, MD

Paula J. Woodward, MD

Professor of Radiology
Adjunct Professor of Obstetrics and Gynecology
University of Utah School of Medicine
Salt Lake City, UT

Gerald F. Abbott, MD

Director of Chest Radiology
Rhode Island Hospital

Associate Professor of Diagnostic Imaging
Brown Medical School
Providence, RI

Managing Editor
Akram M. Shaaban, MBBCh

Assistant Professor of Radiology (Clinical)
University of Utah Medical Center
Salt Lake City, UT

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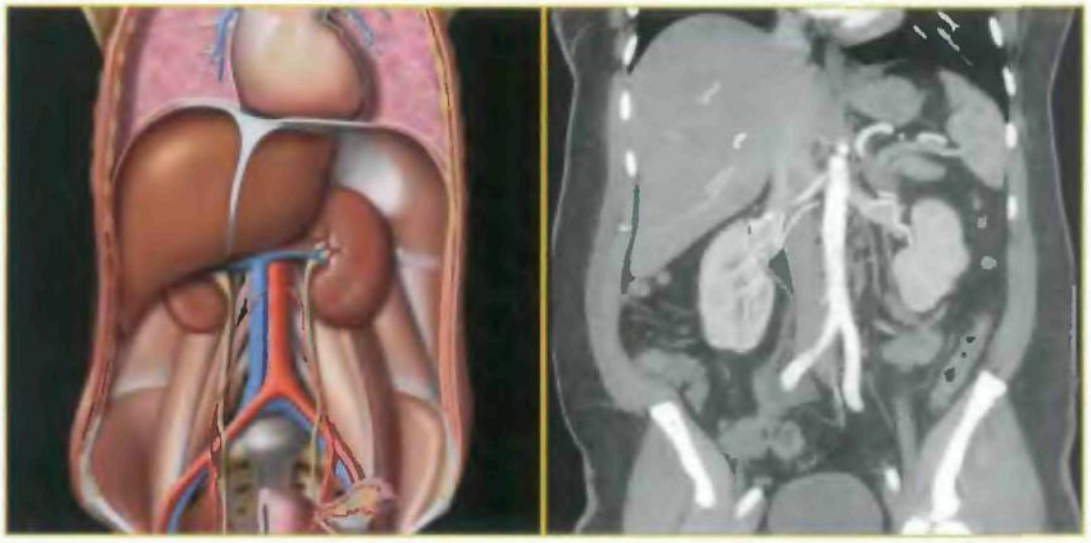

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To Mort Meyers, whose pioneering work opened my eyes to the value of understanding abdominal anatomy and pathophysiology.
MPF

I dedicate this work to my family, especially my husband Dr. Paul J. Christenson, and my daughters Jennifer and Heather who encouraged and supported me throughout this work. I learned a great deal from my good friend and co-author Dr. Gerry Abbott, my co-author Dr. Akram Shaaban and our most gifted illustrator, Mr. Lane Bennion.
MRdC

To all my residents (past, present and future) who have endured endless hours of being "pimped" on anatomy. Here are all the answers!
PJW

To my great friend, mentor, and co-author, Melissa Rosado de Christenson; and, to her husband, Dr. Paul Christenson for his patience, support and good friendship.
GFA

To my parents, I truly owe you everything
To my wife Inji, son Karim and daughter May, the jewels of my life, thanks for your understanding and tremendous support.
AMS

DIAGNOSTIC AND SURGICAL IMAGING ANATOMY: CHEST, ABDOMEN, PELVIS

We at Amirsys, together with our distribution colleagues at LWW, are proud to present *Diagnostic and Surgical Imaging Anatomy: Chest, Abdomen, Pelvis*, the third in our brand-new series of anatomy reference titles. All books in this best-selling series are designed specifically to serve clinicians in medical imaging and each area's related surgical subspecialties. We focus on anatomy that is generally visible on imaging studies, crossing modalities and presenting bulleted anatomy descriptions along with a glorious, rich offering of color normal anatomy graphics together with in-depth multimodality, multiplanar high-resolution imaging.

Each imaging anatomy textbook contains over 2,500 labeled color graphics and high resolution radiologic images, with heavy emphasis on 3 Tesla MR and state-of-the-art multi-detector CT. It is designed to give the busy medical professional rapid answers to imaging anatomy questions. Each normal anatomy sequence provides detailed views of anatomic structures never before seen and discussed in an anatomy reference textbook. For easy reference, each major area (chest, abdomen, pelvis) is subdivided into separate sections that cover detailed normal anatomy of all its constituents.

In summary, *Diagnostic and Surgical Imaging Anatomy: Chest, Abdomen, Pelvis* is a product designed with you, the reader, in mind. Today's typical radiologic, and surgical practice settings demand both accuracy and efficiency in image interpretation for clinical decision-making. We think you'll find this new approach to anatomy a highly efficient and wonderfully rich resource that will be the core of your reference collection in anatomy. The new *Diagnostic and Surgical Imaging Anatomy: Musculoskeletal* is also now available. Coming in 2007 are volumes on Ultrasound as well as a subspecialty- and podiatry-oriented text on Knee, Ankle, and Foot.

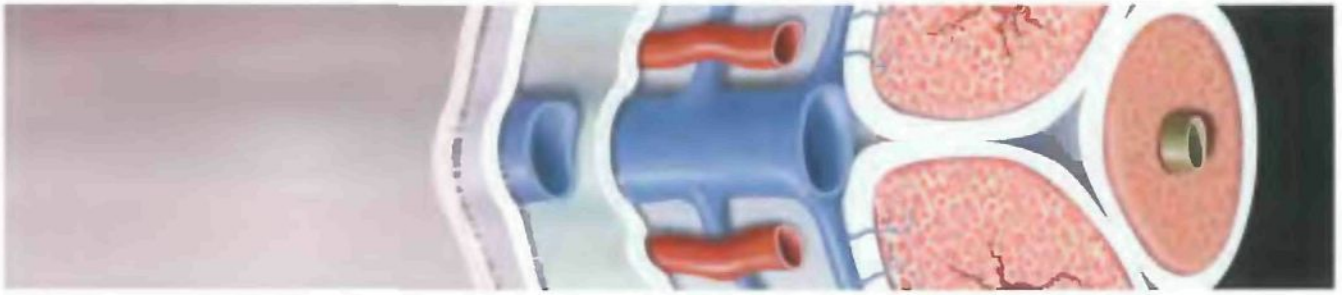
We hope that you will sit back, dig in, and enjoy seeing anatomy and imaging with a whole different eye.

Anne G. Osborn, MD
Executive Vice President and Editor-in-Chief, Amirsys Inc.

H. Ric Harnsberger, MD
CEO & Chairman, Amirsys Inc.

Paula J. Woodward, MD
Senior Vice President & Medical Director, Amirsys Inc.

B.J. Manaster, MD
Vice President & Associate Medical Director, Amirsys Inc.



FOREWORD

As in the great age of exploration when the coastal contours of a continent were first outlined and thereafter its rivers, mountains, and valleys penetrated, so was the terra incognita of the human body explored.

A work published in 1543 influenced the annals of Western medicine forever. *De Humani Corporis Fabrica, Libri Septum* by Andreas Vesalius, usually referred to as the *Fabrica*, was one of the first anatomy texts to systematically provide descriptions derived from actual dissection of the human body. In controverting the ancient theory of Galen, the second-century Greek who had cast his shadow on medical science for over a thousand years, the *Fabrica* was an incontestable breakthrough. Vesalius is regarded as the Columbus of the human body, as a man who literally discovered a new world.

Anatomy was the stepping-stone to the understanding of not only the body's structure but also its functions and malfunctions.

It was other investigations in the sixteenth century on the vascular system and the venous valves complete with their mechanical implications that were crucial for William Harvey's demonstration of the blood circulation. Harvey's 1628 publication *De Motu Cordis* ("On the Motion of the Heart") established that the heart is a pump which causes the blood to circulate through the body, passing from the arteries to the veins. It would remain for Marcello Malpighi, founder of microscopic anatomy, decades later in 1660, to discover the capillaries. These insights marked the step from anatomy to physiology.

In 1761, the Italian physician and anatomist Giovanni Morgagni published *On the Sites and Causes of Disease*, finally establishing the direct relevance of anatomy to clinical medicine. Rudolph Virchow, the father of clinical pathology, declared in 1894 that, with Morgagni, "The new medicine begins".

Over time, surgeons became most adept in the knowledge of anatomy. By the early decades of the 20th century, the eminent surgeon Harvey Cushing could testify that "from the publication of the *Fabrica* almost to the present day the intimate pursuit of ... anatomy has constituted the high road for entry into the practice of surgery."

Today, it is the radiologist who is most facile with highly detailed anatomy and who – it must be emphasized – demonstrates this *in vivo*. This has been brought about by the revolution in diagnostic imaging. ***Dis***sectional anatomy has been superseded by ***cross***-sectional imaging.

This volume which deals with anatomy of the chest, abdomen and pelvis is authored by recognized experts with wide experience and keen insight including: Melissa Rosado de Chirstenson and Gerald Abbott (chest), Michael Federle (abdomen), and Paula Woodward (pelvis). It not only reveals the complex mysteries of the body's structure but further indicates why anatomical applications are still being made today. The information is presented in an engaging and reader-friendly style. Convoluted descriptions are abandoned as key anatomic principles are outlined in succinct format. Medical illustrations of exquisite museum quality are combined with state-of-art diagnostic imaging. A distinctive feature is the frequent use of pathologic examples to highlight certain anatomic structures or features that might otherwise be obscure. The exciting capabilities of *ultrasonography, computed tomograpy, and magnetic resonance imaging* are beyond the wildest dreams of Andreas Vesalius or Harvey Cushing. The reader cannot but be struck by the realization that the state-of-art images often rival and sometimes surpass the artist's depiction in accurate display.

Anatomy is so intimately linked to physiology and pathology that this textbook is a gem for any student or practitioner involved with the human body in modern medicine.

Morton A. Meyers, MD
Emeritus Professor of Radiology and Medicine
Distinguished University Professor
State University of New York at Stony Brook

PREFACE

While in medical school, I hated "Anatomy." Working with cadavers was not only unpleasant but was relatively uninformative as well. Structures of vital importance, such as various ducts and blood vessels, were difficult to identify by dissection. The anatomic drawings in our textbooks seemed to have little or no bearing on what I was observing in the anatomy lab or operating room, and had even less apparent relevance to the practice of medicine or surgery.

When CT came along at the end of my residency, we all had to scramble to learn how to interpret these new cross-sections of the body. Existing texts were of limited help in interpretation of axial CT images, and even less help when MR arrived with its new planes of section and unfamiliar display sequences. Once we gained familiarity with these imaging tools, however, we realized that we had access to detailed anatomic information inaccessible to even the most experienced anatomist. Experience interpreting thousands of CT and MR interpretations has also made us appreciate the considerable variability from "conventional" depictions of anatomy found in standard textbooks.

We feel that the combination of vibrant medical illustrations and multiplanar, high resolution, cross sectional imaging is the ideal way to teach anatomy today. We have included depictions of common anatomic variations and pathological process to make the reader aware of the appearance and relevance of altered morphology.

We hope that the efforts of our talented medical illustrators and radiologist/authors will make the anatomy of the chest, abdomen and pelvis "come alive" for our readers.

Michael P. Federle, MD, FACR
Professor of Radiology
Chief of Abdominal Imaging
University of Pittsburgh Medical Center

ACKNOWLEDGMENTS

Illustrations

Lane R. Bennion, MS

Contributing Illustrators

Rich Coombs, MS
James A. Cooper, MD
Walter Stuart, MFA

Image/Text Editing

Douglas Grant Jackson
Amanda Hurtado
Melanie Hall
Karen M. Pealer, BA, CCRC

Medical Text Editing

Akram M. Shaaban, MBBCh

Case Management

Roth LaFleur
Christopher Odekirk

Case Contributors

Feras Bader, MD; Salt Lake City, UT
Peter L. Choyke, MD; Bethesda, MD
Ralph Drosten, MD; Salt Lake City, UT
M. Robert Florez, BS; Colorado Springs, CO
Douglas Green, MD; Salt Lake City, UT
Jud Gurney, MD; Omaha, NE
Keyanoosh Hosseinzadeh, MD; Pittsburgh, PA
Anne Kennedy, MD; Salt Lake City, UT
Mark King, MD; Columbus, OH
Howard Mann, MD; Salt Lake City, UT
Chris McGann, MD; Salt Lake City, UT
Elizabeth Moore, MD; Davis, CA
Mohamed Salama, MD, Salt Lake City, UT
Jerry Speckman, MD; Gainesville, FL
J.Thomas Stocker, MD; Bethesda, MD
Diane C. Strollo, MD; Pittsburgh, PA
Jade J. Wong-You-Cheong, MD; Baltimore, MD

Project Leads

Melissa A. Hoopes
Kaerli Main

SECTIONS

PART I
Chest

PART II
Abdomen

PART III
Pelvis

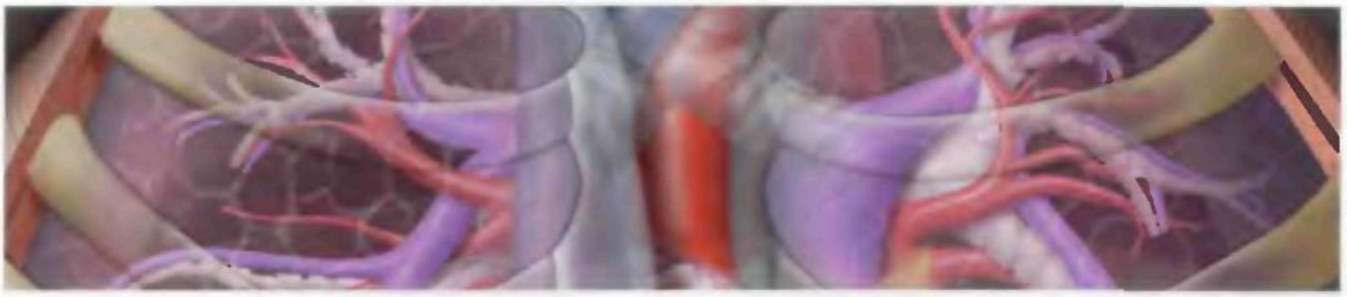


TABLE OF CONTENTS

Part III
Pelvis

DIAGNOSTIC AND SURGICAL

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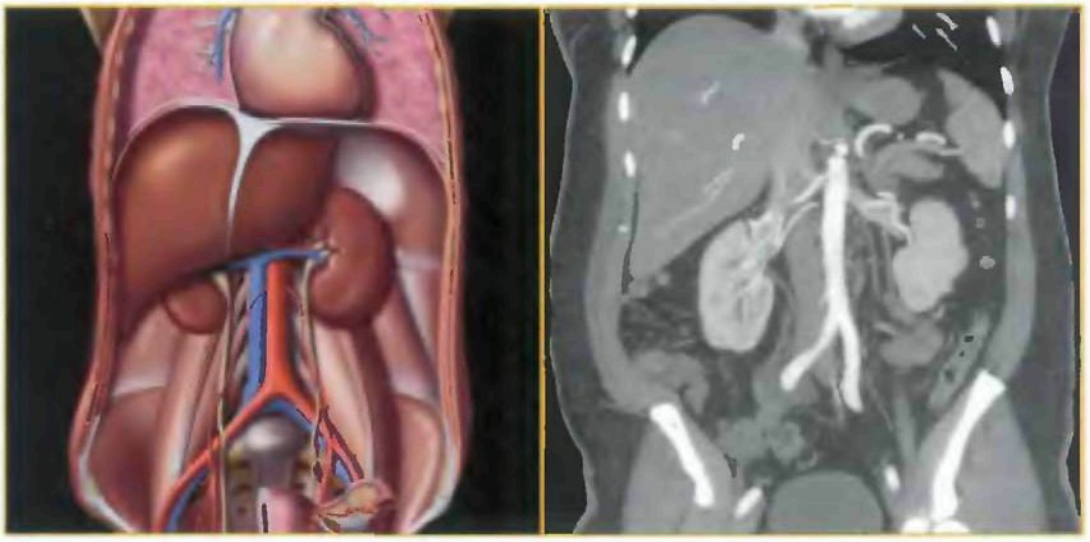


PART I

Chest

Chest Overview

Lung Development

Airway Structure

Vascular Structure

Interstitial Network

Lungs

Hila

Airways

Pulmonary Vessels

Pleura

Mediastinum

Systemic Vessels

Heart

Coronary Arteries and Cardiac Veins

Pericardium

Chest Wall

CHEST OVERVIEW

Terminology

Abbreviations

- Anteroposterior (AP)
- Posteroanterior (PA)
- Image receptor (IR)
- Source-to-image receptor distance (SID)
- Hounsfield units (HU)

General Anatomy and Function

Chest Wall

- Anatomy
  - Spine
  - Sternum
  - Ribs
  - Clavicles
  - Skeletal muscles
  - Chest wall nerves and vessels
  - Skin and subcutaneous fat
- Function
  - Provides protection for lungs, cardiovascular structures and intrathoracic organs
  - Participates in bellows-like process of respiration

Pleura

- Anatomy
  - Thin continuous membrane
  - **Parietal pleura**: Lines non pulmonary surfaces
  - **Visceral pleura**: Lines pulmonary surfaces
  - **Pleural space**: Potential space
- Function
  - Production and absorption of normal **pleural fluid**
    - **Pleural fluid** lubricates pleural surfaces
    - **Pleural fluid** facilitates lung motion during respiration
  - Clearance of abnormal **pleural fluid**

Airways

- Anatomy
  - Trachea
  - Main bronchi
  - Lobar bronchi
  - Segmental bronchi
  - Bronchioles
  - Distal airways and alveoli
- Function
  - Gas exchange during respiration
  - Protective mechanism against foreign particles
    - Ciliary escalator
    - Cough reflex
  - Air transfer to and from the alveolar-capillary interface

Heart and Great Vessels

- Anatomy
  - Venae cavae
  - Right atrium
  - Right ventricle
  - Pulmonary arteries
  - Capillary network
  - Pulmonary veins
  - Left atrium
  - Left ventricle
  - Aorta and branches
- Function
  - Pump action for systemic & pulmonary circulations
  - Transport of deoxygenated blood to capillary-alveolar interface
  - Transport of oxygenated blood to tissues

Chest Radiography

Standard Chest Radiographs

- Imaging study of choice for initial assessment of cardiopulmonary disease
- **PA** and **left lateral chest radiographs**
  - Orthogonal views (at right angles to each other)
  - Analysis of orthogonal views for anatomic localization of imaging abnormalities

Standard Radiographic Positioning

- Upright patient
- Full inspiration and breath hold near total lung capacity
- No rotation or motion
- Attempt to minimize overlying osseous structures
- Area of interest closest to IR
- Radiographic technique
  - SID of 72 inches to minimize magnification
  - Central X-ray beam centered on thorax
  - Beam collimation to include outer portion of chest wall

Radiographic Projections

- **PA chest radiograph**
  - Term **PA**: Describes posteroanterior direction of X-ray beam traversing chest toward IR
  - Anterior chest against IR
  - Head vertically positioned and chin on top of grid device
  - Dorsal wrists on hips and elbows rotated anteriorly to move scapulae laterally
  - Shoulders moved caudally and squarely against IR to bring clavicles below apices
- **Left lateral chest radiograph**
  - Term **left lateral**: Denotes that left lateral chest wall is against IR
  - X-ray beam traverses chest from right to left toward IR
  - Arms above head to move upper extremities away from lungs and mediastinum
- **AP chest radiograph**
  - Term **AP**: Describes anteroposterior direction of X-ray beam traversing chest toward IR
  - Supine and bedside (portable) radiography and imaging of sitting and semi-upright patients
    - Neonates, infants and very young children
    - Debilitated and unstable patients
    - Seriously ill and bed ridden patients
  - Distinctive features
    - Magnification of anterior structures (heart and mediastinum) farthest from IR; shorter SID
    - Clavicles course horizontally and partially obscure apices
    - Ribs assume a horizontal course

CHEST OVERVIEW

- **Lateral decubitus chest radiograph**
  - Recumbent position with right or left side down
  - Elevation of chest on radiolucent support
  - Frontal radiograph (AP or PA) with horizontal X-ray beam
  - Indications
    - Evaluation of pleural fluid in dependent pleural space (X-ray beam tangential to fluid-lung interface)
    - Evaluation of air in non-dependent pleural space (X-ray beam tangential to visceral pleura-air interface)
- **Apical lordotic** (AP or PA axial) **chest radiograph**
  - Superior angulation of X-ray beam from horizontal plane of 15-20°
  - Distinctive features
    - Anterior osseous structures (clavicles and first anterior ribs) project superiorly above lung apices
    - Ribs course horizontally
    - Magnification (foreshortening) of mediastinum
  - Indications
    - Radiographic visualization of **apex**, superior mediastinum and thoracic inlet
    - Enhanced visualization of minor fissure in suspected **right middle lobe atelectasis**
- Expiratory radiography
  - Evaluation of air trapping
  - Evaluation of pneumothorax
    - Limited value
    - No clear difference in sensitivity or specificity for diagnosis of pneumothorax

Radiographic Interpretation

- Assessment of patient's identity and proper placement of right/left markers
- Imaging of entire thorax
  - **Frontal radiographs**
    - Inclusion of all thoracic structures from larynx to costophrenic angles
    - Full inspiration with diaphragm below posterior ninth rib
  - **Lateral radiographs**
    - Inclusion of anteroposterior extent of chest wall
    - Inclusion of upper lung and posterior costodiaphragmatic sulci
- Assessment of **appropriate radiographic positioning**
  - No rotation
    - Spinous process of T3 (posterior structure) centered between medial clavicles (anterior structures) on frontal radiographs
    - Superimposition of right and left ribs posterior to vertebrae on lateral radiographs
  - Medial aspects of scapulae lateral to lungs on frontal radiographs
  - Arms above thorax without superimposition on lung and mediastinum on lateral radiographs
- **Appropriately exposed radiograph**
  - Visualization of peripheral pulmonary vasculature
  - Visualization of pulmonary vessels and thoracic vertebrae through heart on frontal radiographs
- Systematic evaluation
  - Assessment of multiple superimposed structures and tissues
  - Assessment of all visible structures including portions of neck, shoulders and upper abdomen
  - Comparison to prior studies
- Challenges
  - Evaluation of retrocardiac lung
  - Evaluation of retrodiaphragmatic lung
  - Evaluation of apical lung

Radiographic Densities

- Four basic **radiographic densities**
  - **Air**
  - **Water** (fluid, blood and soft tissue)
  - **Fat**
  - **Metal** (calcium, contrast, metallic medical devices, foreign bodies)
- **Silhouette sign**
  - An intrathoracic process (mass, consolidation, pleural fluid) that touches mediastinum or diaphragm obscures visualization of their borders on radiography
  - Critical for radiographic diagnosis of
    - **Atelectasis**
    - **Consolidation**
    - **Pulmonary edema/hemorrhage**
    - **Pleural effusion**

Computed Tomography

General Concepts

- Imaging based on X-ray absorption by tissues with differing atomic numbers
- Display of differences in X-ray absorption in cross-sectional format
- Excellent **spatial resolution**
- Enhanced visualization of structures of different tissue density based on display of a wide range of HU measurements
  - **Window width** refers to number of HU displayed; **window level** refers to median (center) HU
  - **Lung window** (width of 1500 HU; level of -600 HU)
    - Evaluation of lungs, airways and air-containing portions of gastrointestinal tract
  - **Soft tissue or mediastinal window** (width of 300-500 HU; level of 30-50 HU)
    - Evaluation of vascular structures and soft tissues of mediastinum and chest wall
  - **Bone window** (widest width; level of +30 HU)
    - Evaluation of skeletal and calcified structures and metallic objects

Conventional CT

- Evaluation, localization and characterization of abnormalities detected on radiography
- Localization of lesions in preparation for CT-guided biopsy/drainage

Contrast-Enhanced CT

- Administration of intravenous contrast
  - Evaluation of normal vessels
  - Evaluation of vascular abnormalities
  - Distinction of vascular structures from adjacent soft tissues
  - Determination of lesion/tissue enhancement

CHEST OVERVIEW

- Administration of enteric contrast
  - Evaluation of gastrointestinal tract
  - Evaluation of gastrointestinal perforations/leaks

CT Angiography

- Vascular imaging
  - Timing of contrast bolus
  - Imaging of specific vascular structures
    - **CT pulmonary angiography** for evaluation of **thromboembolic disease**
    - **CT aortography** for evaluation of **traumatic aortic injury, dissection** and **aneurysm**

High-Resolution CT

- Technique
  - **Thin-sections** to minimize partial volume effects
  - **High-resolution reconstruction algorithm**
- Indications
  - Evaluation of **diffuse infiltrative lung disease**
  - Evaluation of patients with **dyspnea** and normal radiographs
- Special techniques
  - **Prone imaging** for evaluation of peripheral basilar lung disease
  - **Expiratory imaging** for evaluation of distal airways disease

Special Techniques

- **Multiplanar imaging** with **coronal and sagittal reformations**
  - Evaluation of axially oriented structures and abnormalities
  - Evaluation of anatomic location of lung lesions in relation to fissures
  - Evaluation of chest wall and mediastinal involvement by adjacent pulmonary lesions
- **Surface-rendered techniques** for evaluation of airway and vascular lumens
  - **Virtual bronchoscopy**
  - **Virtual angioscopy**
- **Volume-rendered techniques** for problem solving and education

Magnetic Resonance Imaging

General Concepts

- Application of radiofrequency to excite protons within *a magnetic field*
- Detection of signal emitted by nuclei as they relax to their original alignment with generation of an image of their spatial distribution
- Advantages of MR
  - Excellent **contrast resolution**
  - **Multiplanar imaging**
  - Intrinsic vascular "contrast"
  - Increased soft tissue contrast

Technique

- **Spin-echo** sequences typically used in chest imaging
  - **T1 weighted images**
  - **T2 weighted images**
- **Bright blood** sequences

Indications

- Imaging of the heart and great vessels
- Distinction of vascular structures from adjacent soft tissues without the use of contrast
- Evaluation of mediastinum and hila
- Evaluation of chest wall and diaphragm

Angiography

Pulmonary Angiography

- Venous catheterization
- Cannulation of pulmonary arterial system
- Indications
  - Evaluation of congenital and acquired pulmonary vascular abnormalities
  - Evaluation of thromboembolic disease
    - Decreasing utilization

Aortography

- Arterial catheterization
- Cannulation of proximal aorta
- Indications
  - Evaluation of traumatic aortic and great vessel injury
  - Evaluation of congenital arterial vascular anomalies
  - Evaluation of caliber and integrity of aortic and great vessel lumens

Bronchial Artery & Intercostal Arteriography

- Arterial catheterization
- Selective cannulation of bronchial/intercostal arteries
- Indications
  - Diagnosis and treatment of **hemoptysis**

Other Chest Imaging Modalities

Radionuclide Imaging

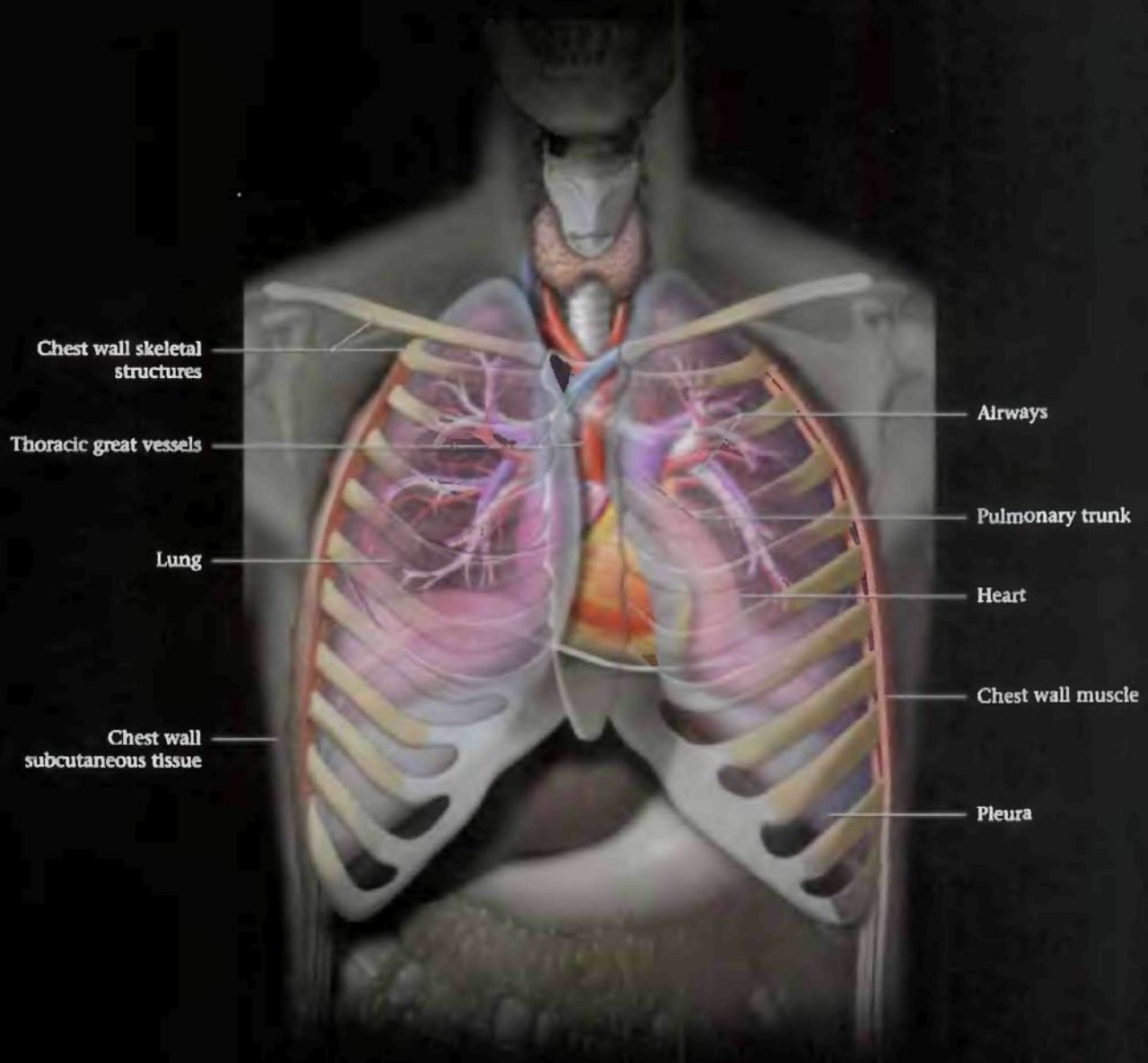
- **Ventilation-perfusion imaging**
  - Evaluation of thromboembolic disease
  - Evaluation of pre- and post-operative lung function
- **Positron-emission tomography**
  - Determination of metabolic activity of lesions
  - Staging of malignant neoplasms
  - Use of integrated **PET-CT imaging**

Ultrasound

- Evaluation of **pleural effusion**
  - Free vs. loculated
  - Thoracentesis planning
  - Biopsy planning
- Evaluation of **diaphragmatic motion**

CHEST OVERVIEW

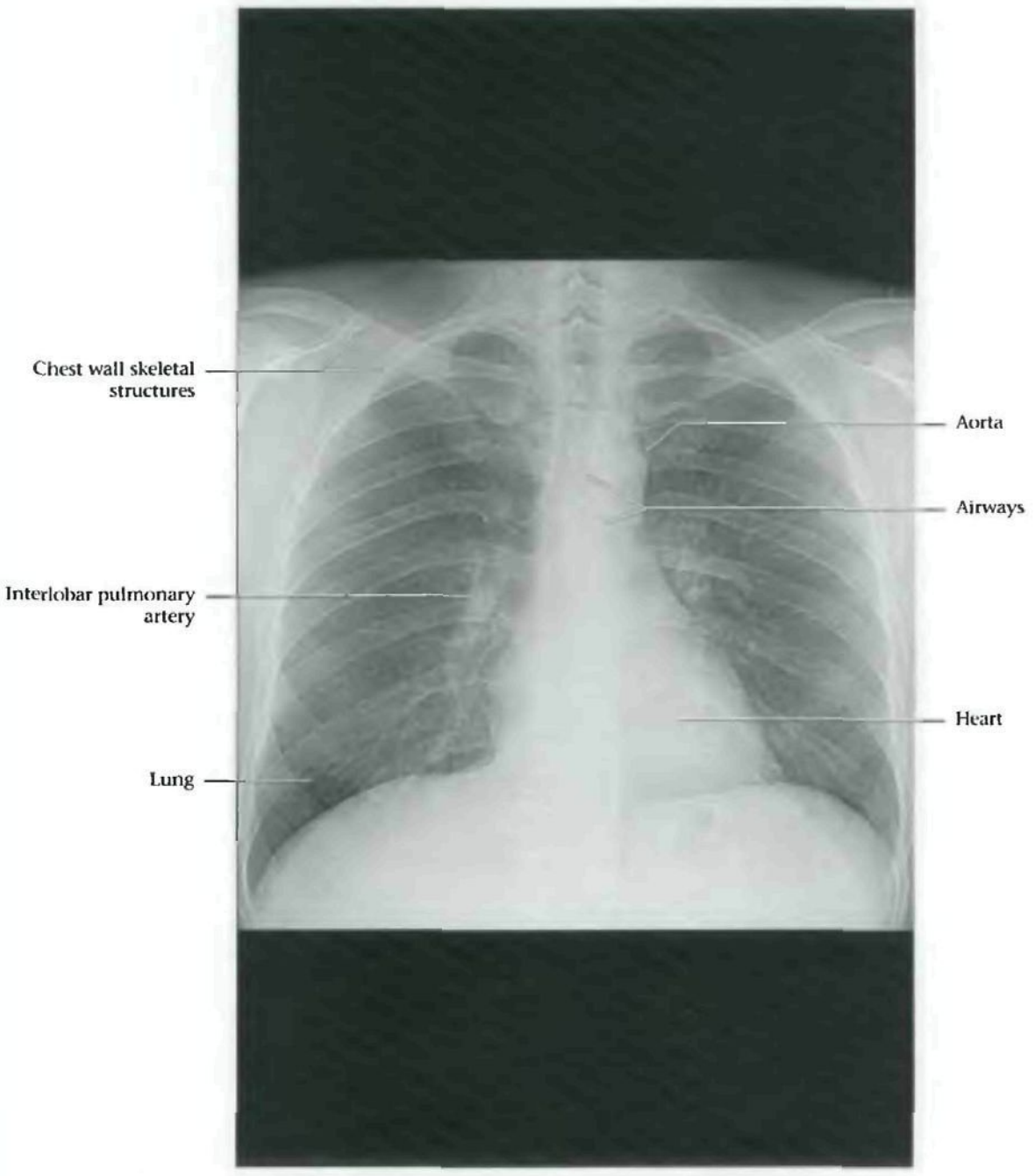
STRUCTURES OF THE CHEST



Graphic shows the complex and diverse structures and organs in the thorax. The chest wall skeletal and soft tissue structures surround and protect the primary organs of respiration, the thoracic cardiovascular system, and the proximal gastrointestinal tract. The apposed pleural surfaces create a potential space that normally contains a small amount of fluid which lubricates the pleura and reduces friction during respiratory motion. The airways deliver oxygen to the alveolar-capillary interface and carry carbon dioxide out to the environment. The heart and vessels deliver deoxygenated blood to the capillary-alveolar interface and oxygenated blood to the peripheral organs and tissues.

CHEST OVERVIEW

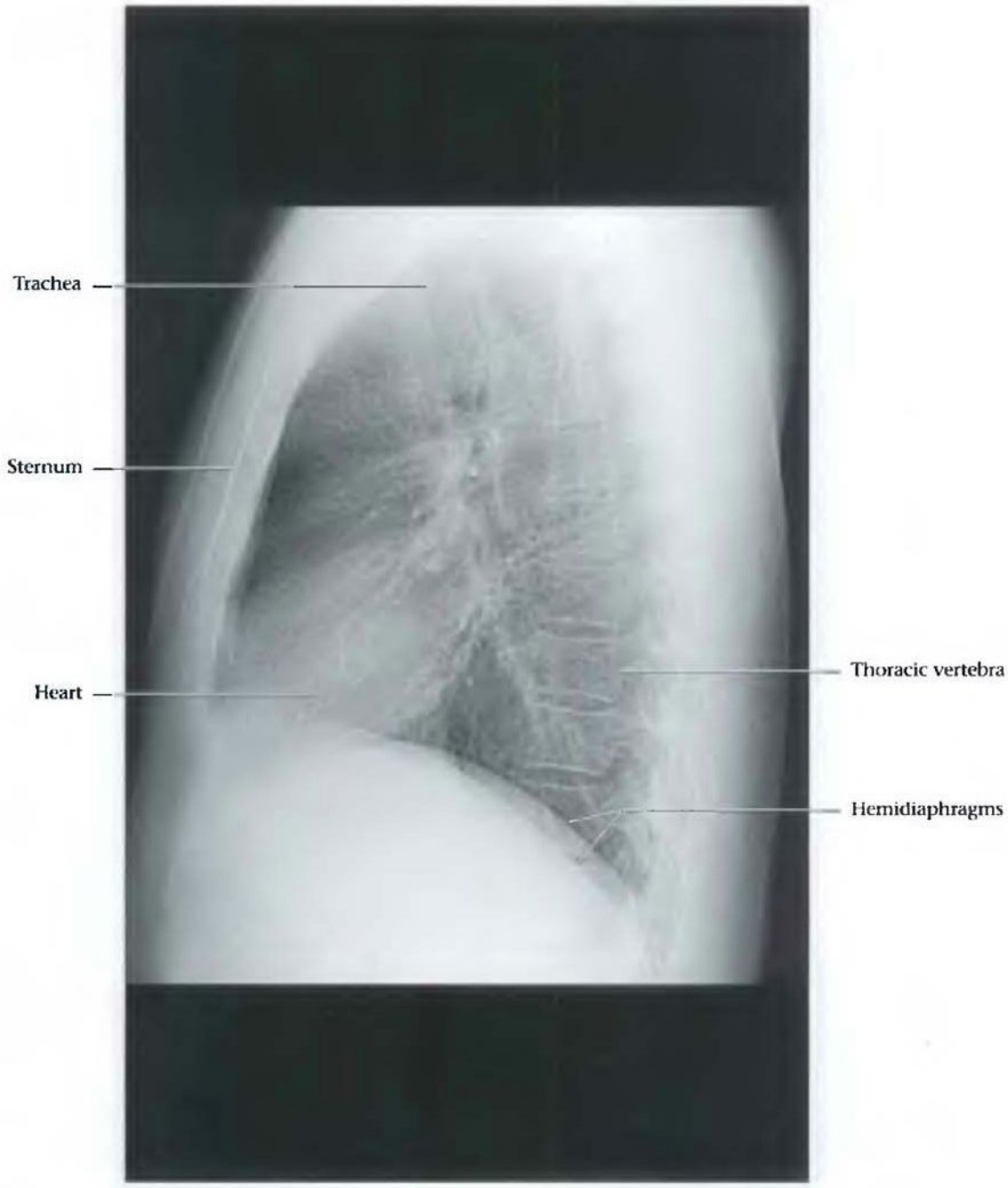
PA CHEST RADIOGRAPH



Normal posteroanterior chest radiograph shows the challenges inherent in the interpretation of radiographs of the thorax. Chest radiographs display a wide range of structures and tissue types with significant superimposition of structures of different radiographic density. Portions of the lung may be obscured by overlying mediastinal soft tissues and skeletal structures. Attention to radiographic image quality is of paramount importance for accurate diagnosis of subtle abnormalities.

CHEST OVERVIEW

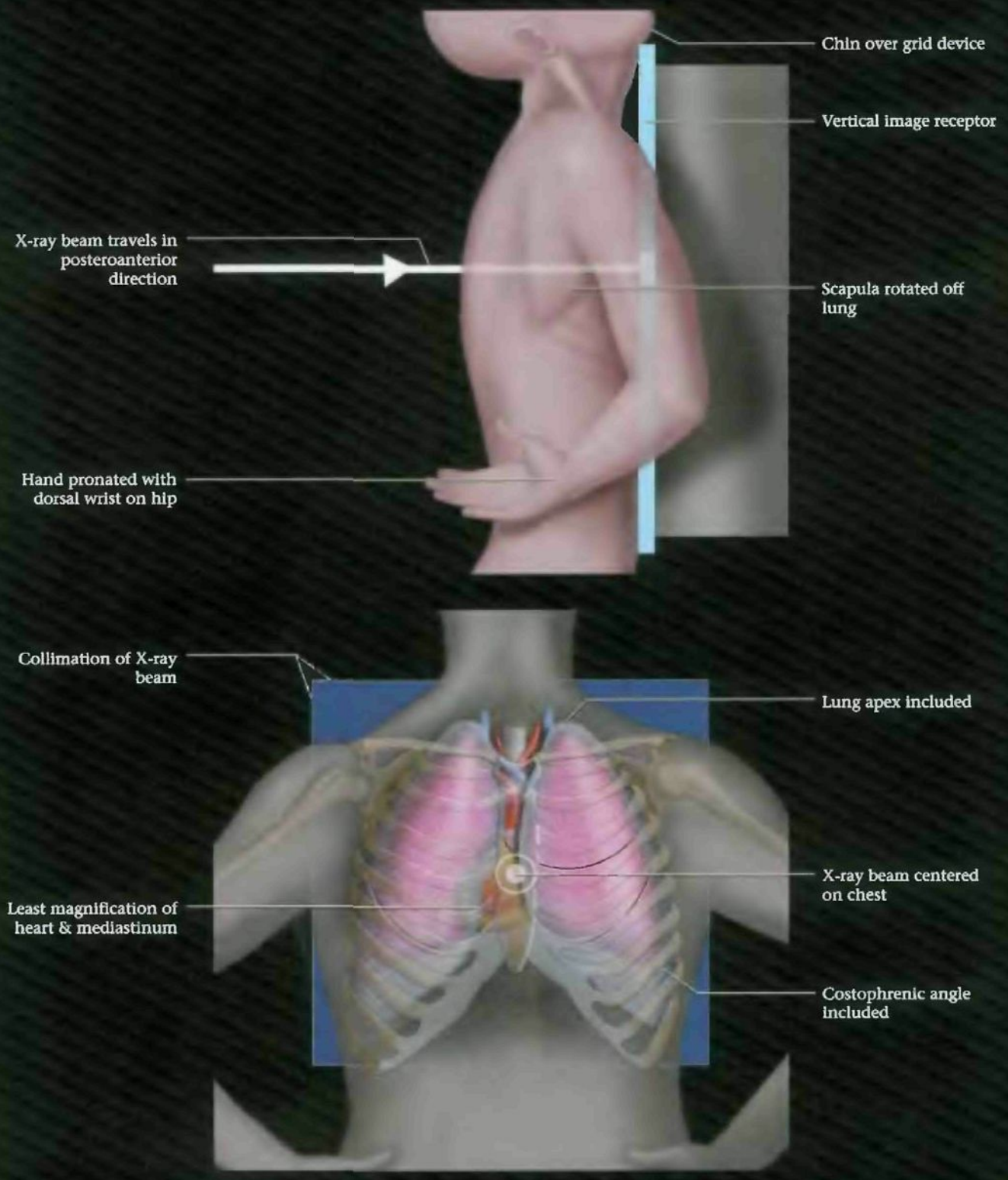
LEFT LATERAL CHEST RADIOGRAPH



The left lateral chest radiograph is orthogonal (at 90°) to the PA chest radiograph. It is a complementary view that allows visualization of the retrocardiac left lower lobe and the retrodiaphragmatic lung bases. It also allows evaluation of the thoracic vertebrae. As in the PA chest radiograph, multiple structures of various densities are superimposed and must be evaluated in a systematic manner.

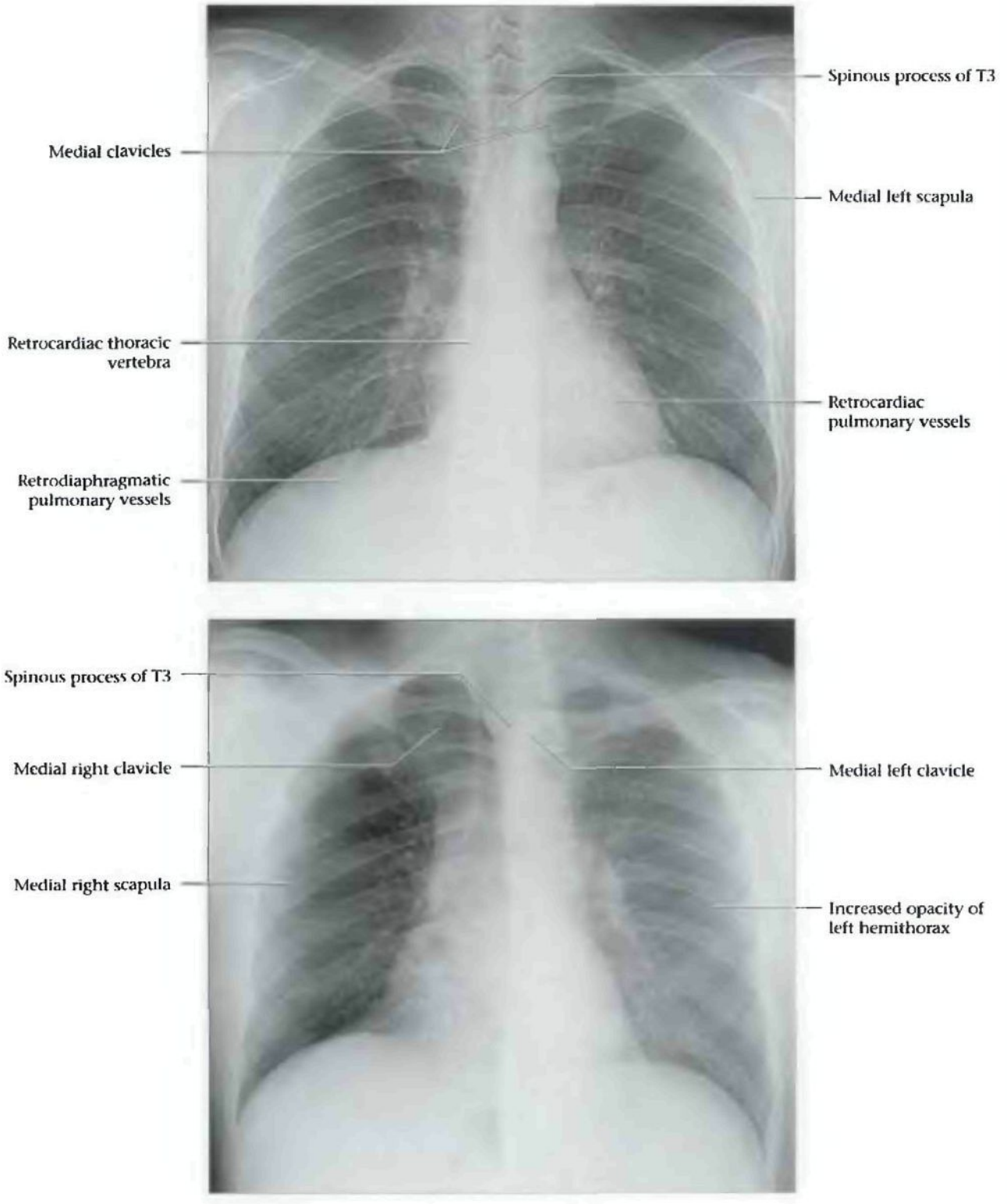
CHEST OVERVIEW

PA CHEST RADIOGRAPHY, POSITIONING & COLLIMATION



(Top) Graphic shows proper positioning for PA chest radiography. The patient is upright with the anterior chest against the vertical IR, the chin over the top of the device, the arms flexed with the backs of the hands on the hips and the shoulders internally rotated to move the scapulae off the lungs. The X-ray beam travels through the patient *in a posteroanterior direction.* ***(Bottom)*** *Graphic shows proper PA chest radiographic collimation for imaging the* lungs and mediastinum. The white target sign shows the centering of the X-ray beam. The blue overlay represents the collimated X-ray beam that extends from the cervical airway superiorly to below the costophrenic angles inferiorly and includes the left and right skin surfaces. The anterior structures of the chest (shown in color) are closest to the IR and experience the least magnification.

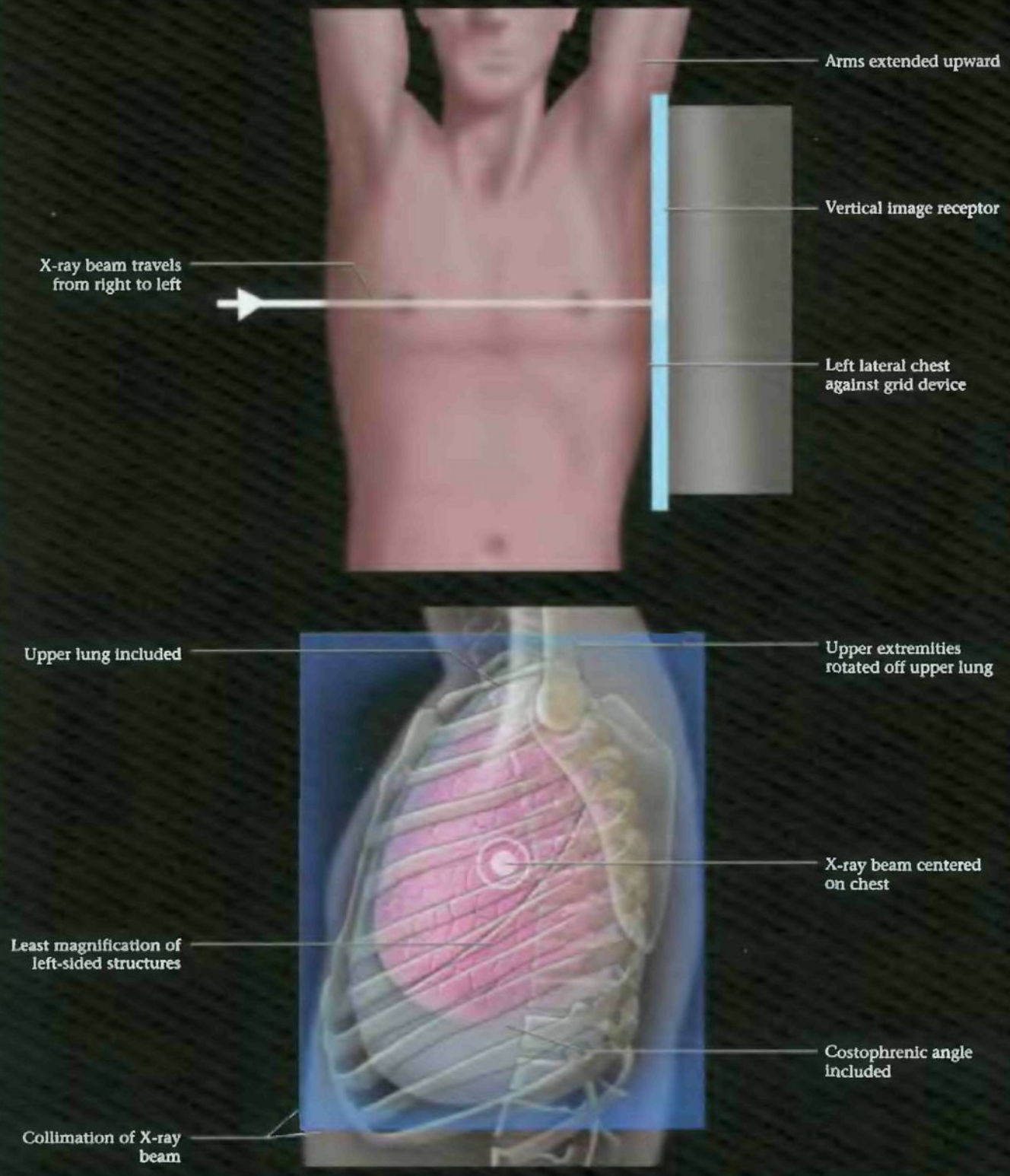
PA CHEST RADIOGRAPHY



(Top) Well-positioned normal PA chest radiograph. The scapulae are rotated off the lungs. The spinous process of T3 is equidistant from the medial clavicles. Proper collimation spans from the cervical trachea superiorly to below the costophrenic angles inferiorly and includes the lateral aspects of the chest wall. Optimal exposure allows visualization of the peripheral pulmonary vessels, the vertebral bodies (visible through the mediastinum), and the retrocardiac and retrodiaphragmatic pulmonary vessels. **(Bottom)** Poorly positioned PA chest radiograph with marked rotation to the right. The left medial clavicle overlies the spinous process of T3 and the right medial clavicle is displaced to the right of midline. Increased density of the left hemithorax results from X-ray penetration of a greater thickness of left-sided chest wall soft tissues due to rotation.

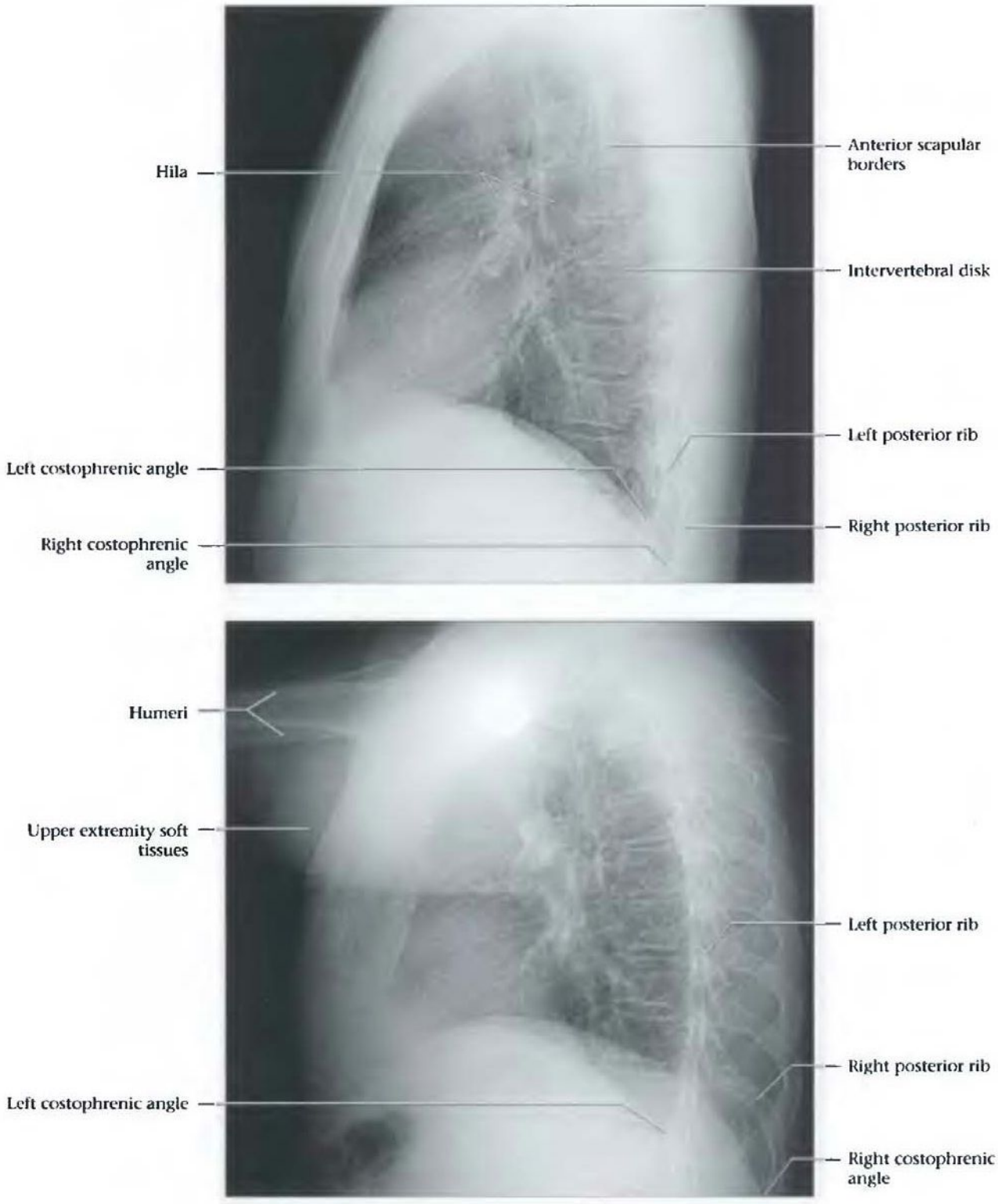
CHEST OVERVIEW

LEFT LATERAL CHEST RADIOGRAPHY, POSITIONING & COLLIMATION



(Top) Graphic shows proper positioning for left lateral chest radiography. The patient is upright with the left lateral chest against the vertical image receptor and the arms extended upward for unobstructed visualization of the upper lungs. The X-ray beam travels through the patient from right to left for a left lateral chest radiograph. **(Bottom)** Graphic shows proper left lateral chest radiographic collimation for imaging the lungs and mediastinum. The white target sign shows the centering of the X-ray beam. The blue overlay represents the collimated X-ray beam that extends from the cervical airway superiorly to below the costophrenic angles inferiorly and includes the anterior and posterior skin surfaces. The structures of the left chest (shown in color) are closest to the image receptor and experience the least magnification.

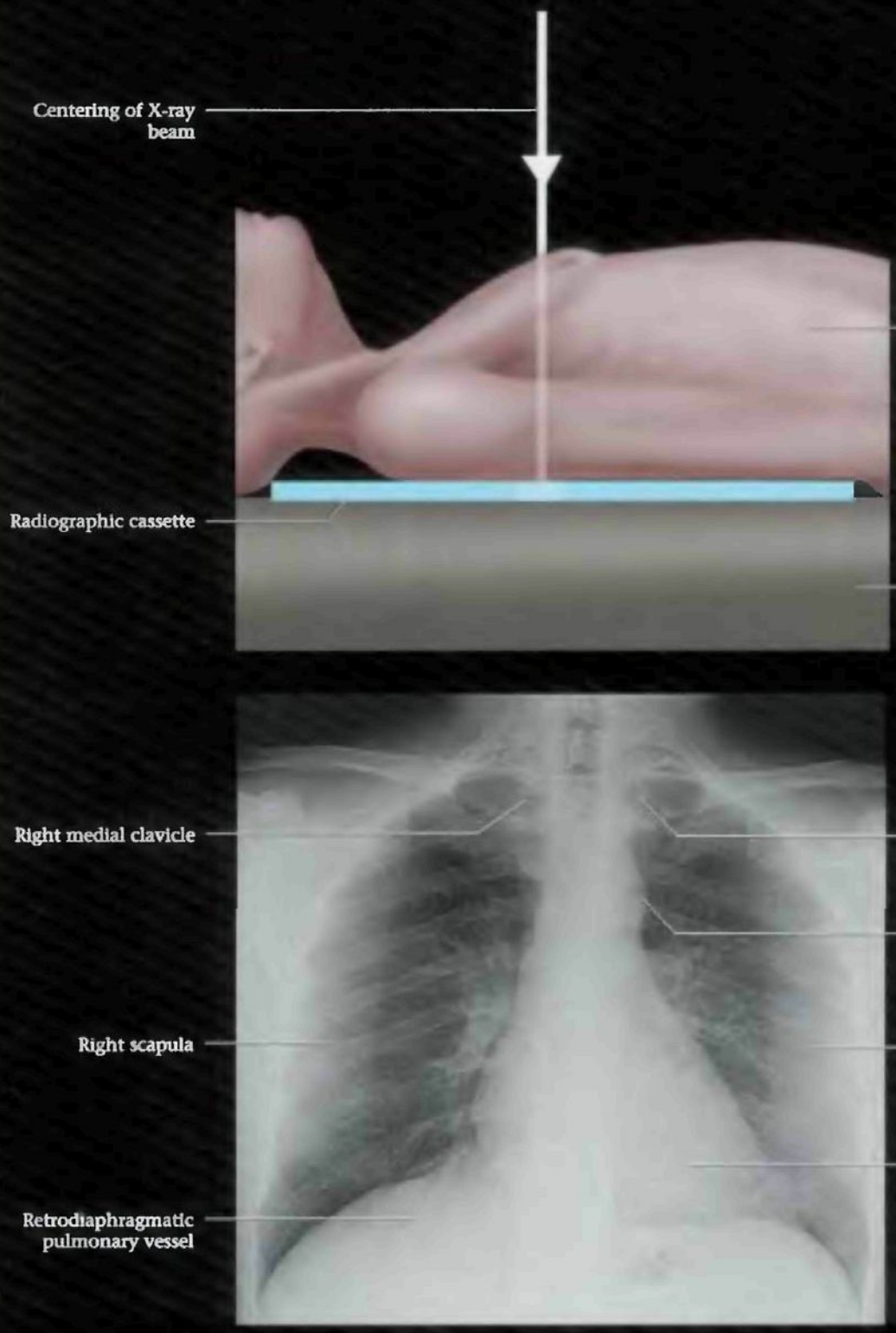
LEFT LATERAL CHEST RADIOGRAPHY



(Top) Well-positioned normal left lateral chest radiograph. The upper extremities are not visible. The hila are centrally located. The thoracic intervertebral disks are visible. The posterior ribs are superimposed and project behind the vertebrae. There is minimal magnification of the left posterior ribs, which appear sharper and smaller than the right posterior ribs. Proper collimation allows inclusion of the lung apices, the posterior costophrenic angles and the anterior and posterior skin surfaces. **(Bottom)** Poorly positioned left lateral chest radiograph. The skeletal and soft tissue structures of the upper extremities obscure the anterior lungs and mediastinum. Rotation prevents superimposition of the posterior ribs. The right posterior ribs appear larger and project behind the left posterior ribs. The right costophrenic angle projects posterior to the left.

CHEST OVERVIEW

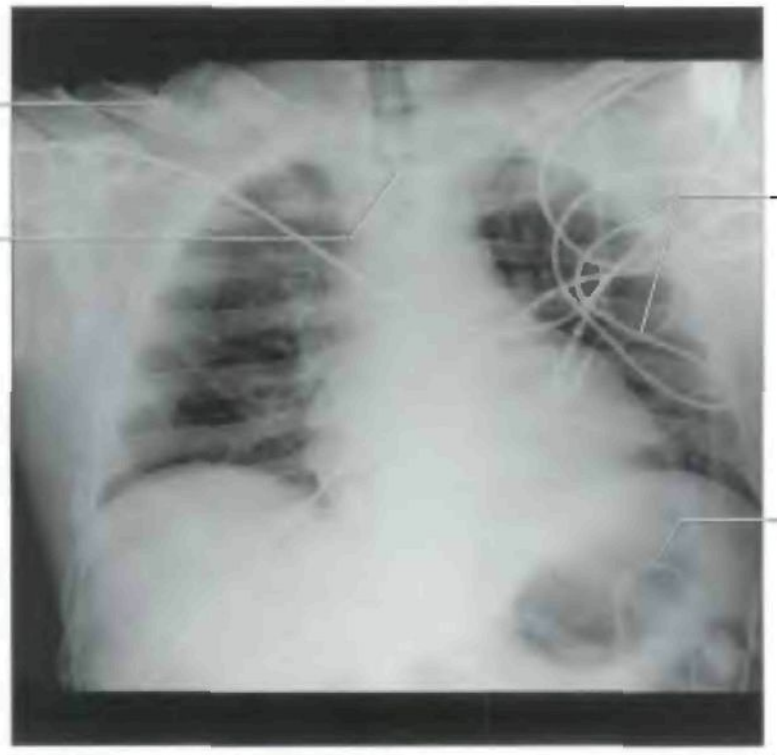
AP CHEST RADIOGRAPHY, POSITIONING & COLLIMATION



(Top) Graphic shows proper positioning for supine AP chest radiography. The patient's back is against the radiographic cassette, the upper extremities are by the patient's sides. Internal rotation of the shoulders will minimize the degree of superimposition of the scapulae on the lateral upper lungs. The X-ray beam travels through the patient in an anteroposterior direction. The heart and anterior chest structures are farthest from the cassette and experience some magnification. **(Bottom)** Normal AP chest radiograph. The heart and great vessels appear mildly magnified. The clavicles show a horizontal course and their medial portions obscure the lung apices. The medial scapulae project over the lateral aspects of the lungs. Note that exposure factors and collimation are optimal with visualization of retrocardiac vertebrae and vessels and retrodiaphragmatic vessels.

CHEST OVERVIEW

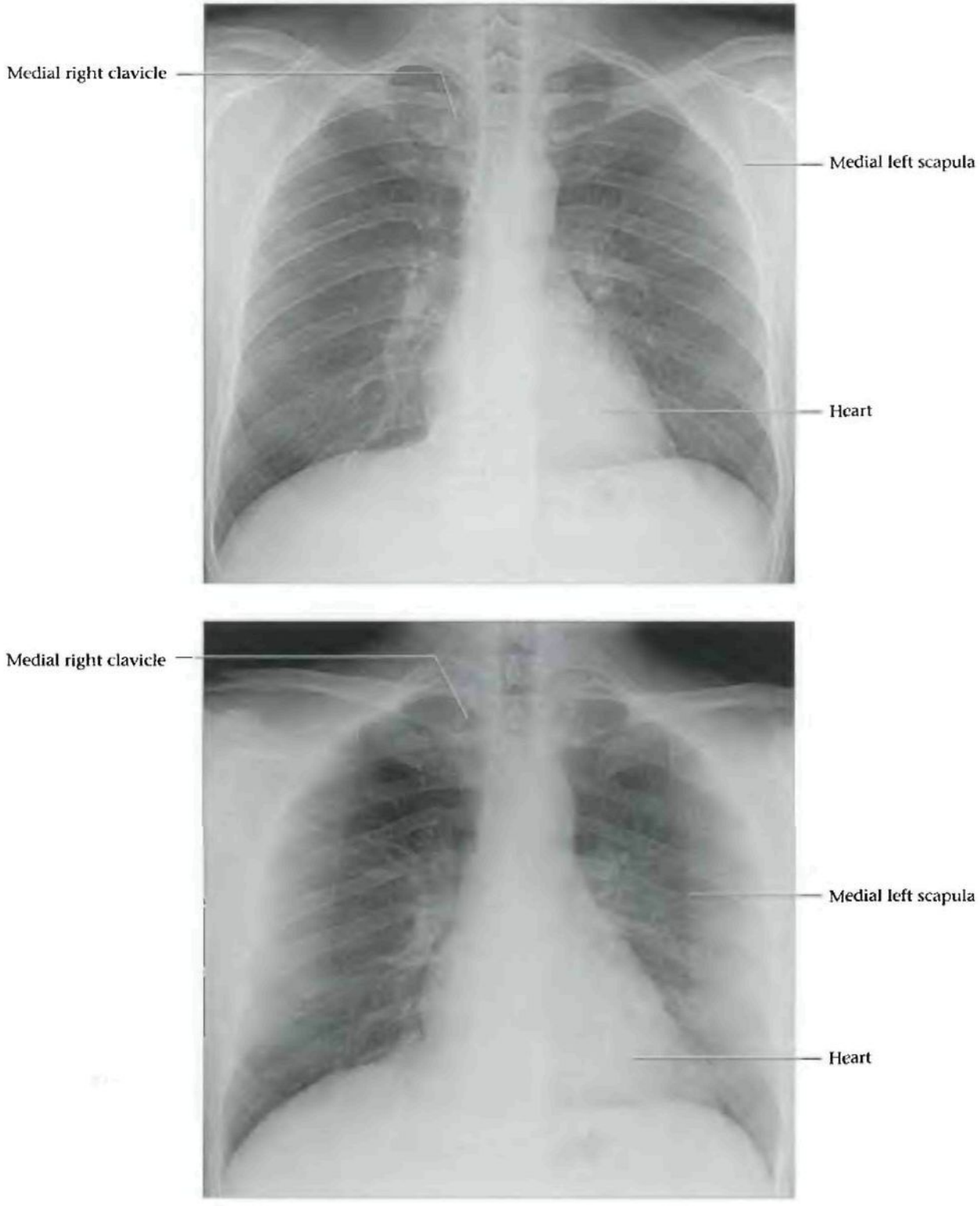
PORTABLE AP CHEST RADIOGRAPHY, TRAUMA & INTENSIVE CARE



(Top) Supine bedside (portable) AP chest radiograph. Portable radiographs are used for imaging debilitated, seriously ill and traumatized patients. *AP chest radiographs in the setting of trauma are often compromised by technical* factors related to overlying radio-opaque monitoring and stabilizing devices. However, they provide a quick assessment of the integrity of the thoracic structures and the position of life support devices. **(Bottom)** Bedside AP chest radiography is optimal for imaging neonates and infants, particularly those who are seriously ill due to congenital lesions and/or prematurity. One day old infant born at 31 weeks gestation is undergoing treatment for prematurity and mild respiratory distress syndrome. Portable radiography allows assessment of life support devices (endotracheal tube, umbilical artery/vein catheters) and pulmonary parenchyma.

CHEST OVERVIEW

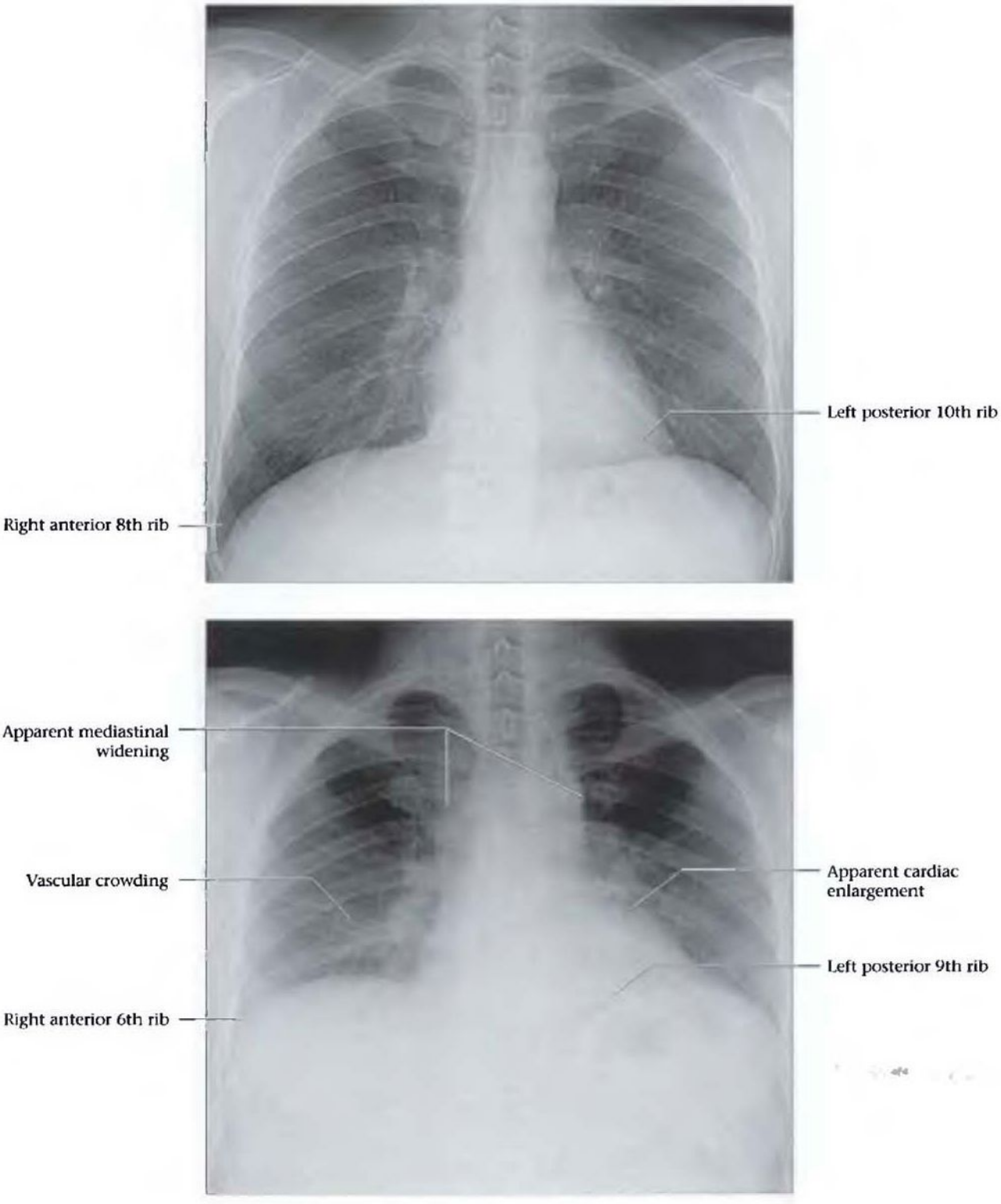
PA & AP CHEST RADIOGRAPHS



(Top) First of four normal radiographs of the same patient. On the PA chest radiograph, the heart and mediastinum are closest to the image receptor and undergo the least magnification. The medial clavicles curve inferiorly and do not obscure the lung apices. The scapulae are rotated laterally and do not obscure the lateral aspects of the lungs. **(Bottom)** On the AP chest radiograph, the heart and mediastinum appear slightly larger as they are farthest from the image receptor and undergo some magnification. The clavicles exhibit a horizontal course and their medial aspects obscure the lung apices. The medial portions of the scapulae overlie the lateral aspects of the lungs.

CHEST OVERVIEW

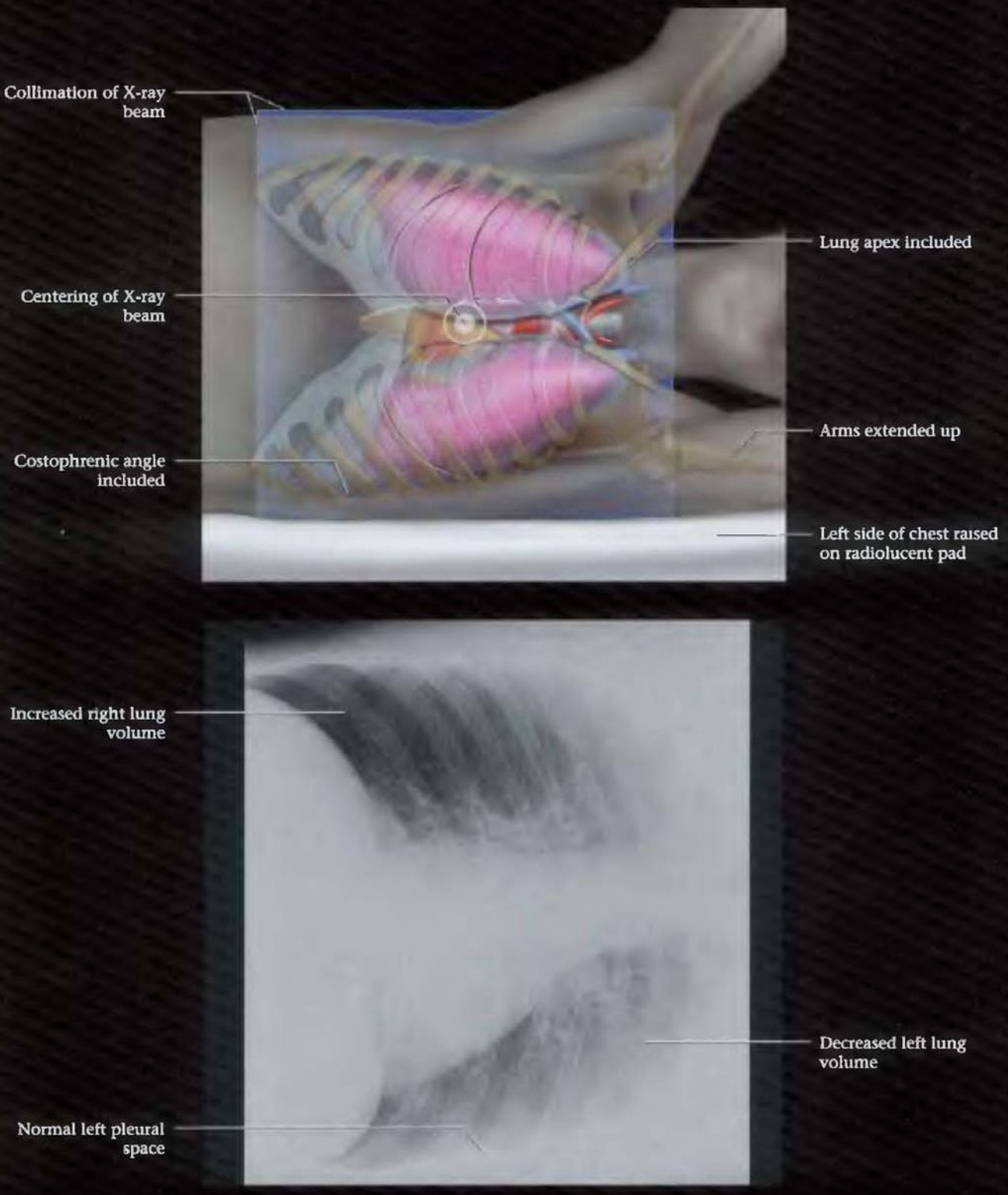
INSPIRATORY AND EXPIRATORY CHEST RADIOGRAPHS



(Top) Normal PA chest radiograph obtained at full inspiration shows optimal visualization of the lung bases and the retrocardiac and retrodiaphragmatic lung. A portion of the 8th anterior right rib is visible through the lung and projects above the hemidiaphragm. A portion of the 10th posterior left rib is visible through the lung and projects above the hemidiaphragm. **(Bottom)** Normal PA chest radiograph obtained at end expiration shows low lung volumes. The lung bases are partially obscured with increased basilar density and vascular crowding with resultant poor visualization of the retrodiaphragmatic lung. A portion of the right 6th anterior rib is visible through the lung and projects above the hemidiaphragm. A portion of the left 9th posterior rib is visible through the lung and projects above the hemidiaphragm.

CHEST OVERVIEW

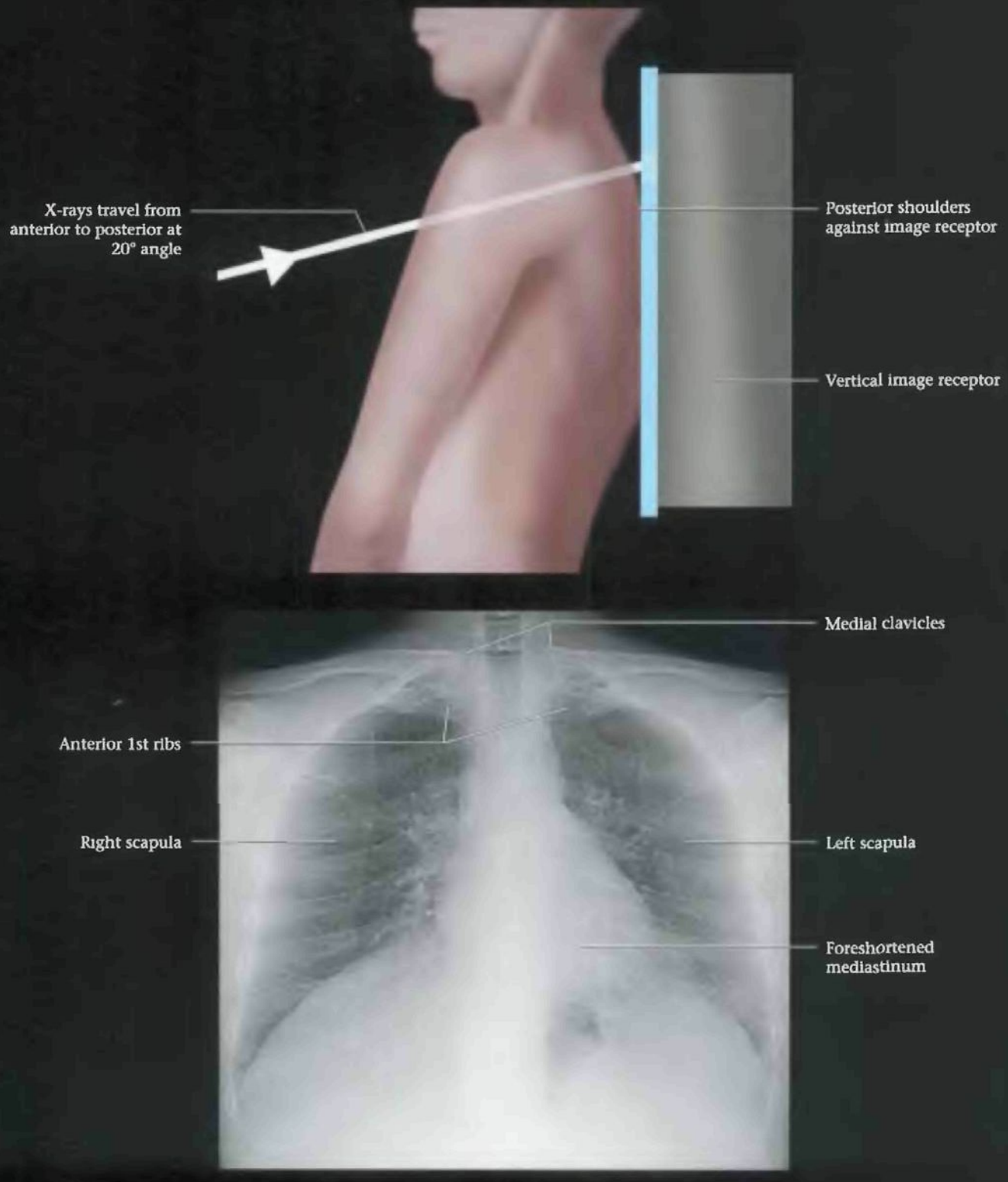
LATERAL DECUBITUS CHEST RADIOGRAPHY, POSITIONING & COLLIMATION



(Top) Graphic shows proper lateral decubitus PA radiographic collimation for imaging the lungs and mediastinum. The white target sign shows the centering of the X-ray beam. The blue overlay represents the collimated X-ray beam that extends from the cervical airway superiorly to below the costophrenic angles inferiorly and includes the left and right skin surfaces. The thorax is elevated on a radiolucent pad to ensure inclusion of the dependent pleural surface and chest wall. The anterior structures of the chest (shown in color) are closest to the image receptor and experience the least magnification. **(Bottom)** Normal left lateral decubitus radiograph shows a larger lung volume in the non-dependent right lung and volume loss manifesting as increased density in the dependent left lung. There is no pleural thickening or fluid.

CHEST OVERVIEW

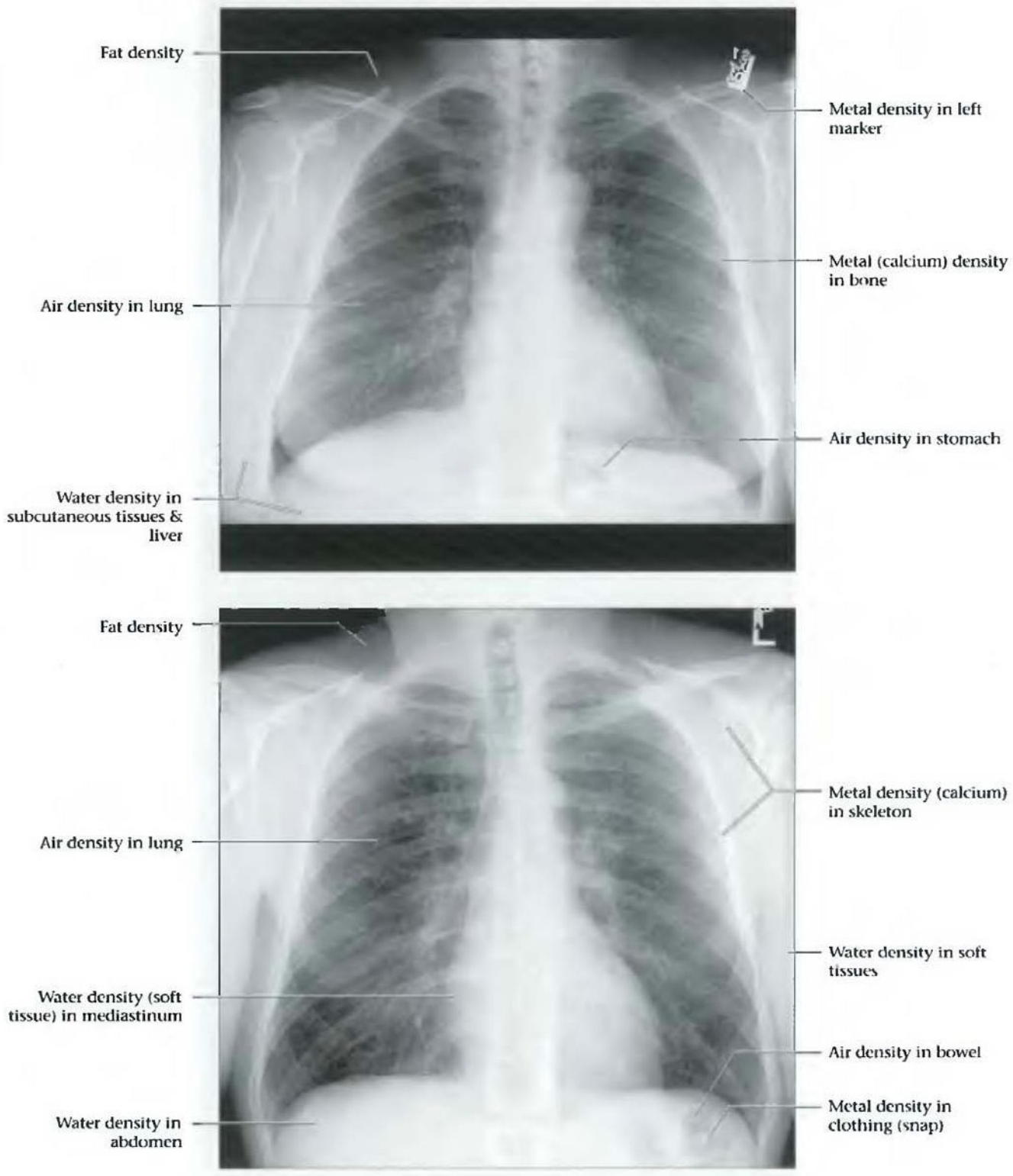
APICAL LORDOTIC CHEST RADIOGRAPHY, POSITIONING



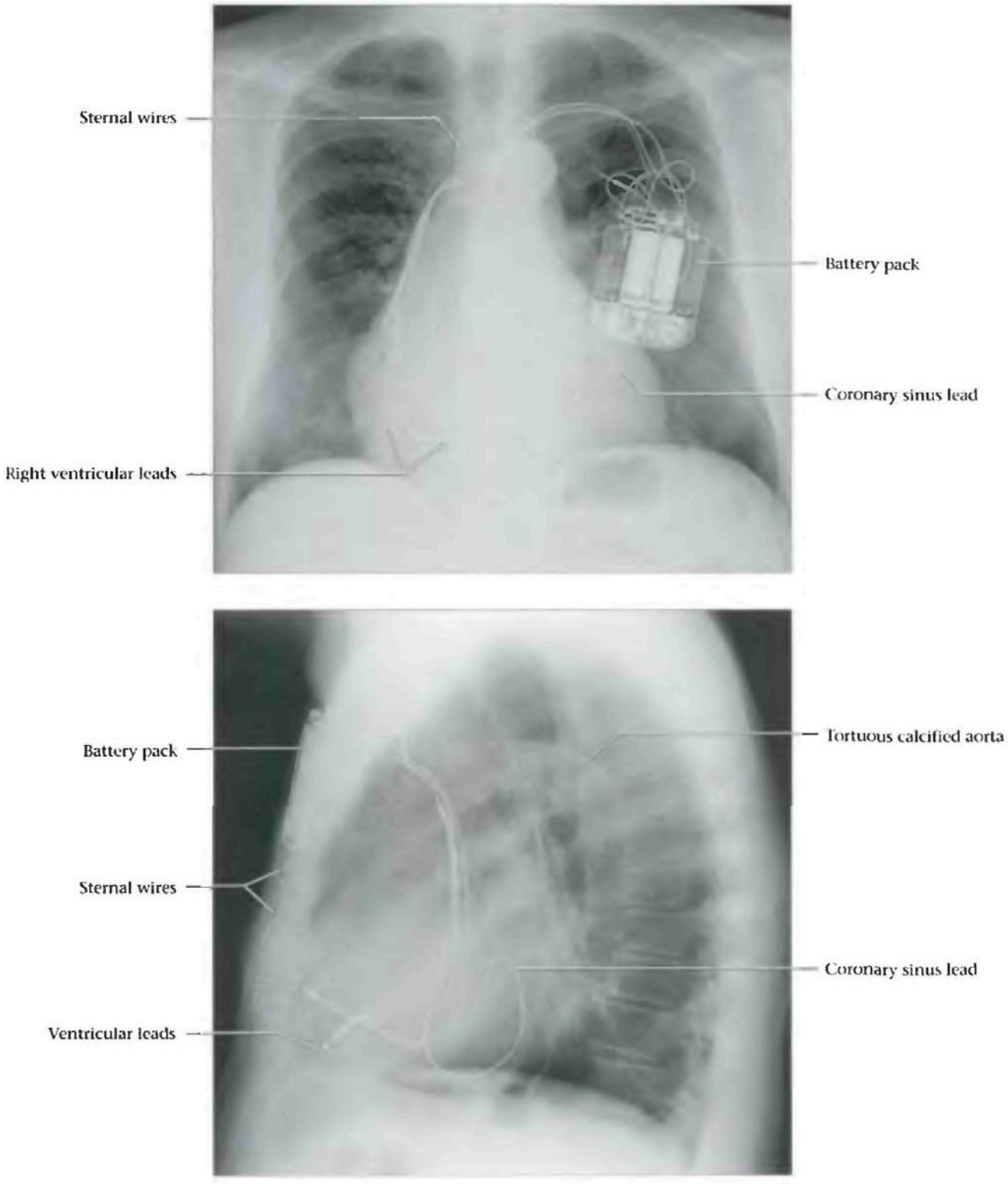
(Top) Graphic shows proper positioning for AP apical lordotic chest radiography. The patient is upright with the posterior shoulders against the vertical image receptor, the arms are internally rotated to move scapulae away from the lungs. The X-ray beam travels through the patient from anterior to posterior and is centered at the manubrium sternum and oriented superiorly at a 20° angle from the horizontal plane. **(Bottom)** Normal apical lordotic chest radiograph projects the medial aspects of the clavicles off the lung apices. Note that the apex is partly obscured by the anterior aspects of the first ribs and their costochondral junctions in this case. The mediastinum is foreshortened and mildly magnified. The scapulae overlie a significant portion of the lateral lungs.

CHEST OVERVIEW

RADIOGRAPHIC DENSITIES



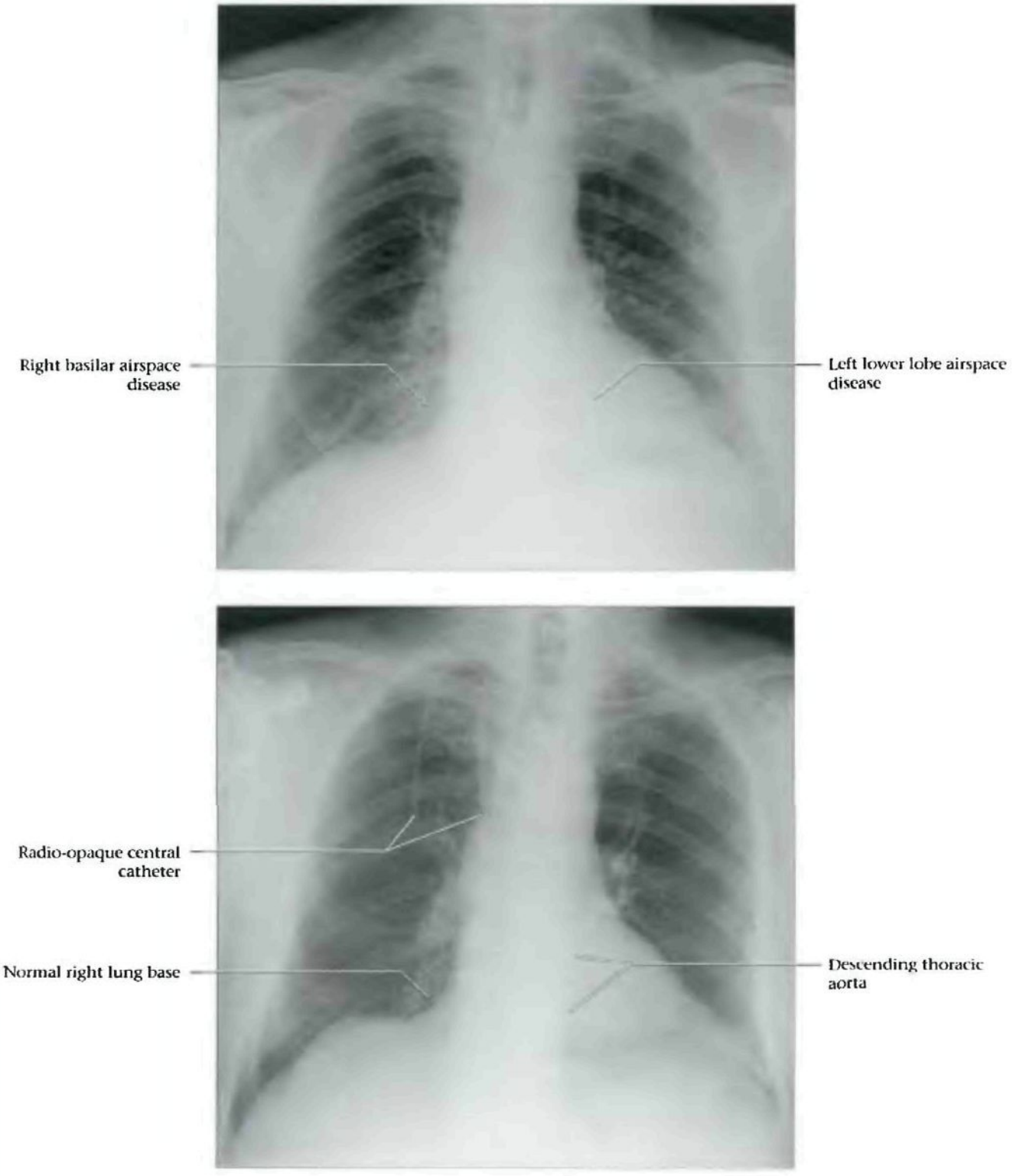
(Top) Normal PA chest radiograph shows the four radiographic densities. Air is present in the lungs bilaterally and within the stomach. Water (or soft tissue) density is seen in the mediastinum, abdomen and subcutaneous tissues. Fat density is visible between the normal soft tissues of the upper thorax. Metal density is noted in the skeletal structures (calcium) and the metallic left marker. **(Bottom)** Normal PA chest radiograph shows the four radiographic densities. Air density is present in the lungs and within bowel. Water (soft tissue) density is seen in the mediastinum, abdomen and subcutaneous soft tissues. Fat is more difficult to demonstrate in this thin patient but is present between the normal soft tissues of the upper chest. Metal is represented by the skeletal structures (calcium), the metallic left marker and a snap on the patient's gown.



(Top) First of two chest radiographs of a patient with a biventricular pacemaker and automatic implantable cardioverter defibrillator with a battery pack. Orthogonal radiographs allow accurate assessment of the integrity and position of medical devices. PA chest radiograph shows two pacer leads in the right ventricle and one in the coronary sinus. The metallic battery pack obscures visualization of the left mid lung. There is cardiomegaly and tortuosity and calcification of the thoracic aorta. The lungs are clear. Sternal wires are present. **(Bottom)** Left lateral chest radiograph shows two right ventricular leads and a third lead in the coronary sinus. The left lung behind the battery pack is now visible although superimposed on the contralateral right lung. Cardiomegaly, aortic tortuosity and calcification and sternal wires are again noted.

CHEST OVERVIEW

SILHOUETTE SIGN



(Top) First of two chest radiographs of a patient with multifocal pneumonia who presented with fever. AP chest radiograph shows right basilar airspace disease manifesting as increased basilar opacity and obscuration of the right cardiac border. Left lower lobe airspace disease manifests with obscuration of the retrocardiac descending aorta. Multifocal pneumonia was suspected clinically and was confirmed on chest CT. **(Bottom)** PA chest radiograph obtained two years earlier shows a normal appearance of the right lung base, visualization of the right cardiac border and a normal left lower lobe with visualization of the retrocardiac descending aorta. A right internal jugular catheter is also present. This case illustrates the value of the silhouette sign and the value of comparison with prior studies in the diagnosis of subtle radiographic abnormalities.

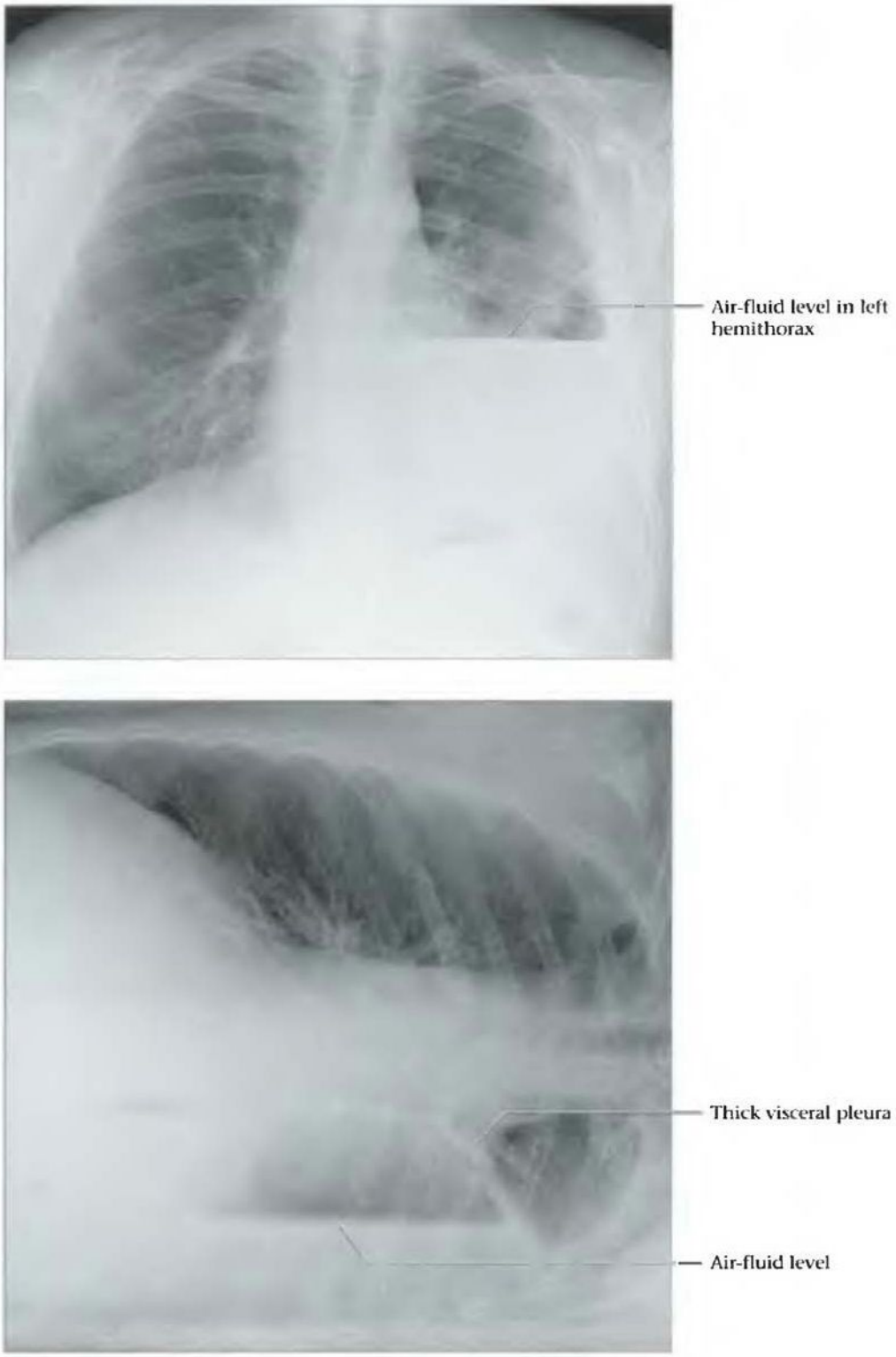
CHEST OVERVIEW

ANATOMIC LOCALIZATION WITH ORTHOGONAL RADIOGRAPHS

(Top) First of two radiographs of the same patient. PA chest radiograph shows a bullet over the soft tissues of the upper abdomen to the left of the midline. There is blunting of the left costophrenic angle related to remote trauma. **(Bottom)** The orthogonal left lateral chest radiograph allows anatomic localization of the bullet in the soft tissues of the posterior left chest wall. The patient is rotated. Note that the bullet projects posterior to the sharper, smaller and anteriorly located left posterior ribs. The right posterior ribs appear less sharp and larger as they are farther from the IR. The right and left hemidiaphragms can be confidently identified based on their relationship to the corresponding ipsilateral ribs. PA and lateral radiographs allow anatomic localization of imaging abnormalities.

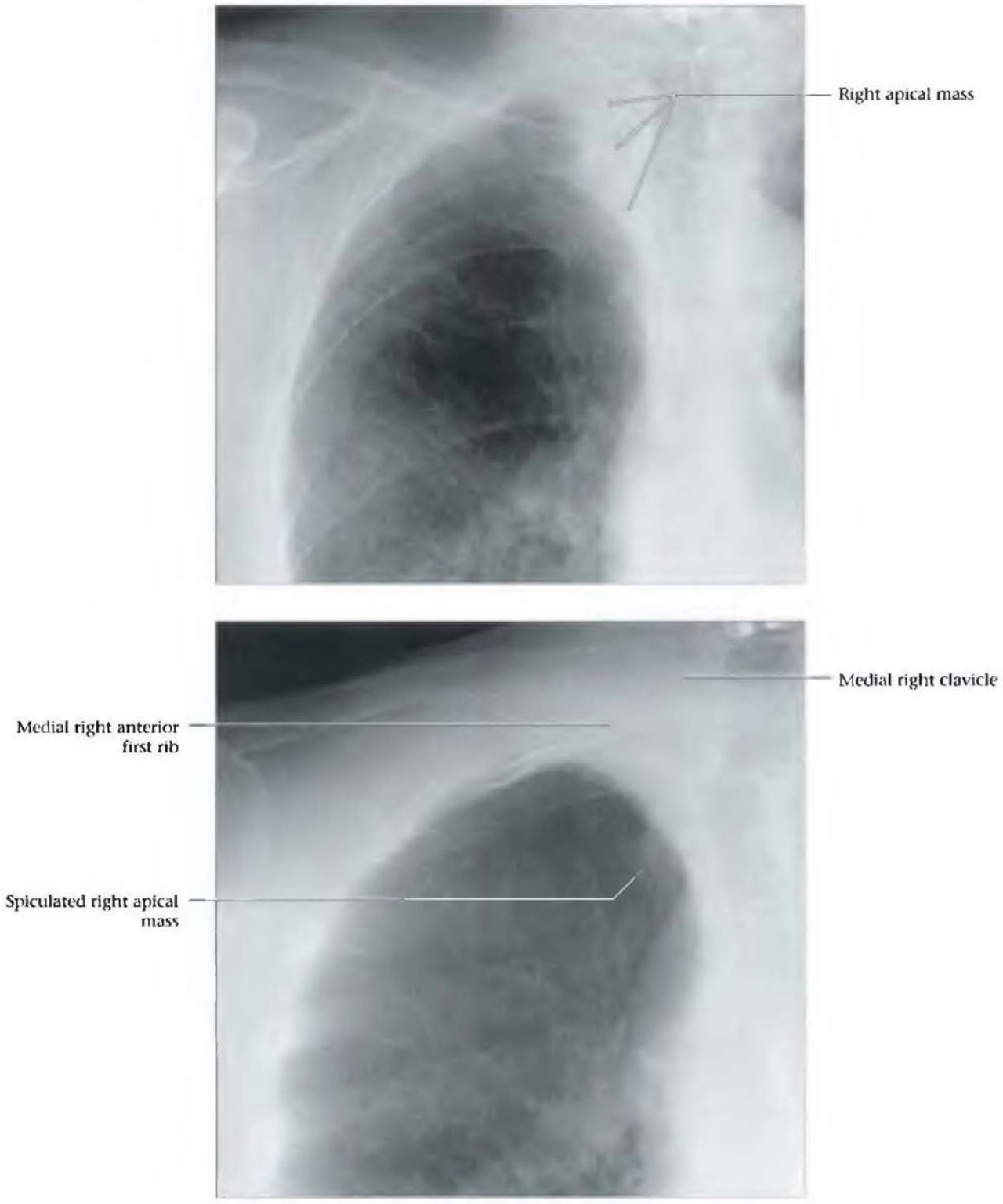
CHEST OVERVIEW

DECUBITUS RADIOGRAPHY FOR EVALUATION OF COMPLEX PLEURAL DISEASE



(Top) First of two chest radiographs of a patient with a left empyema. PA chest radiograph shows a large air-fluid level in the left inferior hemithorax. **(Bottom)** Left lateral decubitus chest radiograph shows a discrepant length of the air-fluid level (it appears longer than on the PA radiograph) indicating that the collection has an elongate shape. Note the thick medial wall of the air and fluid collection. The findings are characteristic of a loculated pleural collection. The presence of air indicates a communication with the tracheobronchial tree (bronchopleural fistula) and the findings are diagnostic of a complicated empyema. In this case, the lateral decubitus radiograph allows pleural localization of the abnormality and distinction from parenchymal disease.

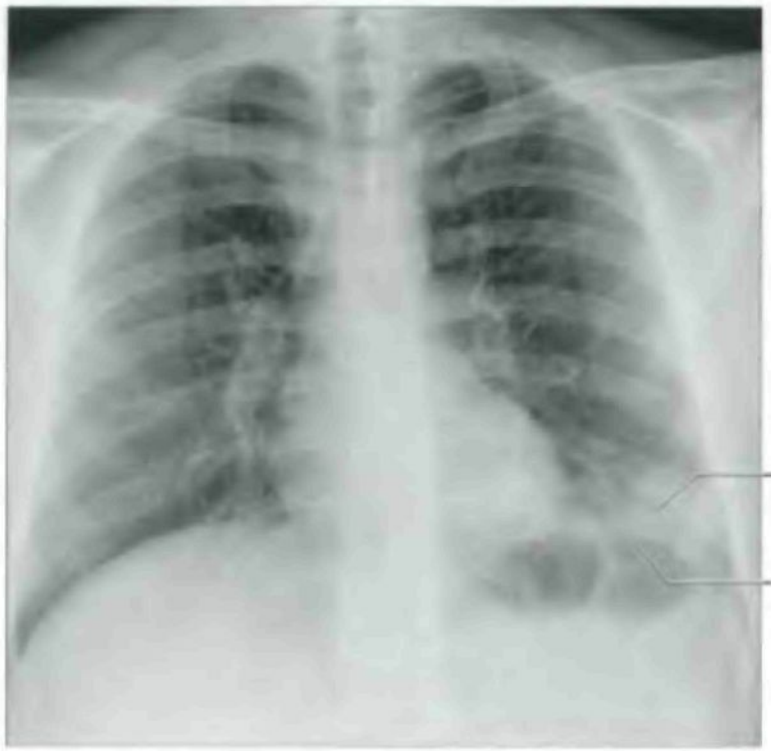
LORDOTIC CHEST RADIOGRAPHY FOR EVALUATION OF APICAL LESION

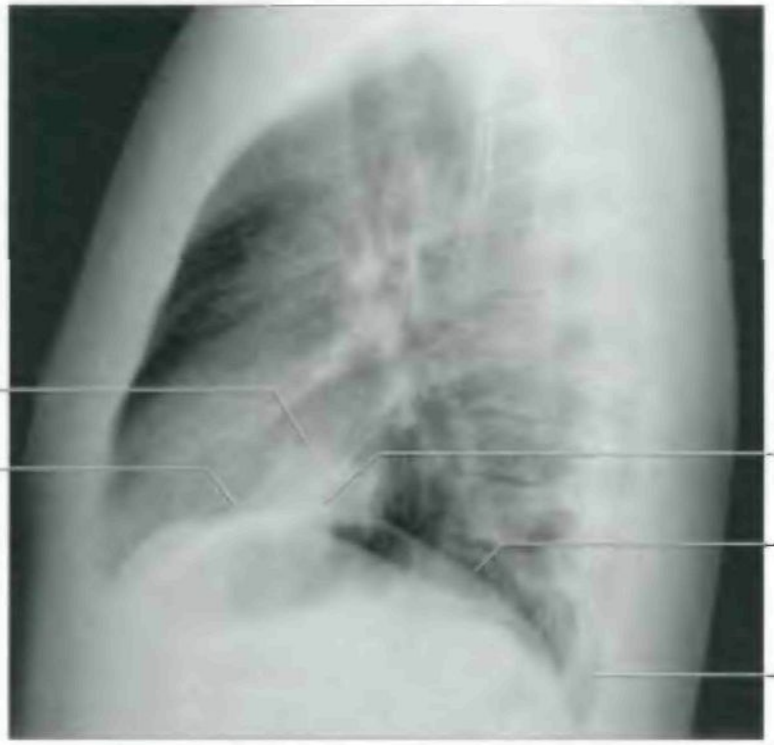


(Top) First of two radiographs of a patient with a right apical mass. PA chest radiograph coned-down to the right apex demonstrates an abnormal irregular apical mass and thickening of the medial aspect of the right apical pleura. **(Bottom)** AP apical lordotic radiograph coned to the right upper lobe allows visualization of the medial aspect of the right apical lung by projecting the right medial clavicle and right first anterior rib above the lung apex. The spiculated lateral border of this right apical non-small cell lung cancer is now visible.

CHEST OVERVIEW

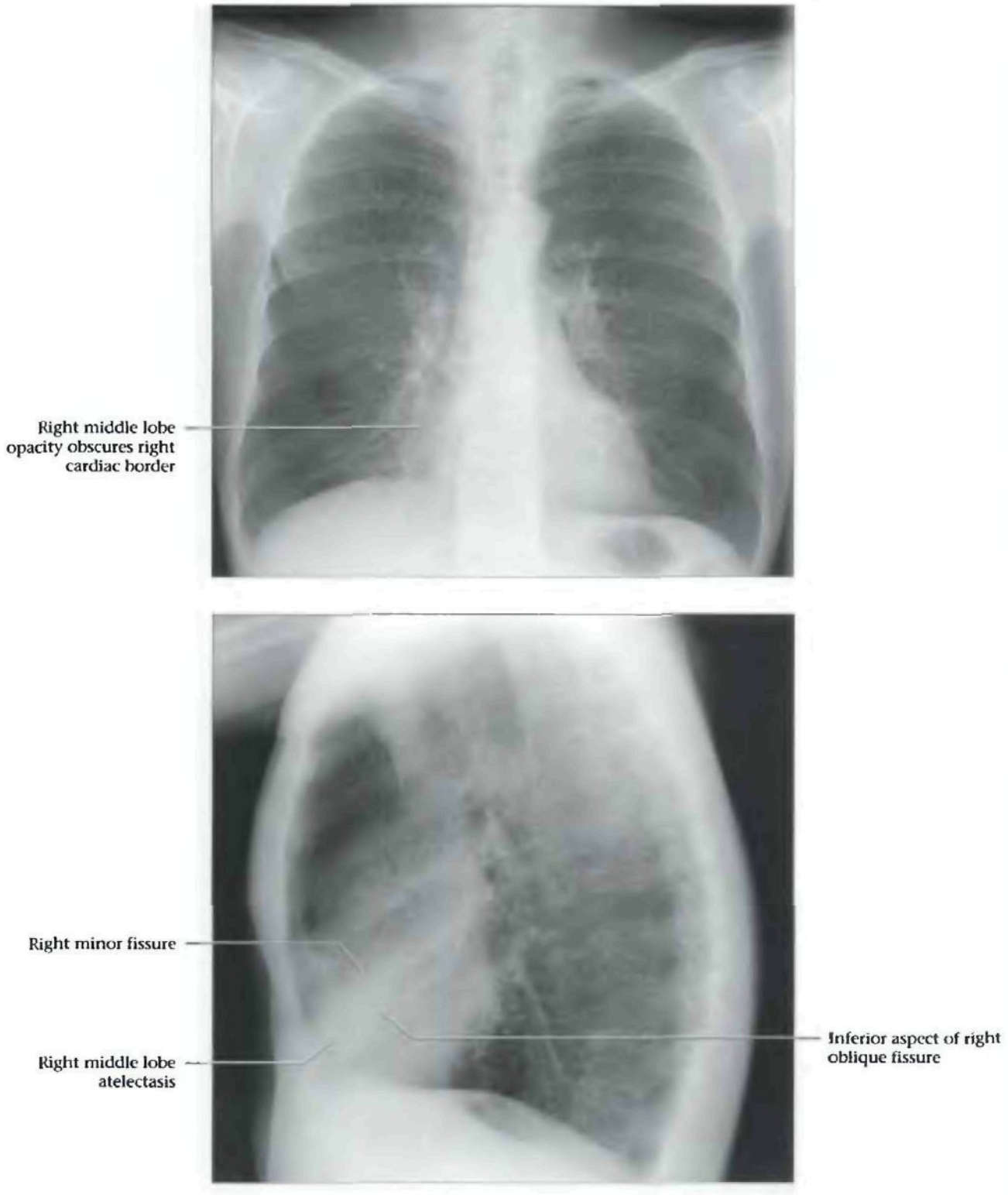
SILHOUETTE SIGN, LEFT LOWER LOBE AIRSPACE DISEASE





(Top) First of two chest radiographs of a patient with left lower lobe consolidation. PA chest radiograph shows a left basilar air space opacity that obscures the left hemidiaphragm. While the left hemidiaphragm is not visible, its location is inferred by the presence of adjacent abdominal air-filled loops of bowel. The alveolar air in the left lower lobe has been replaced by an inflammatory process producing the silhouette sign. **(Bottom)** Lateral chest radiograph shows that the consolidation abuts the oblique fissure anteriorly and is located in the anteromedial basal segment of the left lower lobe. The left lateral chest radiograph allows identification of the left (least magnified) ribs that are closest to the IR and the ipsilateral left hemidiaphragm.

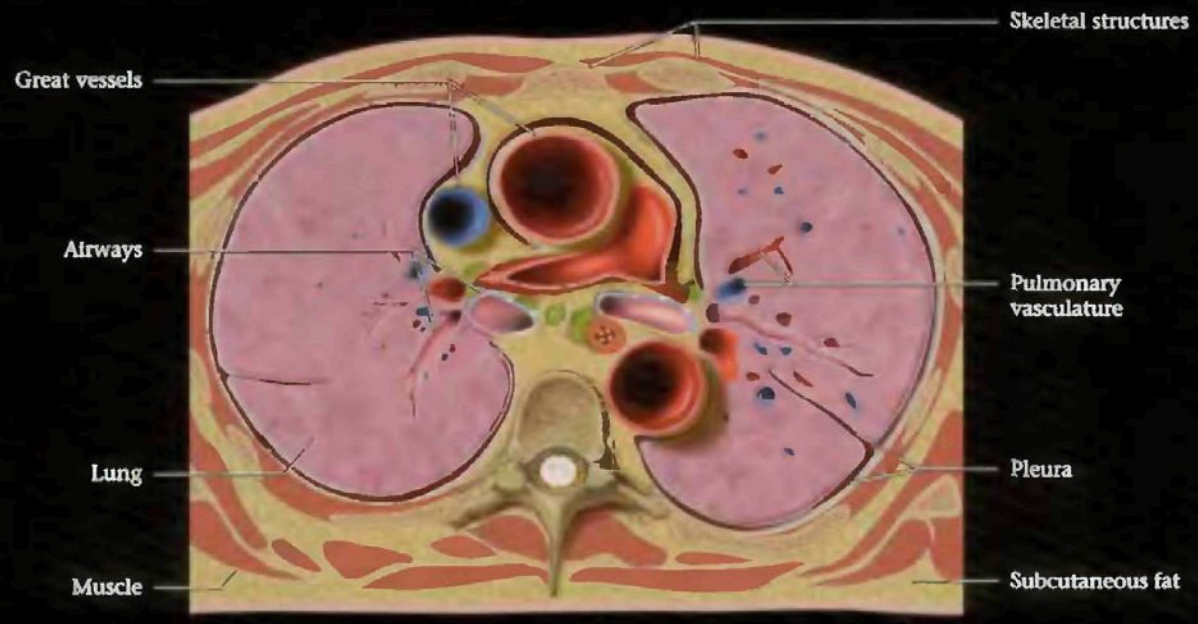
SILHOUETTE SIGN, RIGHT MIDDLE LOBE AIRSPACE DISEASE



(Top) First of two chest radiographs of a patient with right middle lobe atelectasis. PA chest radiograph shows air space opacity in the medial aspect of the right lower lung zone which obscures the right cardiac border. The location of the process can be inferred by the inability to visualize the right cardiac border while the right hemidiaphragm is visualized. Atelectasis has resulted in evacuation of the alveolar air from the right middle lobe producing the silhouette sign. **(Bottom)** Lateral chest radiograph shows a triangular opacity that projects over the heart and represents the atelectatic right middle lobe. Postero-inferior displacement of the minor fissure and antero-superior displacement of the inferior aspect of the right major fissure are typical of right middle lobe volume loss and distinguish atelectasis from consolidation.

CHEST OVERVIEW

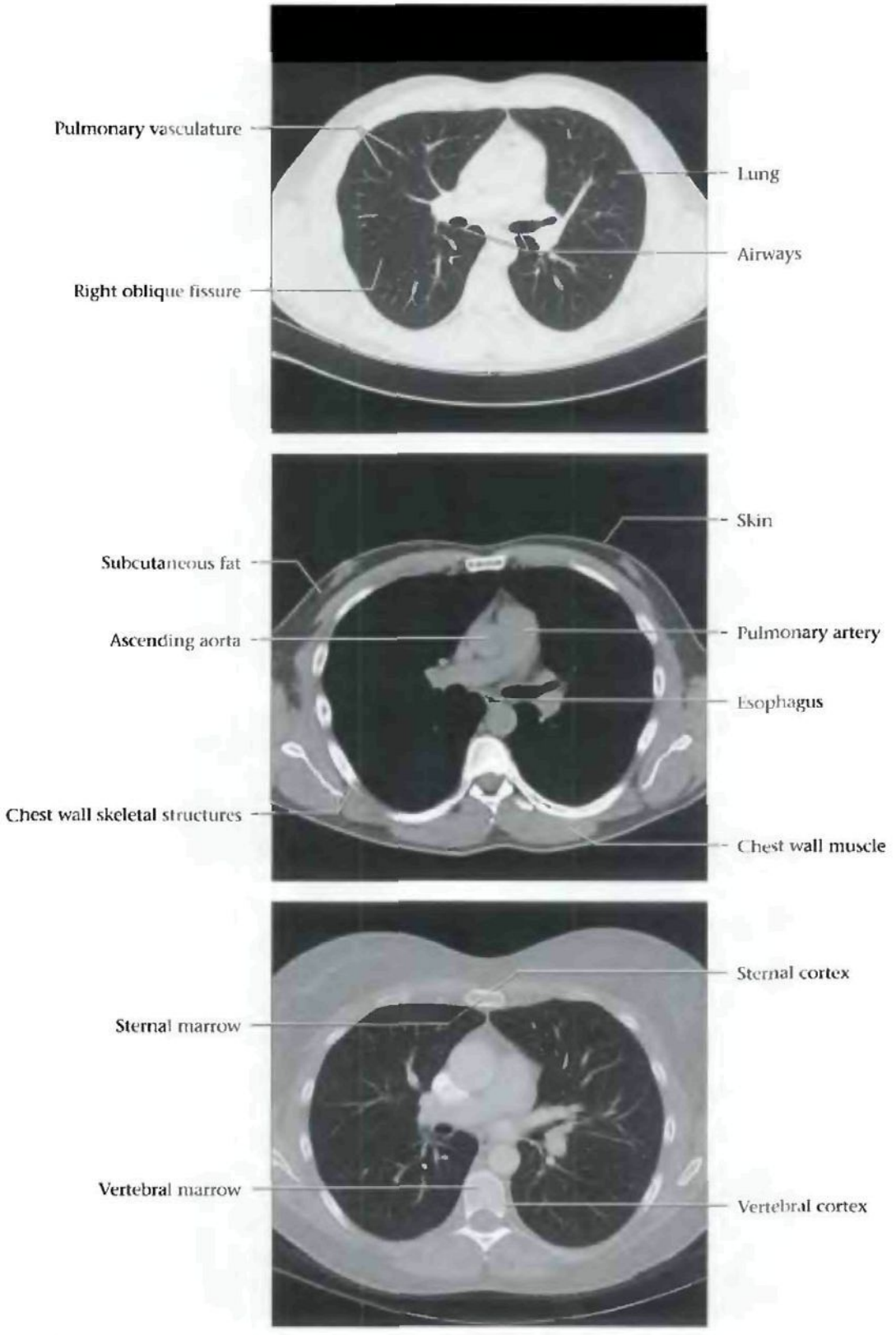
CROSS-SECTIONAL ANATOMY



Graphic shows the cross-sectional appearance of the mid thorax and illustrates visualization of numerous organs and tissues in cross-section. Cross-sectional imaging allows assessment of the various and diverse organs, structures and tissues of the chest. The soft tissues of the chest wall consist of skin, subcutaneous fat and chest wall muscles. Together with the skeletal structures, the soft tissues of the chest wall surround and protect the thoracic cavity and its internal organs and tissues. The apposed pleural surfaces form the pleural space. The pulmonary arteries and veins course through the lungs. The mediastinal fat, mediastinal vascular structures, esophagus, central tracheobronchial tree and lymph nodes are also depicted.

CHEST OVERVIEW

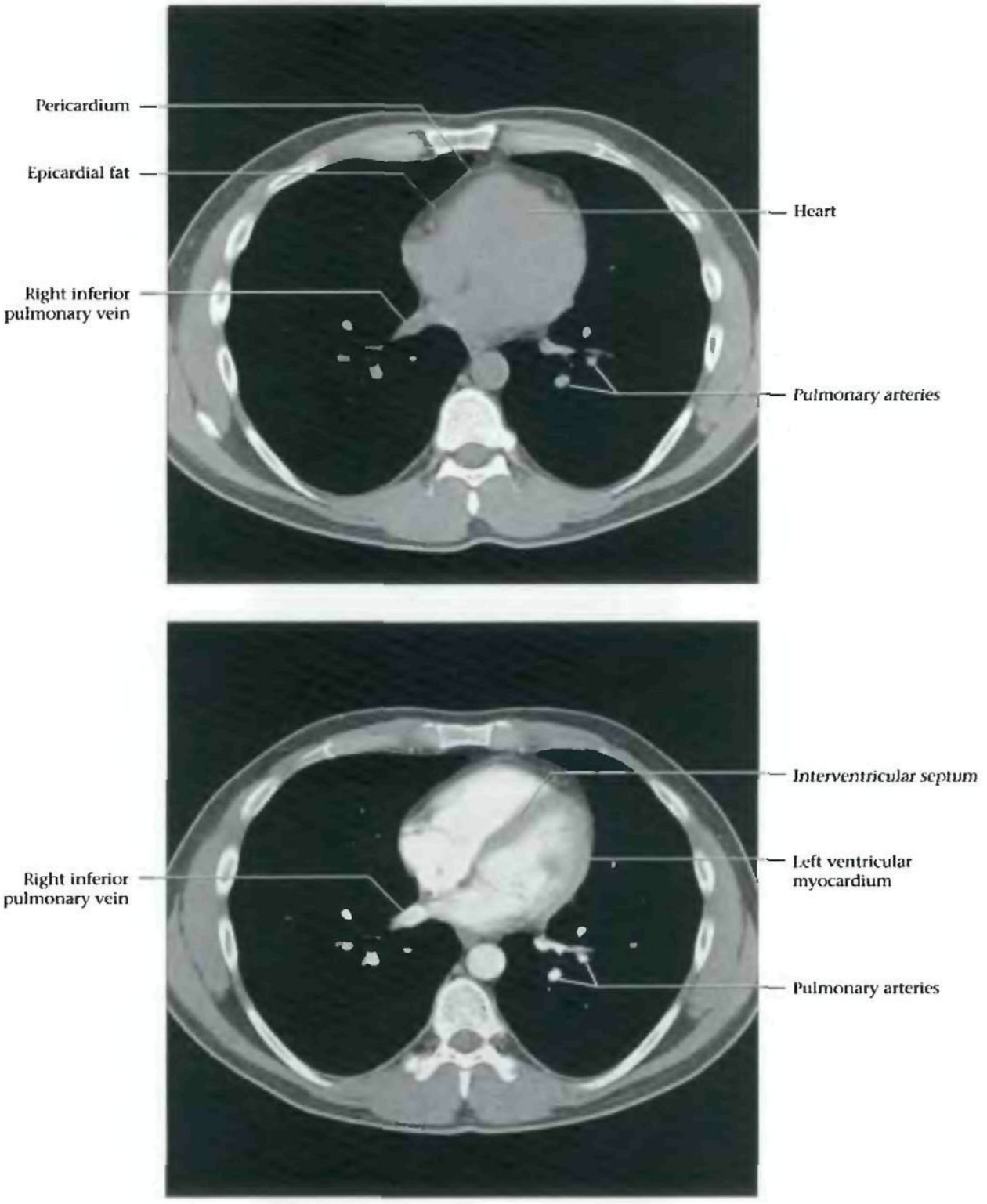
AXIAL CT, CROSS-SECTIONAL IMAGING



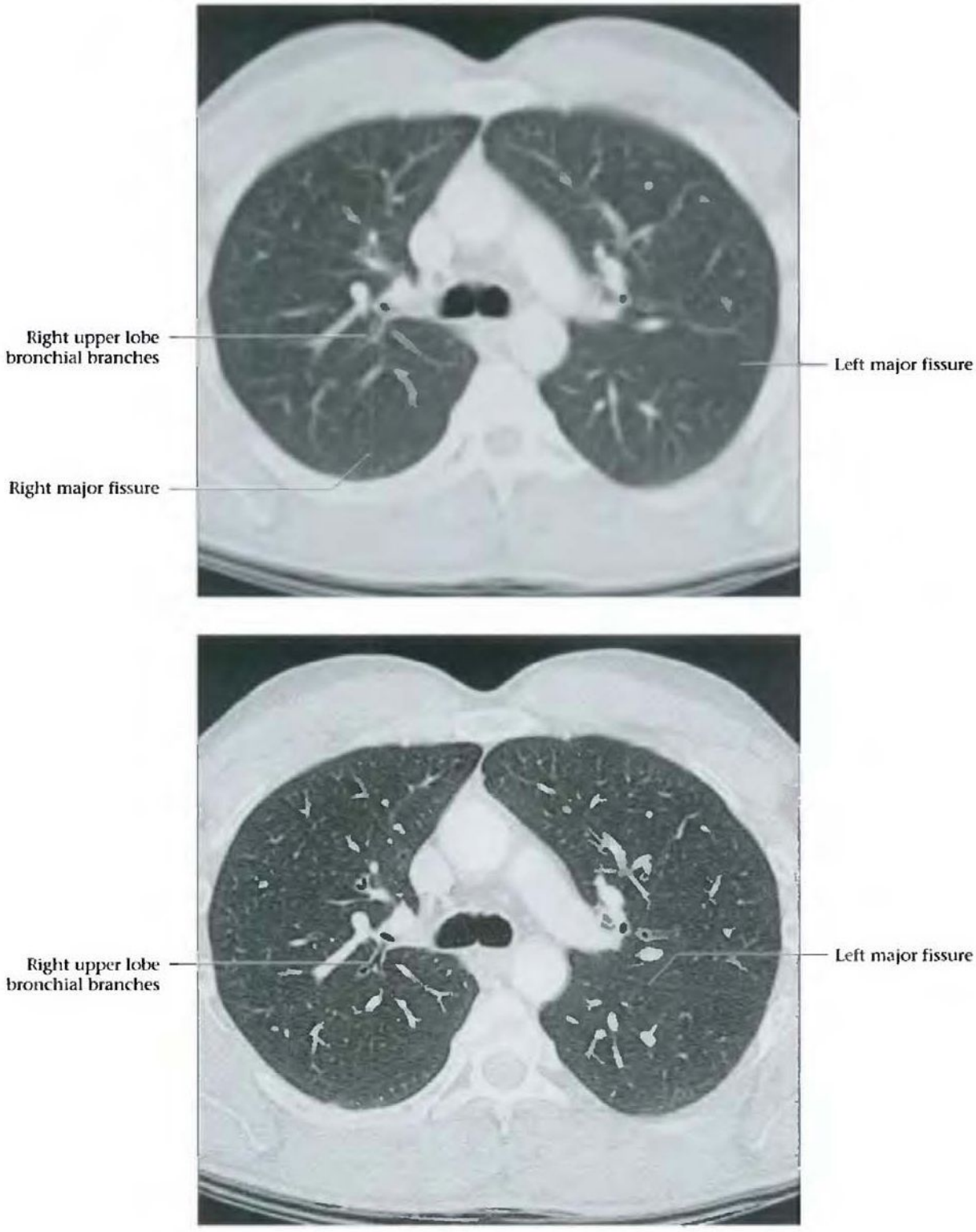
(Top) Normal contrast-enhanced chest CT (lung window) allows evaluation of the lungs, pulmonary vasculature, central tracheobronchial tree and pleural surfaces. The mediastinum and chest wall are poorly evaluated in this window setting. **(Middle)** Normal unenhanced chest CT (mediastinal window) allows evaluation of the soft tissue structures of the mediastinum and the soft tissues and skeletal structures of the chest wall. The pulmonary parenchyma, pleura and central tracheobronchial tree are not well evaluated. **(Bottom)** Normal contrast-enhanced chest CT (bone window) allows optimal assessment of the skeletal structures with visualization of their cortices and marrow spaces. Note improved skeletal visualization when compared to the mediastinal window image (previous image). This window setting is also useful for evaluation of calcifications and metallic medical devices.

CHEST OVERVIEW

UNENHANCED & CONTRAST-ENHANCED CT



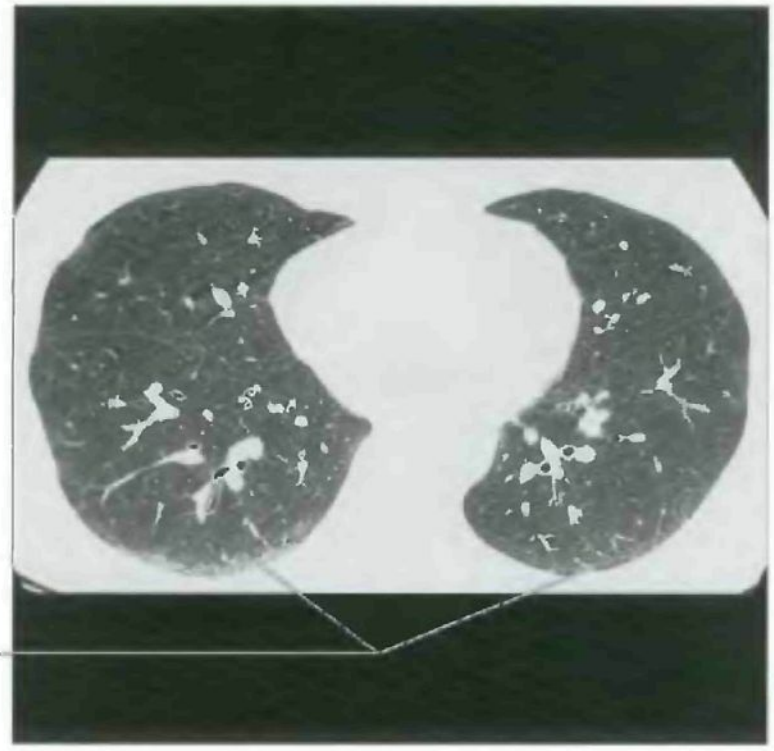
(Top) First of two normal chest CT images through the heart. Unenhanced chest CT (mediastinal window) shows the heart surrounded by epicardial fat and contained within the pericardium. The inferior pulmonary veins are visible bilaterally. Note that individual cardiac chambers cannot be resolved. **(Bottom)** Contrast-enhanced chest CT (mediastinal window) shows excellent visualization of the inferior pulmonary veins, pulmonary arteries and cardiac chambers. The interventricular septum and the left ventricular myocardium are well demonstrated.

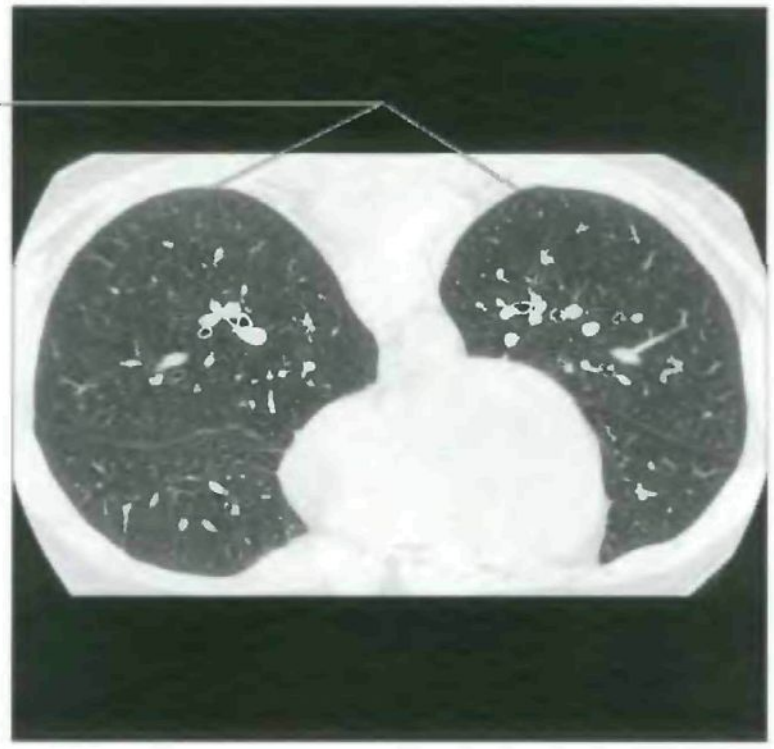


(Top) First of two images of a normal contrast-enhanced chest CT. Conventional chest CT (lung window) with 5 mm slice thickness shows adequate visualization of the lung parenchyma, pulmonary vasculature and tracheobronchial tree. The major fissures are visible as avascular bands coursing obliquely through the lungs. **(Bottom)** HRCT with 1.2 mm slice thickness at the same level as the previous image shows improved visualization of pulmonary detail. The left major fissure is now seen as a distinct line. There is improved visualization of the bronchial walls and sharper outlines of the pulmonary vessels.

CHEST OVERVIEW

SUPINE & PRONE HRCT

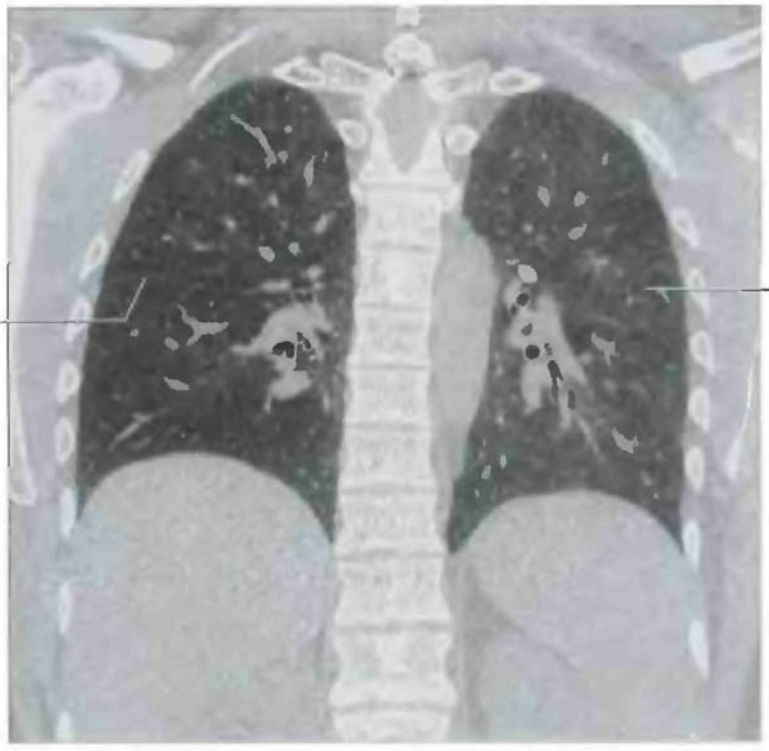




(Top) First of two images of a normal HRCT in a patient with mild dyspnea. Supine HRCT shows posterior subpleural ground-glass opacity that is more prominent on the right. There is no architectural distortion or other abnormality. **(Bottom)** Prone HRCT image shows complete clearance of basilar subpleural ground-glass opacities and confirms that they related to dependent or supine atelectasis.

Minor fissure

Normal lung attenuation



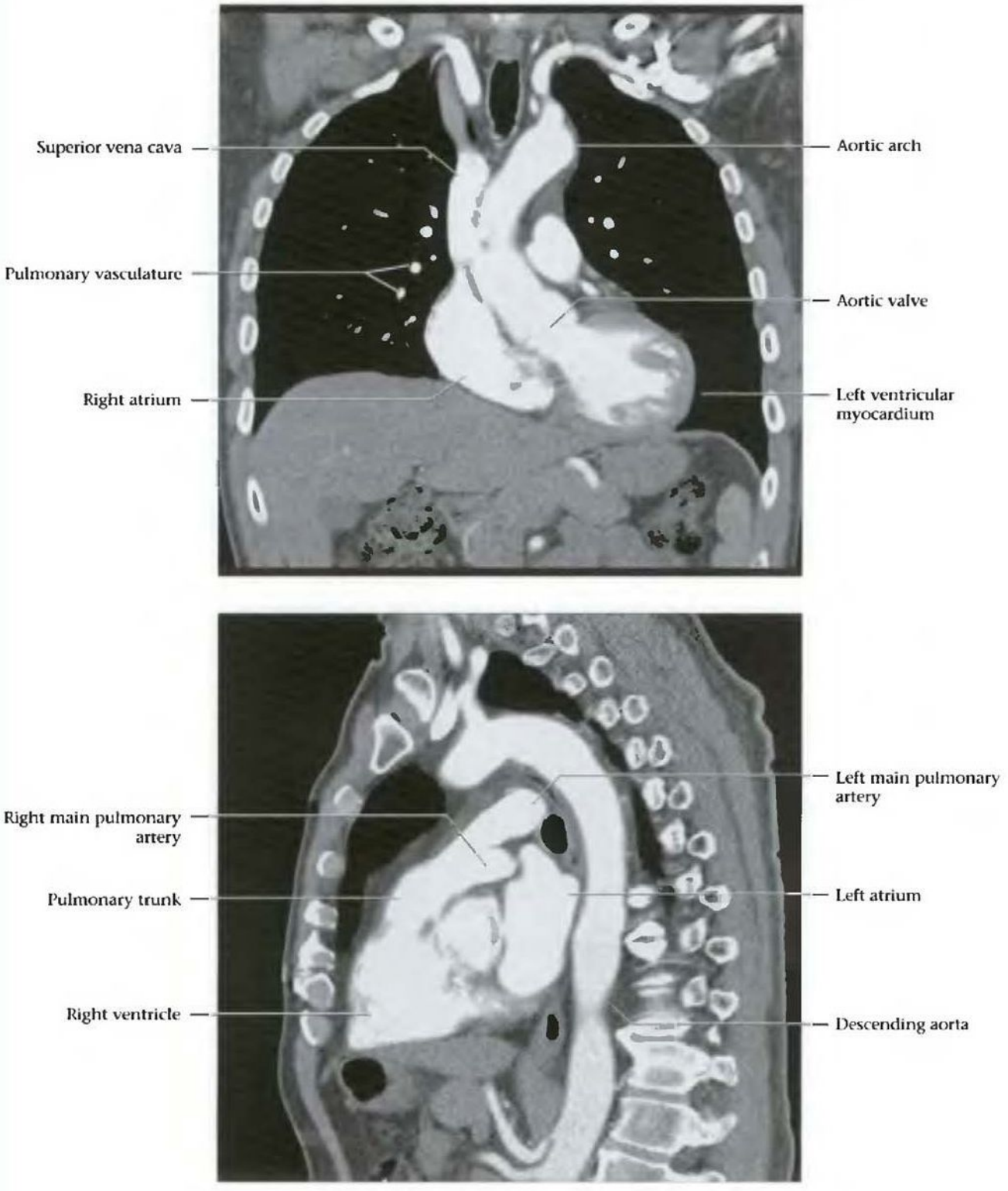
Minor fissure

Increased lung attenuation on expiratory imaging

(Top) First of two images from a normal HRCT. Inspiratory high-resolution CT (coronal reconstruction) shows normal homogeneous pulmonary attenuation. Note excellent visualization of vascular structures, central bronchi and pleural surfaces. **(Bottom)** Expiratory HRCT (coronal reconstruction) at the same level as the previous image shows elevation of the hemidiaphragms, decrease in lung volume and increased heterogeneous attenuation of the lung parenchyma. Although lung attenuation is heterogeneous, there is no evidence of air trapping. In this case, the right lung appears slightly more lucent than the left on expiratory imaging.

CHEST OVERVIEW

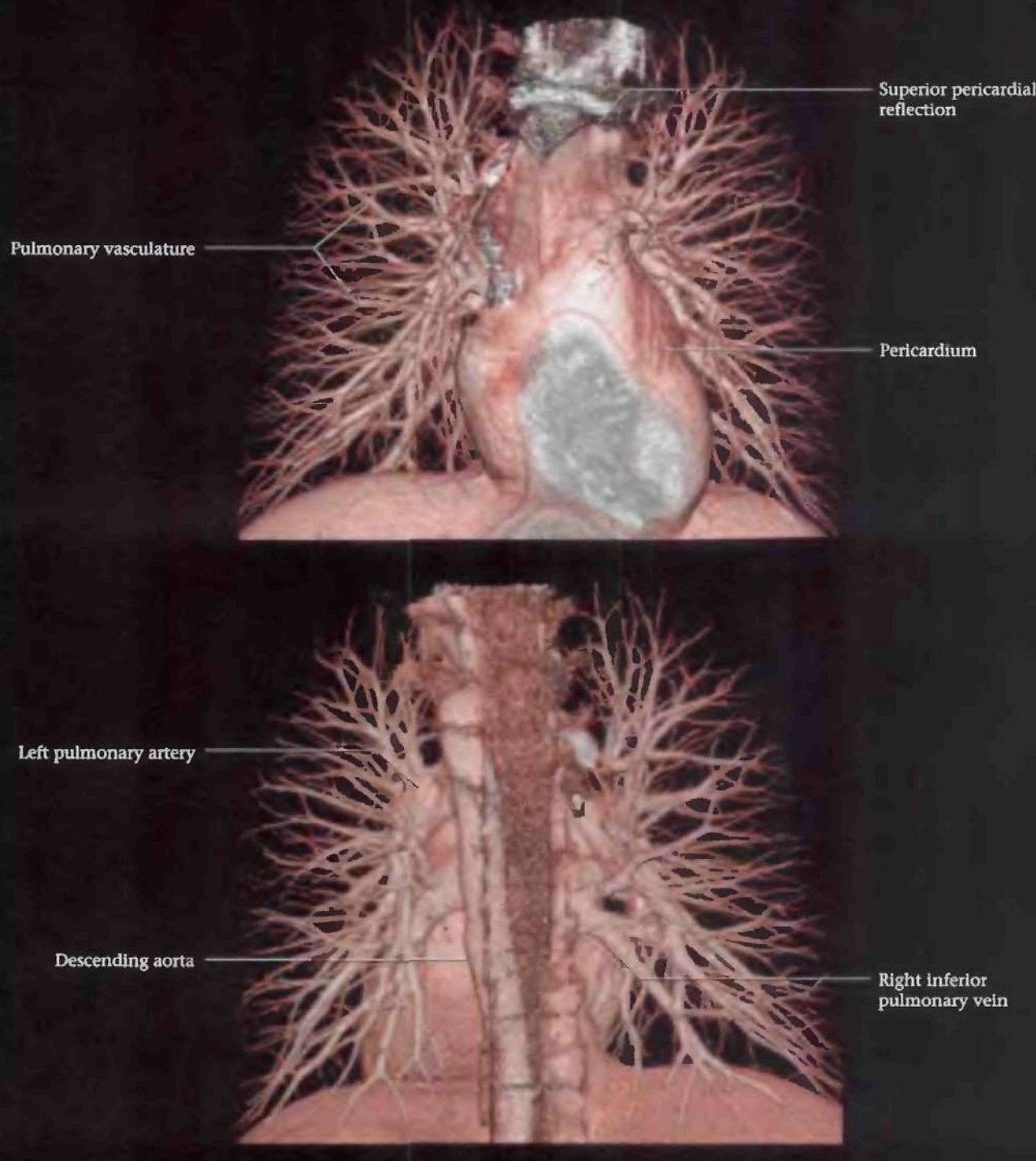
CT ANGIOGRAPHY, CORONAL & SAGITTAL RECONSTRUCTIONS



(Top) First of two images from a normal CT angiogram of the chest. Coronal CT angiogram (mediastinal window) allows visualization and evaluation of the cardiac chambers and the vascular lumens of the thoracic great vessels. CT angiography also allows assessment of the peripheral pulmonary vasculature for exclusion of pulmonary thromboembolic disease. **(Bottom)** Sagittal CT angiogram (mediastinal window) allows visualization of the descending thoracic aorta and its branches. Note visualization of the right ventricle, the right ventricular outflow tract, and the right and left main pulmonary arteries. Multiplanar reconstructions of CT angiograms allow exquisite visualization of the vascular lumens and cardiac chambers for evaluation of luminal enlargement, endoluminal thrombus or tumor, vascular disruption and congenital anomalies.

CHEST OVERVIEW

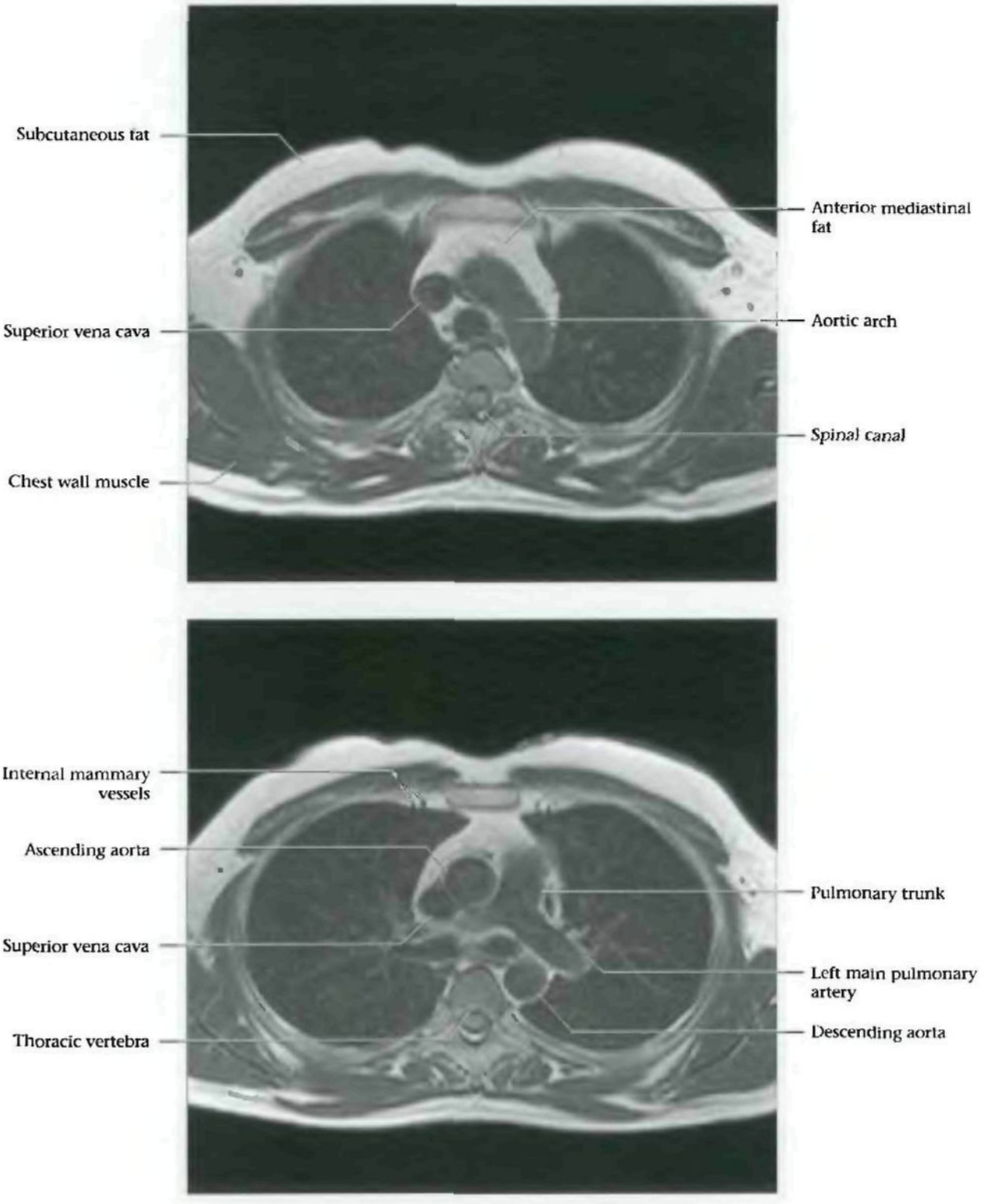
CT, VOLUME RENDERED TECHNIQUES



(Top) First of two volume rendered CT images of the chest. The coronal volume rendered CT image of the anterior chest shows the pulmonary vasculature and the superior extent of the pericardium. **(Bottom)** Posterior coronal volume rendered CT image display allows distinction of pulmonary veins from pulmonary arteries and shows portions of the descending thoracic aorta.

CHEST OVERVIEW

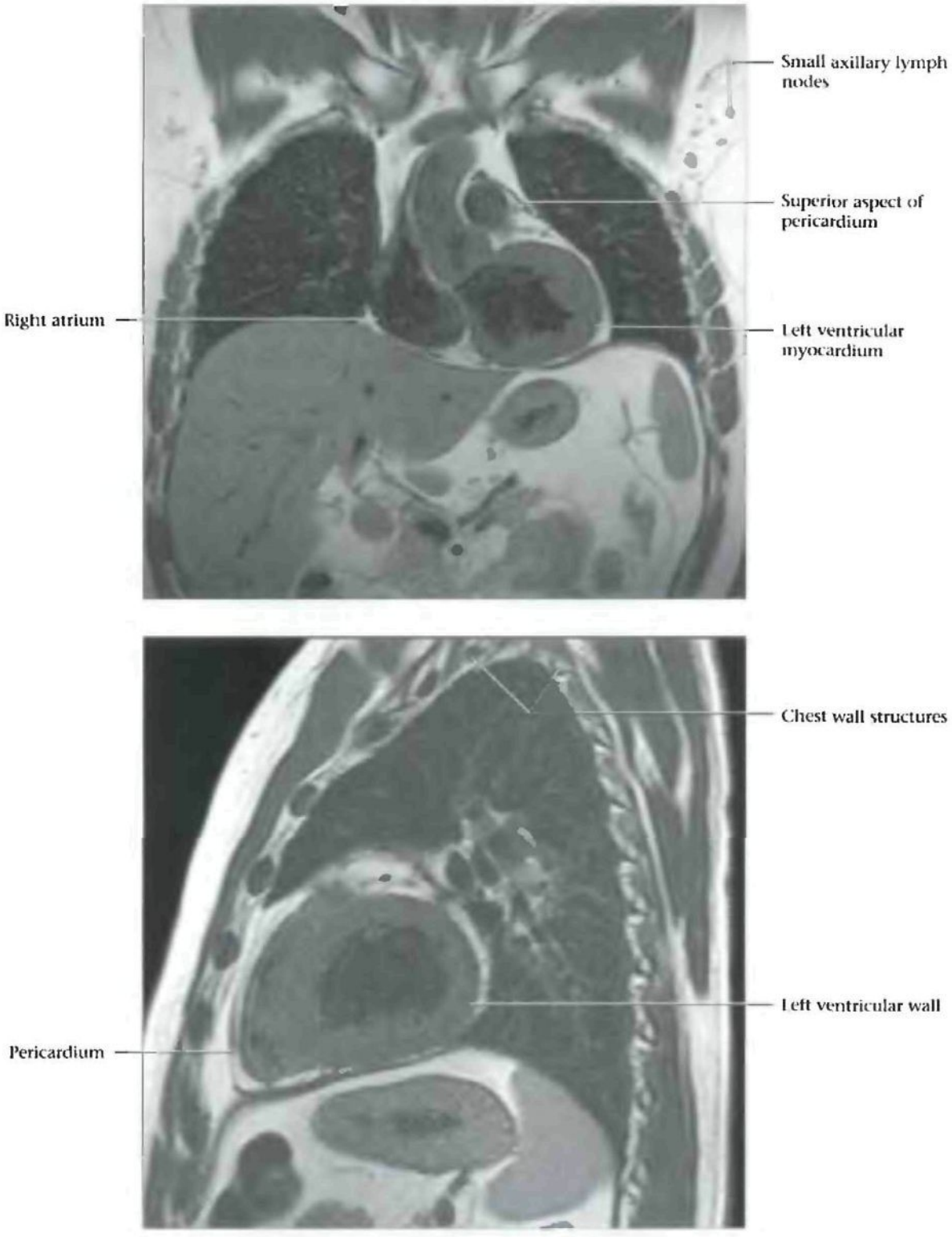
AXIAL MR, CROSS-SECTIONAL IMAGING



(Top) Axial cardiac gated MR through the aortic arch shows excellent contrast resolution that allows evaluation of *mediastinal and chest wall structures. Note the distinction of the mediastinal and subcutaneous fat from adjacent* soft tissue structures. Visualization of the lungs is less optimal and is mildly compromised by motion. **(Bottom)** Axial cardiac gated MR through the pulmonary trunk shows the value of MR in the evaluation of thoracic vascular structures without the use of iodinated contrast. The internal mammary vessels are also demonstrated.

CHEST OVERVIEW

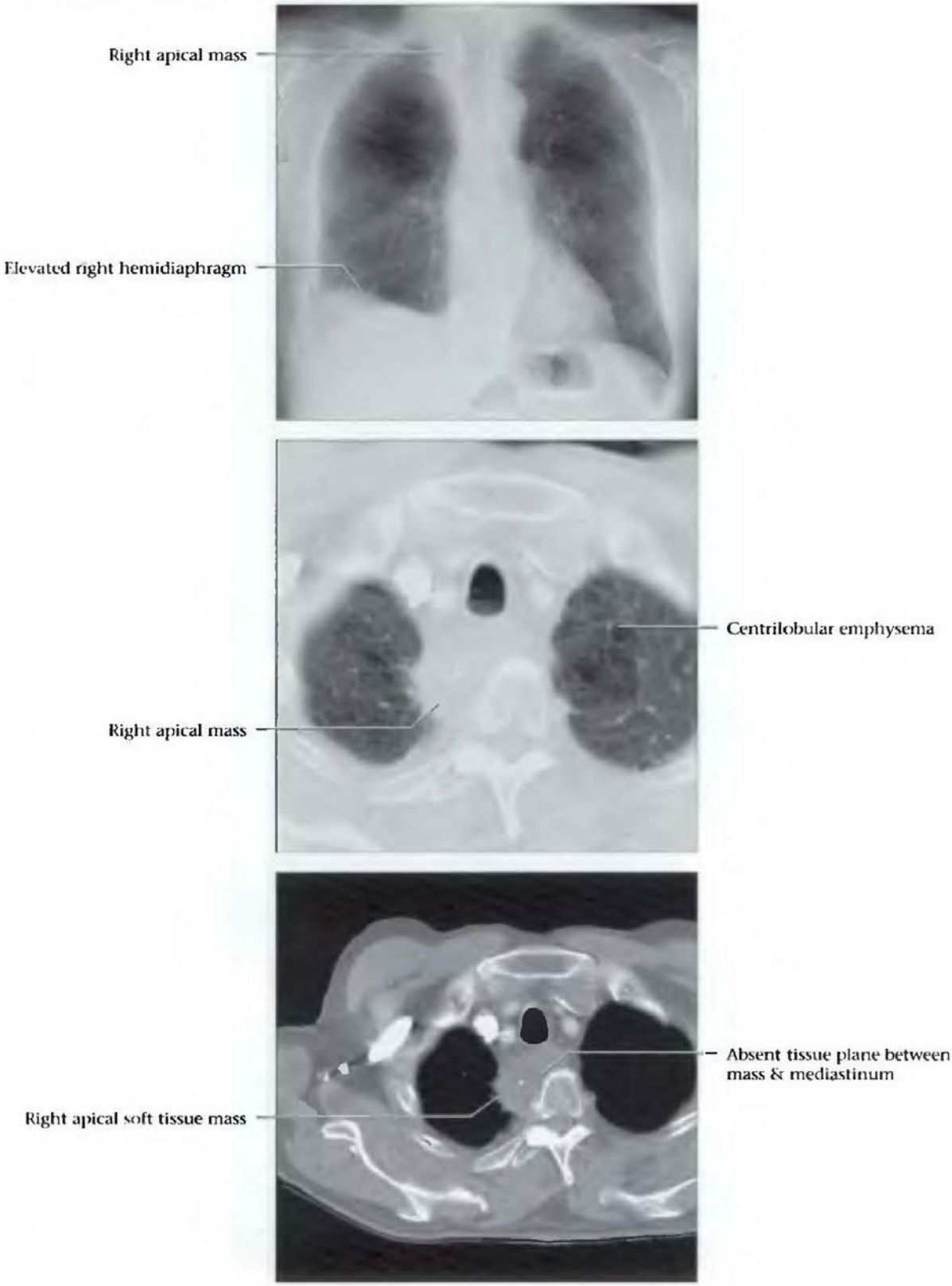
CORONAL & SAGITTAL MR, CROSS-SECTIONAL IMAGING



(Top) Coronal cardiac gated chest MR shows outstanding imaging of the mediastinum and diaphragm. Note the excellent visualization of the cardiac chambers and ventricular myocardium. The pericardium is particularly well visualized in this case. **(Bottom)** Sagittal cardiac gated chest MR shows exquisite visualization of soft tissue structures in the chest wall. MR is used as a problem solving modality for assessment of mediastinal and chest wall tumor invasion and is particularly useful for staging apical tumors.

CHEST OVERVIEW

CT EVALUATION OF APICAL LESIONS



(Top) First of three images of a patient with a right apical non-small cell lung cancer. PA chest radiograph shows the right apical mass and elevation of the ipsilateral right hemidiaphragm. While this lesion can be better visualized with apical lordotic radiography, CT is the method of choice for the evaluation of thoracic malignancies. **(Middle)** Chest CT (lung window) shows the right apical tumor and its spiculated lateral border. Note bilateral upper lobe centrilobular emphysema. **(Bottom)** Chest CT (mediastinal window) demonstrates the soft tissue mass with punctate internal calcification. There is no tissue plane between the mass and the adjacent mediastinum, a finding that suggests direct mediastinal involvement by the lesion. CT allows lesion localization and characterization and is used for pre-operative staging of patients with lung cancer.