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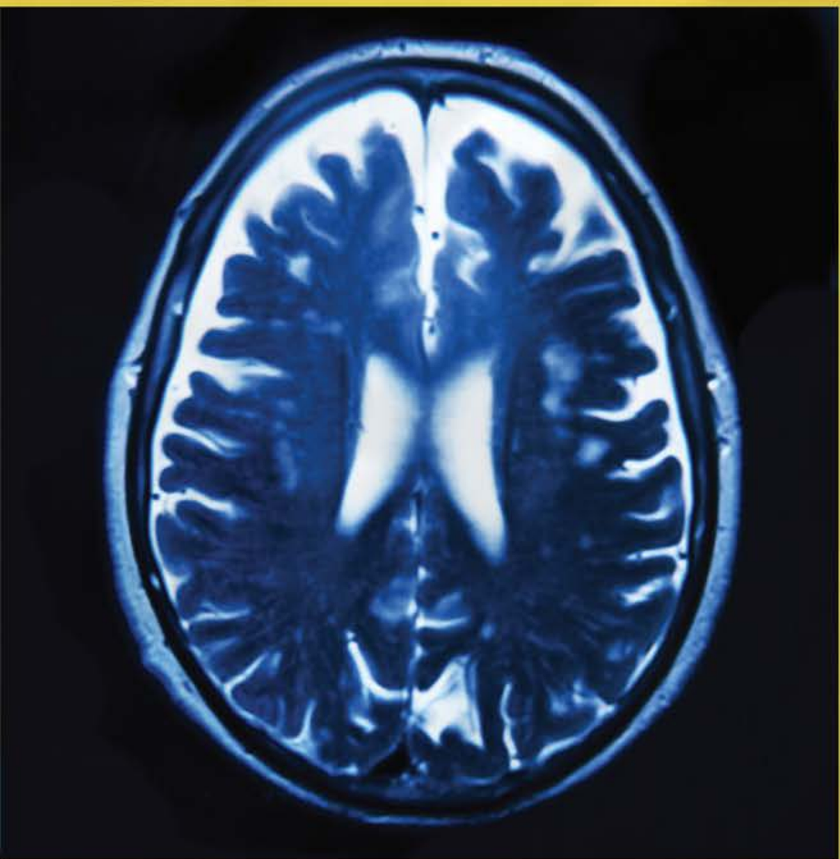
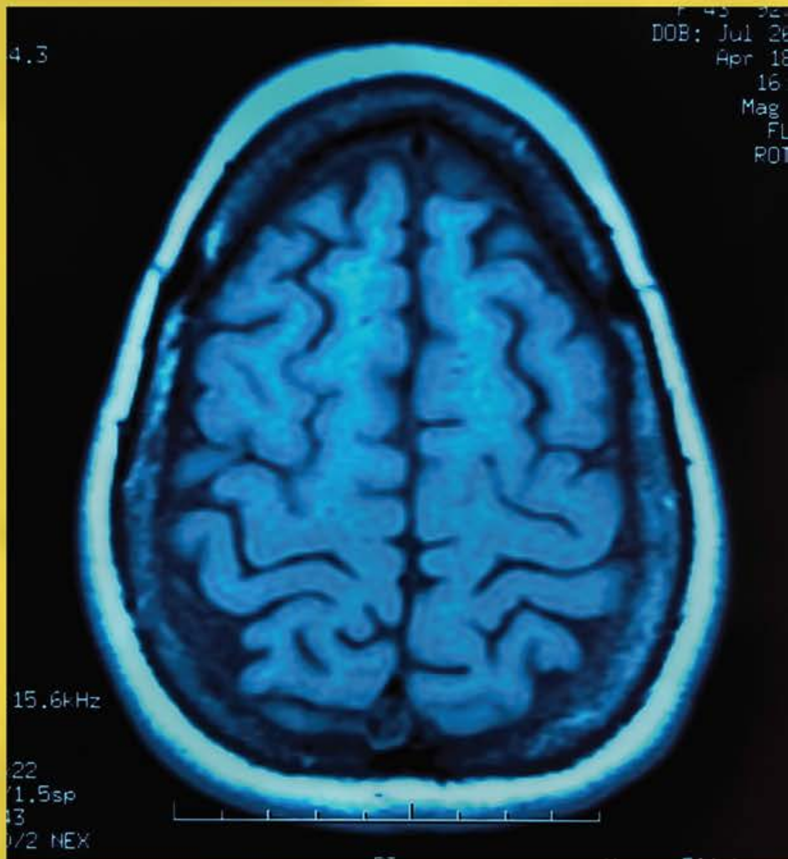
FUNDAMENTALS OF SECTIONAL ANATOMY

AN IMAGING APPROACH

SECOND EDITION





DENISE L. LAZO

FUNDAMENTALS OF SECTIONAL ANATOMY

AN IMAGING APPROACH

SECOND EDITION

DENISE L. LAZO, MA, RT (R) (M)

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This book is dedicated to my students,
past, present, and future.

∞

CONTENTS

5 THORAX 162

6 ABDOMEN 209

7 PELVIS 309

8 VERTEBRAL COLUMN 380

9 UPPER EXTREMITY 403

FIGURE CREDITS

CHAPTER 1

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CHAPTER 6

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PREFACE

The intent of this revised edition of *Fundamentals of Sectional Anatomy: An Imaging Approach* remains unchanged from the first edition—to facilitate the learning of anatomy, section by section, in virtually any plane. Students studying any imaging modality, whether it be radiography, computed tomography (CT), magnetic resonance imaging (MRI), sonography, nuclear medicine, cardiac interventional, vascular interventional, or radiation therapy, should optimally be proficient in their ability to identify organs from any perspective, as well as spatially rotate those organs mentally. They also should be able to visualize organs with respect to their approximate location within the body, size, and relationship to other organs.

PURPOSE

As an instructor in the radiography program at the Community College of Rhode Island (CCRI), one of my teaching assignments is a course called Sectional Imaging. Having struggled to find an ideal textbook, I ultimately crafted a proposal for a book that included those features that I felt provided a realistic approach and streamlined the process of learning sectional anatomy.

ORGANIZATION

I conceptualized a book that included a systematic and organized presentation of anatomy from head to pelvis, adding as the final chapters the vertebral column and upper and lower extremities. One of my self-imposed strict requirements was that each section of the body has associated with the chapter a minimum of two sets of CT and/or MR images, fully labeled and captioned with explanations. The choice of CT and/or MR images was based on the ability of those modalities to demonstrate the anatomy. At the end of each chapter, review questions were included. It is helpful if the student has previously studied anatomy and physiology, but the text is designed to teach sectional anatomy regardless of the student's educational background.

The book can be used in conjunction with lectures on the subject of sectional anatomy or as an independent study guide.

NEW TO THIS EDITION

While I remain committed to the essential core elements of the first edition, with personal consideration and input from reviewers, improvements have been added. In keeping with current imaging trends, over 200 MR images have been added to the chapters on the neck, abdomen, and pelvis. In addition, there are many new line art pieces. A study of the muscles found in the region of the thorax is new to this edition, and existing images have had labels of the muscles added. The introduction has substantive changes reflecting those in imaging. It has also been expanded to include information on the anatomical position, directional terms, body planes, body cavities, body habitus, and abdominopelvic quadrants and regions. Given this extensive revision, it now warrants being designated as Chapter 1 instead of being just an introduction as it was in the previous edition. A section of review questions has been added at the end. The material in Chapter 6, "Abdomen," has been rearranged to correspond more closely with the ordering of material in anatomy and physiology books. Also, images have been more prominently labeled with reference to the imaging plane. Learning objectives and a chapter summary have been added to each chapter to provide students with a useful study aid and highlight key ideas presented throughout the chapters.

STUDENT RESOURCES

Workbook to Accompany Fundamentals of Sectional Anatomy

ISBN-13: 978-1-133-96085-0

The student workbook has been revised to include MR image labeling exercises in Chapters 4, 6, and 7. All image labeling exercises have been modified to better challenge the students with the abbreviated word lists for each CT and MR exercise removed and replaced with word lists for each chapter found at the end of the workbook.

Additionally, a new item available to the students is an electronic labeling exercise offering them the opportunity to practice labeling a second set of images for most chapters.

The electronic labeling exercise is available through CourseMate (see the following description).

Instructor Companion Site to Accompany Fundamentals of Sectional Anatomy

ISBN-13: 978-1-285-83694-2

The Instructor Companion Site includes a PDF of the Instructor's Manual, test banks, an image library, Microsoft PowerPoint® slides that coordinate with chapters, and a correlation grid comparing the text to its two closest competitors on the market.

The instructor's manual is written by the author and includes practical tips on teaching this particular subject, as well as a sample syllabus and suggested lesson plans.

CourseMate Printed Access Card (PAC) for Fundamentals of Sectional Anatomy

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CourseMate Instant Access Code (IAC) for Fundamentals of Sectional Anatomy

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In gathering information for this revision, I consulted with CT and MR staff members throughout Rhode Island and nearby Massachusetts, including David Card, R.T. (R) (CT) (MR) (ARRT) , Scott Chapman, R.T. (R) (MR) (ARRT), Paul Cunningham, R.T. (R) (T) (MR) (ARRT), Peter Cyr, R.T. (R) (ARRT), Charles Deschamps, R.T. (R) (MR) (ARRT), John Doyle, Jr., R.T. (R) (CT) (ARRT), Joe Finan III, R.T. (R) (N) (MR) (ARRT), Cathleen Griffin, R.T. (R) (M) (CT) (ARRT), Jim Howard, R.T. (R) (CT) (ARRT), Patricia Kendall, R.T. (R) (MR) (ARRT), Karen Laurie, R.T. (R) (CT) (ARRT), Sarah Menard, R.T. (R) (CT) (ARRT), Gina Merola, R.T. (R) (M) (CT) (ARRT), Derek Palazini, R.T. (R) (CT) (ARRT), Mindy Schultz, R.T. (R) (CT) (ARRT), Kathy St. Pierre, R.T. (R) (CT) (ARRT), and David Wiggins, R.T. (R) (MR) (ARRT). This list represents a wealth of knowledge, experience, and expertise, and I am grateful to these people for sharing it with me.

A very special thanks to Richard Lavallee, R.T. (R) (CT) (MR) (ARRT).

I also wish to acknowledge the associate product manager assigned to me by Cengage Learning, Christina Gifford, and the senior content developer responsible for pulling this project together, Natalie Pashoukos.

Finally, many of the fine illustrations in this book can be credited to Joe Chovan. It was good fortune to have him assigned as illustrator for this project.

ABOUT THE AUTHOR BIOGRAPHY

Denise Lazo trained to be a radiographer at the Mary Fletcher Hospital, in Burlington, Vermont and then immediately earned her B.S. degree at Salem College, in Salem, West Virginia. A few years later, she got her M.A. at Rhode Island College. She has practiced as a radiographer and mammographer, holding positions at Jefferson Hospital, in Philadelphia, Pennsylvania; Rhode Island Hospital, in Providence, Rhode Island; and St. Joseph's Hospital, also in Rhode Island. She has been a full-time faculty member of the Allied Health department at the Community College of Rhode Island since 1996 and presently is an associate professor in the radiography program, also serving as clinical coordinator. The program has 11 clinical affiliates. Lazo is a member of the American Society of Radiologic Technologists (ASRT) and has reviewed several books for the society's journal. Within the college community, she serves as vice president of the Community College of Rhode Island's Faculty Association.

CHAPTER 1 INTRODUCTION

OUTLINE

I. Anatomic Position
II. Directional Terms
III. Body Planes
IV. Body Cavities
V. Body Habitus
  A. Asthenic
  B. Hyposthenic
  C. Sthenic
  D. Hypersthenic
VI. Abdominopelvic Quadrants
VII. Abdominopelvic Regions
VIII. Shifting World of Medical Imaging
IX. Computed Tomography
  A. Principles
  B. Protocols
  C. Image Appearance
  D. Contrast Media
  E. Dosage Reduction
X. Magnetic Resonance Imaging
  A. Advantages
  B. Principles
  C. Magnet Strength
  D. T1/T2 Weighting
  E. Length of Exam
  F. Protocols for Pregnant Women
  G. Safety Issues
  H. Contrast Media
  I. Study Trends
XI. Summary
XII. Review Questions

OBJECTIVES

1. To acquire knowledge of the basic terms necessary to study sectional anatomy related to the anatomic position, directional terms, body planes, cavities, habitus, and abdominopelvic regional divisions.
2. To acquire a basic simple understanding of image production with a computed tomographic (CT) scanner.
3. To acquire a basic understanding of tissue representation on a CT image.
4. To identify the types of contrast media employed in CT imaging.
5. To acquire a basic simple understanding of the principles of magnetic resonance imaging (MRI).
6. To acquire a basic simple understanding of the effect of an alteration in T1 or T2 weighting on the appearance of an MR image.
7. To become familiar with MRI safety issues.
8. To identify the types of contrast media employed in MR imaging.

ANATOMIC POSITION

To begin your study of sectional anatomy, a basic understanding of key terms is necessary. Shown on Figure 1-1 is a drawing of a figure in the **anatomic position**. Note the placement of the palms, facing forward.

DIRECTIONAL TERMS

All directional terms are made referencing the body in the anatomic position. In the following list are commonly used directional terms, many of which are shown on Figure 1-1:

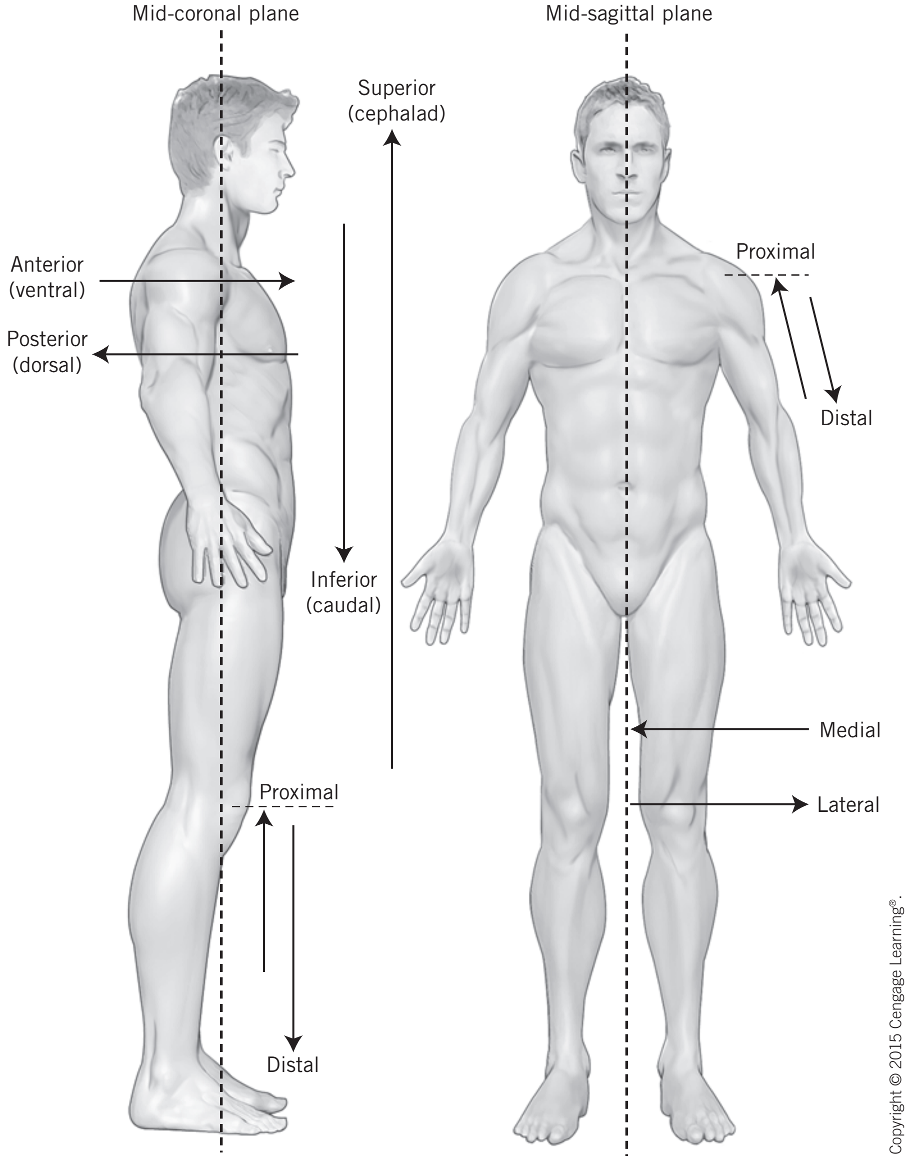

Figure 1-1 Anatomic position, directional terms

- **Anterior (ventral)—**The front of the body or body part
- **Posterior (dorsal)—**The back of the body or body part
- **Medial—**Toward the midline of the body
- **Lateral—**Away from the midline of the body
- **Cephalad (superior)—**Toward the head
- **Caudal (inferior)—**Toward the tail end of the spine
- **Proximal—**Closer to the point of attachment
- **Distal—**Farther from the point of attachment
- **Internal—**Nearer the inside or core of the body or an organ
- **External—**Nearer the outside of the body or an organ
- **Supine—**Lying on the back, face upward
- **Prone—**Lying on the abdomen, face downward

BODY PLANES

A **plane** is an imaginary flat surface passing through the body. In the following list are the types of planes, many of which are shown on Figure 1-2:

- **Midsagittal or median—**A plane running vertically or longitudinally from front to back through the midline of the body, dividing the body equally into right and left parts

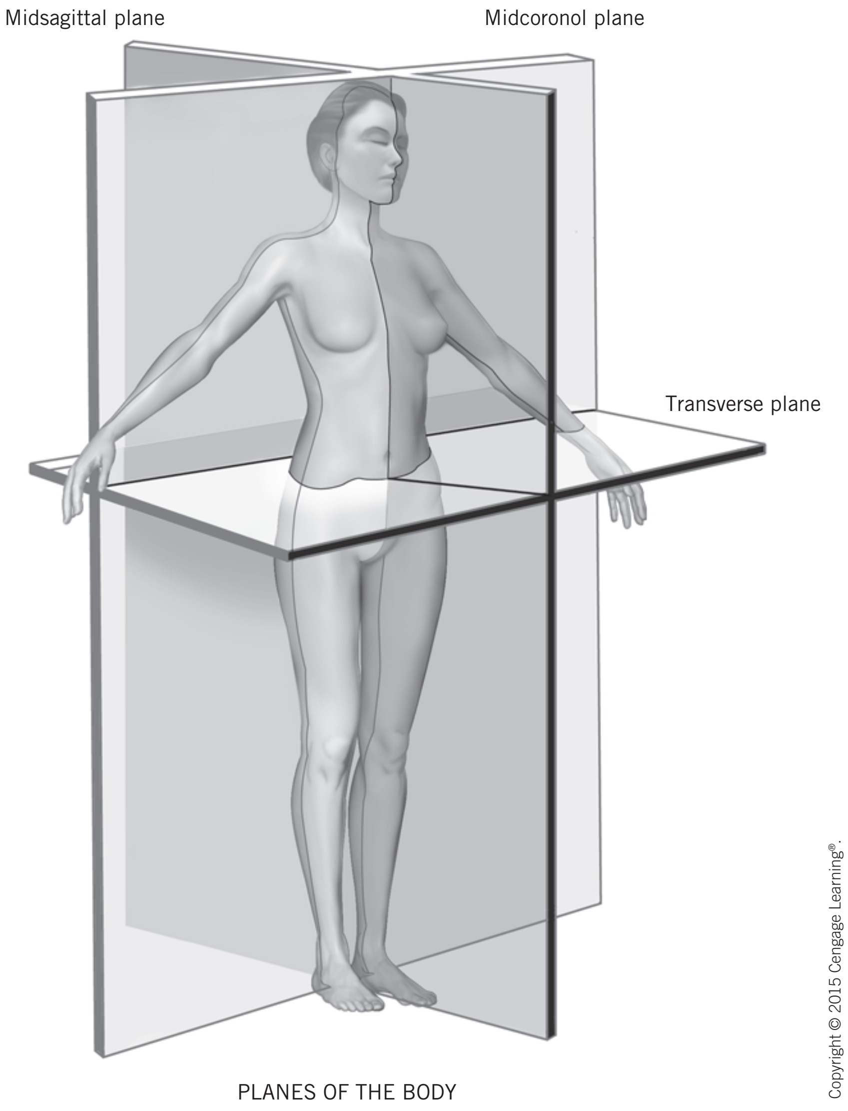

Figure 1-2 Body planes

- **Sagittal—**Commonly used to refer to a plane running vertically or longitudinally from front to back parallel to the midsagittal or median plane, dividing the body into right and left parts
- **Midcoronal or midaxillary—**A plane running vertically or longitudinally from right to left, dividing the body into equal anterior and posterior parts
- **Coronal or frontal—**A plane running vertically or longitudinally from right to left parallel to the midcoronal or midaxillary plane, dividing the body into anterior and posterior parts
- **Horizontal, transverse or axial—**A plane running crosswise through the body at right angles to the sagittal and coronal planes, dividing the body into superior and inferior parts
- **Oblique—**A plane running at an angle, not parallel to the sagittal, coronal, or horizontal plane

BODY CAVITIES

The body contains several cavities, as shown on Figure 1-3. The **thoracic** and **abdominopelvic cavities** are located anteriorly, and the **cranial** and **spinal cavities** are found posteriorly. The abdominopelvic

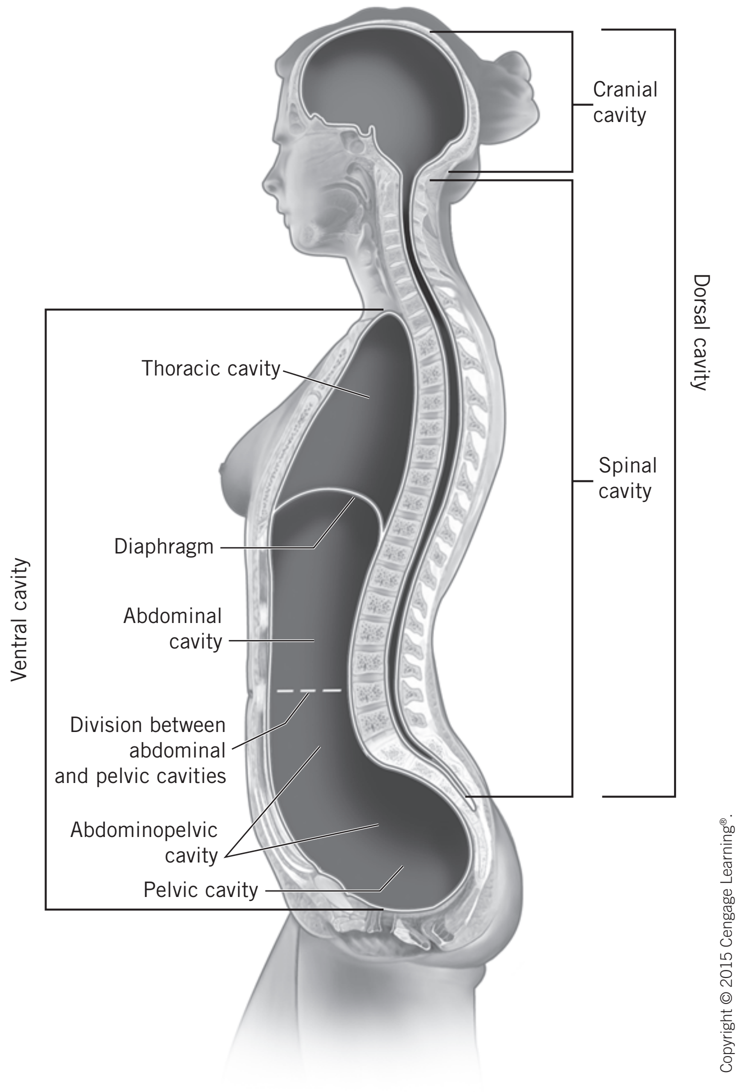

Figure 1-3 Body cavities

cavity can be subdivided into the **abdominal** and **pelvic** cavities. While there is a physical structure, the diaphragm, that separates the thoracic cavity from the abdominopelvic or abdominal cavity, no such structure separates the abdominal cavity from the pelvic cavity. Chapter 6 discusses the method used to describe the boundary. See Chapters 5, 6, and 7 for a listing of those organs found in the thoracic, abdominal, and pelvic cavities, respectively.

A distinct point, the foramen magnum, defines the point of demarcation separating the cranial and spinal cavities. See Chapter 2 and Chapter 8 for a listing of those organs found in the cranial and spinal cavities, respectively.

BODY HABITUS

The shape of the trunk of the body varies from one individual to another, not necessarily related to height, weight, or physical condition. A method of categorizing the various shapes has been devised, allowing the location of organs within the thoracic, abdominal, and pelvic cavities to be predicted with some degree of accuracy. This information is very relevant to the study of sectional anatomy. The four categories are **asthenic**, **hyposthenic**, **sthenic**, and **hypersthenic**, with the majority of the population best being described as hyposthenic and sthenic. Below is a brief description of each category with respect to build and organ locations.

Asthenic

Accounting for 10% of the population, asthenic individuals generally have a slight build, with a long, narrow, shallow thorax, which is wider more superiorly. The organs found within the thoracic cavity, including the heart and lungs, are also long and narrow; the diaphragm is very low; and the ribs tend to be almost vertical. The apices of the lungs extend well above the clavicles. Conversely, the abdomen tends to be short, and narrower more superiorly. Because of the length of the thoracic cavity, the stomach, gallbladder, and colon are low and lie closer to the midline.

Hyposthenic

Accounting for 35% of the population, hyposthenic people have a build somewhere between asthenic and sthenic.

Sthenic

Accounting for 50% of the population, sthenic people are considered to be average with respect to height, weight, and torso length, with a moderately short, broad, and deep thorax. The heart sits more transversely than in the asthenic or hyposthenic type, and the diaphragm is higher. Within the moderately long abdominal cavity, the stomach is found high on the left, the gallbladder is centered on the right in the upper abdomen, and the colon is spread out, with the left splenic flexure found high. The transverse colon dips minimally. Compared to the thoracic and abdominal cavities, the pelvic cavity is relatively small.

Hypersthenic

Accounting for 5% of the population, hypersthenic individuals have a massive truncated build, with a short, broad, deep thorax. The vertically shallow but wide heart sits almost transversely, the lungs are very short, broader inferiorly, and the diaphragm is very high. The ribs run almost transversely. The apices do not extend much above the clavicle. The abdomen is very long, narrow inferiorly, with the stomach also sitting very high and almost horizontally in the upper abdomen. Likewise, the gallbladder is very high, closer to the lateral abdominal wall. The colon is found along the peripheral borders of the abdomen, with the transverse colon higher as compared to the other categories described. The pelvis is narrow.

ABDOMINOPELVIC QUADRANTS

The abdominopelvic cavity can virtually be divided into four quarters or **quadrants**, as shown on Figure 1-4. A clinician, drawing on familiarity with organ location and a patient's description of pain location, can begin to speculate as to which organ is involved.

ABDOMINOPELVIC REGIONS

A more precise system exists with the abdominopelvic cavity divided into nine regions, thus allowing the anatomist to be more specific in describing organ location. Figure 1-5 is a drawing identifying the nine **regions**: the right and left **hypochondriac**, **epigastric**, **right** and **left lumbar**, **umbilical**, and **right** and **left inguinal**, or **iliac**, and **hypogastric**, or **pubic**. The naming of the

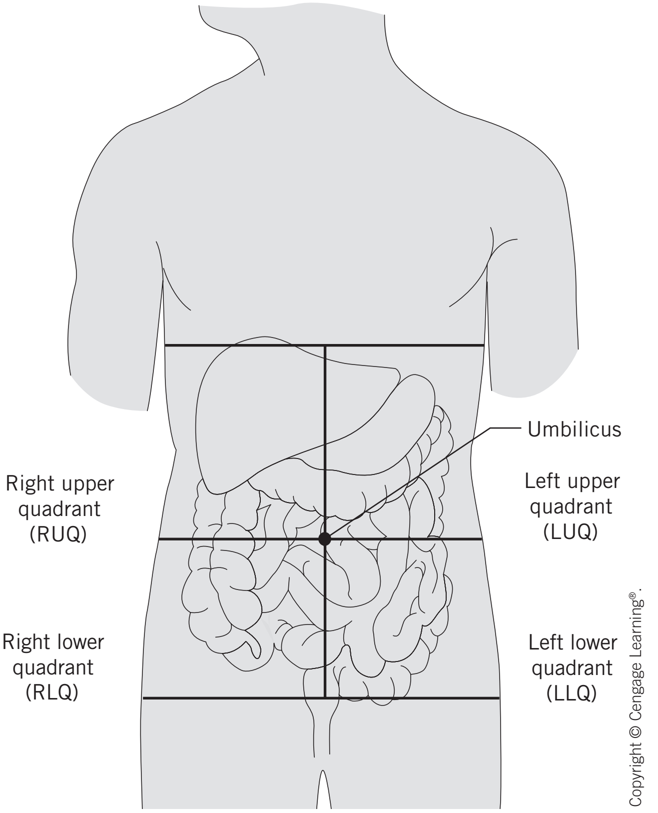

Figure 1-4 Abdominopelvic quadrants

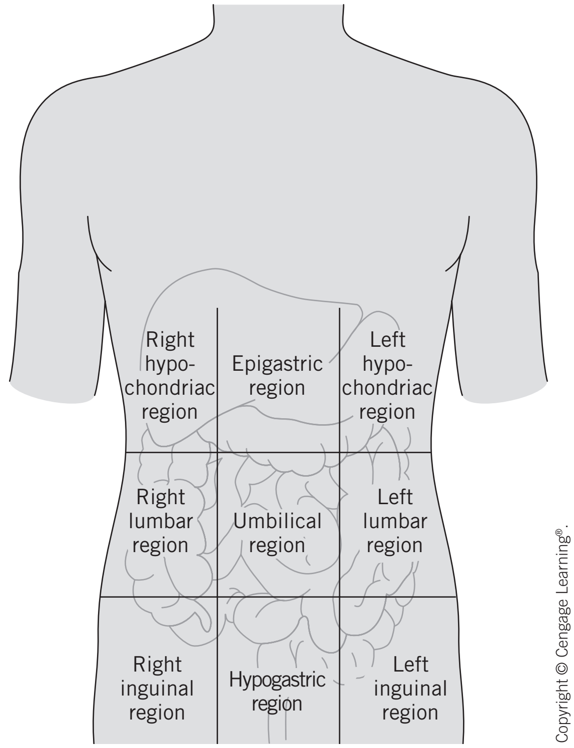

Figure 1-5 Abdominopelvic regions

regions draws on medical terminology and organ locations.

SHIFTING WORLD OF MEDICAL IMAGING

Since Wilhelm Roentgen produced his first radiograph on November 8, 1895, the field of radiology has grown by leaps and bounds. New methods of imaging emerge constantly. It is a natural question for the untrained to ask, "Which modality is best?" The answer is that no one modality is best, for each serves a particular function. In many instances, studies previously done in the conventional imaging department have shifted to other modalities, offering the benefit of more diagnostic information and/or reduced exposure to ionizing radiation. An example is the replacement of cholecystograms (the study of gallbladders with conventional imaging) with ultrasonography of the gallbladder, or, in some instances, a nuclear medicine study. Conventional radiographs of the skull have become almost extinct today, as most concerns can be addressed with computed tomography (CT). Arthrograms have transitioned from the radiography department to the magnetic resonance imaging (MRI) department. Colonoscopies have supplanted barium enemas, and CT or MRI enterography have replaced small bowel studies. There are those who would argue that more functional information is obtained from MRI enterography compared to CT enterography, especially with respect to motility; and there is the added benefit of not being exposed to ionizing radiation, but one suggested disadvantage of MRI enterography is the possibility of missing smaller lesions. Few intravenous pyelograms are currently scheduled, while the number of CT renal studies has dramatically increased. Computed tomographic angiography (CTA) studies are now commonly performed, as are run-offs.

Although MRI is the preferred modality to demonstrate the competency of the circle of Willis, if the patient cannot have an MRI, a CT scan is ordered. Many procedures normally done in the cardiovascular interventional departments are now, at least initially, being replaced with CT exams. The benefits of this approach are reduced radiation dosage, shorter length of exam, reduced amounts of contrast media, greater cost-effectiveness, and reduced patient risk. An innovative interventional procedure being performed by interventional radiologists in CT is radiofrequency ablation (RFA) of tumors, a procedure utilized for inoperable liver, lung, and renal tumors. A similar procedure is cryablation. The majority of pulmonary embolism (PE) studies have shifted from nuclear medicine to CT, adversely affecting available staffing hours in the nuclear medicine departments. Those still having nuclear medicine studies for PE are those with a history of iodinated contrast reactions and those with elevated creatinine levels. Generally, skeletal CT exams are a follow-up to an already diagnosed fracture, with the exception of a question of cervical spine, facial bone, and/or cranial fractures. On occasion, non-ambulatory hips and pelves are ordered if a conventional image does not demonstrate a fracture. Vertebroplasty, most often lumbar, is another procedure now scheduled in the CT department as are myelograms and discograms.

CT cardiac imaging is generally limited to specialized imaging centers, with a 64-slice scanner being the preferred minimum requirement. CT, rather than MR, is the preferred imaging modality for cardiac imaging, with its main advantage being reduced imaging time. A deterrent to this study being routinely performed at more imaging centers is the requirement that cardiac studies be read by both a radiologist and cardiologist.

Several other factors determine what procedures are performed at an institution, including the comfort level of the radiologists and the hospitals' consideration of cost-effectiveness. Reimbursements also drive the industry's decision making. Some insurance companies now require preapproval of CT and MR exams unless the patient is an emergency room (ER) patient. For this and other reasons, the percentage of ER patients having CT exams is now estimated to be as high as 40–60%, with most of those exams being heads, C spines, and abdomens/pelves, in that order. The advantage of a CT cervical spine is the ability to perform the exam with the neck collar in place; thus, a CT scan of the cervical spine has now replaced the conventionally imaged shoot-through of the cervical spine in many, if not most, institutions.

Entry-level students of all imaging and treatment modalities need to have a thorough grounding in sectional anatomy. Knowledge of gross anatomy is no longer sufficient. The intended and sole purpose of this book is to teach sectional anatomy as demonstrated on routine sectional images. The most accurate sectional representations of the body are on CT and MR images. With CT, it is possible to see virtually all body structures on a series of images starting at the vertex of the skull and ending at the symphysis pubis. MRI can provide a similar opportunity, although it is less commonly employed in the thoracic region. For joints of the upper and lower extremities, the modality of choice is determined by the tissue of interest. The sectional anatomy student who has previously studied anatomy will have an advantage.

Both CT and MRI have distinct advantages. CT is better than MRI at imaging compact bone (see the section entitled "Magnetic Resonance Imaging" later in this chapter for an explanation), although with a microfracture, MRI would have the advantage of better demonstrating edema, an indicator of this type of fracture. CT is the preferred modality for patients with head trauma as skull fractures and brain injuries are demonstrated. Although metal may cause imaging artifacts on CT images, it is not dangerous. Conversely, a ferromagnetic object within, on, or near the patient can pose serious, even potentially fatal, problems during an MRI procedure. Thus, a patient on life-support or monitoring equipment could feasibly have a CT, but if any of the equipment has magnetic properties, it would not be allowed in the MRI scanning room. As a rule, the scanning time for CT is considerably less than MRI, especially with multislice volumetric scanners, so CT is the preferred modality for combative or uncooperative patients. CT offers better tolerance for patient motion. Additionally, CT is less costly than MRI. Unless the medical facility is fortunate enough to possess one of the portable CT scanners new to the market, a patient who is non-transportable will be unable to have either a CT or MR study.

COMPUTED TOMOGRAPHY

Principles

The CT procedure involves placing a patient on a couch that slides through a circular gantry. Within the gantry is an X-ray tube that rotates around the patient. Opposite the X-ray tube are detectors that record the amount of unattenuated radiation (radiation not absorbed by the patient), and convert that information into a signal. The detectors replace the film or sensors used as image receptors in conventional imaging. The signal given by the detectors is converted from an analog format to a digital format and sent to a computer, where the data is used to construct an image.

With the newest volumetric multislice helical scanners, there is one continuous movement of the X-ray tube around the gantry as the couch moves through the gantry. Multiple rows of detectors measure the unattenuated radiation. The number of slices obtained with each revolution is directly related to the number of rows of detectors, as is the imaging and reformatting time. The entire section is imaged with one activation of the X-ray tube. Unfortunately, 360 degrees of information are not obtained for each slice, but the data can be used to obtain slices at different levels, utilizing the same parameters without reexposing the patient. Exam time is reduced to seconds, and there is improved spatial resolution.

Protocols

Medical sites have their own specific examination protocols for each exam, determining the thickness and number of slices to be obtained, although the protocol can be adjusted manually. Most CT images are initially acquired transaxially, with the cuts generally being perpendicular to the long axis of the body. An exception is head CT imaging, where the gantry is angled approximately 15 degrees from the long axis of the body to minimize the interface artifacts in the posterior inferior portion of the cranium caused by the intense contrast differences between the dense bone and soft tissue of the brain. (See Figure 1-6.) Another advantage of the tubal angulation is a reduction in radiation dosage to the eyes. While the X-ray beam is generally perpendicular to the part being imaged in conventional radiography, with CT, it is parallel. Occasionally, some images are acquired in the coronal plane. Sagittal image acquisitions are rare, as they are difficult to obtain. The computer can reformat the data to produce images in other planes that are no longer of inferior quality, so long as the cuts are reformatted in thinner cuts than the acquired thickness.

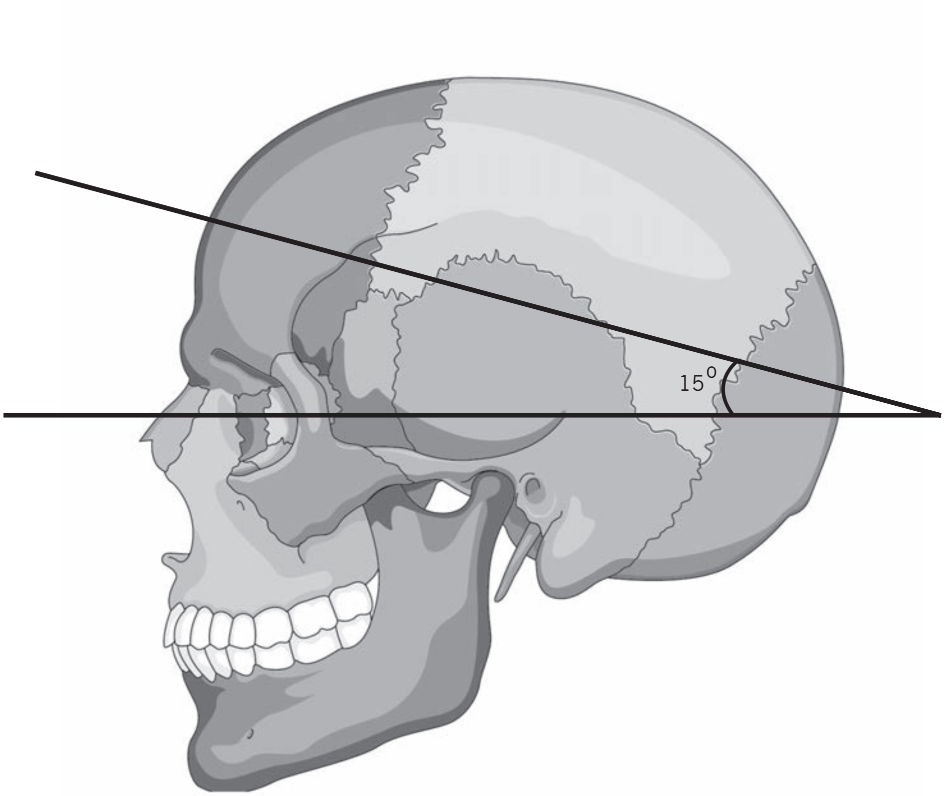

Figure 1-6 Typical CT head imaging plane

Brains and chests are typically imaged in one plane: transaxial. Abdomens/pelves are produced in axial and coronal planes, and vascular and orthopedic exams are demonstrated in three planes. Rarely are abdomens or pelves studied independent of each other, although for the purposes of teaching sectional anatomy, this book has separated them into two chapters. Coronal pulmonary emboli (PE) images will pick up PEs that might be missed on axial cuts because they are too small.

Image Appearance

Looking at CT images of the brain is similar to looking at conventional X-ray images, with bone appearing white (high attenuation), air appearing black (low attenuation), and fat and other medium-density structures appearing in some shade of gray. By varying the window level and window width, the density and contrast can be varied to better visualize certain structures. However, bone still appears white and air still is very dark. Figure 1-7 A and B show two images produced by a CT computer using the same data and at the same level in the thorax, but 1-7 A would more clearly demonstrate lung pathology, while 1-7 B permits examination of the structures in the mediastinum.

Contrast Media

At least 50% of the time, a contrast medium is administered, that percentage depending upon the types of studies most commonly performed at a site. The contrast medium may be a water-soluble, iodinated medium administered intravenously (IV). The blood-brain barrier, a mechanism discussed in Chapter 2, should prevent the medium from penetrating the brain tissue. As with all contrast medium injections, the patient is prescreened for contraindications such as a previous history of contrast medium reactions. Most sites use only nonionic contrast medium in CT to minimize the risk of reactions. Often, if a patient has an existing tumor, "ring enhancement" of the tumor is evident, resulting from the contrast medium

CT images provided by Our Lady of Fatima Hospital, North Providence, Rhode Island.

Figure 1-7 A and B (A) CT image of the thorax selecting window width and level to demonstrate lungs *(continues)*