RADIOGRAPHIC PATHOLOGY FOR TECHNOLOGISTS

Sixth Edition

NINA KOWALCZYK

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3251 Riverport Lane
Maryland Heights, MO 63043

RADIOGRAPHIC PATHOLOGY FOR TECHNOLOGISTS 978-0323-08902-9

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The Publisher

Library of Congress Control Number 2007932477
Kowalczyk, Nina, author.
Radiographic pathology for technologists / Nina Kowalczyk. – Sixth edition.
p. ; cm.
Includes bibliographical references and index.
ISBN 978-0-323-08902-9 (pbk. : alk. paper)
I. Title.
[DNLM: 1. Radiography–methods. 2. Pathology–methods. WN 200]
RC78
616.07–dc23

2013021567

Executive Content Strategist: Sonya Seigafuse
Content Development Specialist: Amy Whittier
Publishing Services Manager: Catherine Jackson
Production Editor: Sara Alsup
Design Direction: Paula Catalano

Printed in China

Last digit it the print number: 9 8 7 6 5 4 3 2 1

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PREFACE

The sixth edition of *Radiographic Pathology for Technologists* has been thoroughly updated and revised to offer students and medical imaging professionals information on the pathologic appearance of common diseases in a variety of diagnostic imaging modalities. It also presents basic information on the pathologic process, signs and symptoms, diagnosis, and prognosis of the various diseases.

The sixth edition includes the latest information concerning recent advances in genetic mapping, biomarkers, and up-to-date imaging modalities used in daily practice. The authors have attempted to present this material in a succinct, but reasonably complete, fashion to meet the needs of professionals in various imaging specialties. With each new edition, the authors have also expanded the scope of the material covered in the text to provide the reader with a broader base of knowledge.

NEW TO THIS EDITION

- The chapter order and arrangement have been changed to accommodate the general revision of existing material.
- Over 50 new illustrations have been added to complement new, updated, or expanded material.
- Human genetic technology information has been expanded, and altered cell biology has been added to Chapter 1.
- Genetic marker and information regarding biomarkers have been added throughout the text.
- The most recent American College of Radiology Appropriateness Criteria has been incorporated throughout the text.
- Several new terms have been added to the glossary, and other definitions have been expanded or updated.

LEARNING ENHANCEMENTS

- Each chapter begins with an outline, followed by key terms and learning objectives.
- Chapter content is followed by a summary table, general discussion questions, and multiple-choice review questions, all of which can be used by the reader to assess acquired knowledge or by the instructor to stimulate discussion.
- Bold print has been used to focus the reader's attention on the key terms in each chapter, which are defined in the glossary at the end of the book along with other relevant terms.

USING THE BOOK

The presentation of the sixth edition presumes that the reader has some background in human anatomy and physiology, imaging procedures, and medical and imaging terminology. The reader may build on this knowledge by assimilating information presented in this text.

To facilitate a working knowledge of the principles of radiologic pathology, study materials presented in the sixth edition remain sophisticated enough to be true to the complexity of the subject, yet simple and concise enough to permit comprehension by all readers. For student radiographers, sonographers, radiation therapists, and nuclear medicine technologists, this text is best used in conjunction with formal instruction from a qualified instructor. The practicing imaging professional may use this book as a self-teaching instrument to broaden and reinforce existing knowledge of the subject matter and also as a means to acquaint himself or herself with changing concepts and new material. The book can serve as a resource for continuing education because it provides an extensive range of information.

ANCILLARIES

Evolve Resources

Evolve is an interactive learning environment designed to work in coordination with *Radiographic Pathology for Technologists*. Included on the Evolve website are a test bank in Exam View containing approximately 400 questions, an electronic images collection consisting of images from the textbook, and a PowerPoint presentation. Instructors may use Evolve to provide an Internet-based course component that reinforces and expands the concepts presented in class. Evolve may be used to publish the class syllabus, outlines, and lecture notes; set up "virtual office hours" and e-mail communication; share important dates and information through the online class calendar; and encourage student participation through chat rooms and discussion boards. Evolve also allows instructors to post examinations and manage their grade books online. For more information, visit http://evolve.elsevier.com/Kowalczyk/pathology/ or contact an Elsevier sales representative.

ACKNOWLEDGMENTS

Over twenty years ago, two young and fairly naïve radiography educators collaborated to undertake the task of developing a pathology textbook for radiography students. At that time, only one small textbook was commercially available and little did we know that the text-book we conceived and created would result in five subsequent editions spanning almost 25 years! As I began to revise this sixth edition, I was amazed at the changes that have occurred over the past 20 years relative to understanding pathologic processes. Great strides have been made in genetic mapping and the identification of biomarkers that allow the advent of personalized medicine. Although this is a complex area of study, basic information has been added to the sixth edition of this text because it is crucial for all radiation science professionals to have an understanding of the impact of genomics in current medical practice.

In 1986, working together, JD Mace and Nina Kowalczyk combined their course materials, added information by researching outside pathology sources, and began the task of contacting publishers with the concept of creating a comprehensive textbook to meet this need. Although both authors worked on developing the content for review, JD Mace assumed the lead role in contacting and communicating with various publishers to bring the work to fruition. JD's initiative and dedication to this project led to the first edition of *Radiographic Pathology for Technologists*, which was published in 1988. JD Mace played a major role in the development of the concept for this textbook, its format, and all administrative tasks associated with this project. JD also continued to be a major contributor to the following three editions of *Radiographic Pathology for Technologists*. However, shortly after the first edition was published, his professional career path led him away from education to radiology and healthcare administration. JD remained committed to the role of lead author for subsequent editions, but over the years his professional focus led him further away from clinical practice and education. Although his role was limited in the fifth edition, the textbook would never have been created if not for the lead role he assumed in the late 1980s. JD Mace is a true professional and has given much to the field of radiologic technology. I am sorry that he is no longer a co-author in this current edition, but thankful he is a true friend for life. His foresight and contributions are greatly missed.

I certainly could not have completed the sixth edition of this text without a great team of people who wanted it to be successful and to accomplish its primary mission. I would like to thank my son, Nick, for his support; my students, past and present, for their inspiration; and my colleagues for their encouragement. I also want to thank the editorial team at Elsevier who worked diligently to keep me on track throughout the revision process.

The images in this book come from a variety of fine organizations that are to be thanked for graciously allowing us to use their material. They include the American College of Radiology, as well as The Ohio State University Wexner Medical Center, Riverside Methodist Hospitals, and Nationwide Children's Hospital—all located in Columbus, Ohio.

Nina Kowalczyk

CONTENTS

CHAPTER 1

Introduction to Pathology

LEARNING OBJECTIVES

On completion of Chapter 1, the reader should be able to do the following:

- Define common terminology associated with the study of disease.
- Differentiate between signs and symptoms.
- Distinguish between disease diagnosis and prognosis.
- Describe the different types of disease classifications.
- Cite characteristics that distinguish benign from malignant neoplasms.
- Describe the system used to stage malignant tumors.
- Identify the difference in origin of carcinoma and sarcoma.

OUTLINE

KEY TERMS

Acute
Asymptomatic
Atrophy
Autoantibodies
Autoimmune disorders
Benign neoplasm
Carcinoma
Chronic
Congenital
Degenerative
Diagnosis
Disease
Dysplasia
Epidemiology
Etiology
Genetic mapping
Genome
Halotype
Hematogenous spread
Hereditary
Hyperplasia
Hypertrophy
Iatrogenic
Idiopathic

Incidence
Infection
Inflammatory
Invasion
Lesion
Leukemia
Lymphatic spread
Lymphoma
Malignant neoplasm
Manifestations
Metabolism
Metaplasia
Metastatic spread
Morbidity rate
Morphology
Mortality rate
Neoplastic
Nosocomial
Pathogenesis
Physical mapping
Prevalence
Prognosis
Sarcoma
Seeding
Sequelae
Sign
Single-nucleotide polymorphisms
Symptom
Syndrome
Traumatic
Virulence

Pathology is the study of disease. Many types of disease exist, and, in general, many conditions can be readily demonstrated by imaging studies. Additionally, image-guided interventional procedures and therapeutic protocols are often utilized in the management of disease. Therefore, it is critical for radiologic professionals to have a thorough understanding of basic pathologic processes. This foundation begins with a working knowledge of common pathologic terms, an understanding of impact of disease and prevention on U.S. health care expenditures, and the role of genetics in the development and individualized treatment of different pathologic processes. It is also important to understand the role of the Centers for Disease Control and Prevention (CDC) in terms of tracking, monitoring, and reporting trends in health and aging. This information is captured and reported by the National Center for Health Statistics (NCHS).

This chapter serves as a brief introduction to terms associated with pathology, recent health trends, and a review of cellular biology and genetics.

PATHOLOGIC TERMS

Any abnormal disturbance of the function or structure of the human body as a result of some type of injury is called a **disease**. After injury, **pathogenesis** occurs. *Pathogenesis* refers to the sequence of events producing cellular changes that ultimately lead to observable changes known as **manifestations**. These manifestations may be displayed in a variety of fashions. A **symptom** refers to the patient's perception of the disease. Symptoms are subjective, and only the patient can identify these manifestations. For example, a headache is considered a symptom. A **sign** is an objective manifestation that is detected by the physician during examination. Fever, swelling, and skin rash are all considered signs. A group of signs and symptoms that characterizes a specific abnormal disturbance is a **syndrome**. For example, respiratory distress syndrome is a common disorder in premature infants. However, some disease processes, especially in the early stages, do not produce symptoms and are termed **asymptomatic**.

Etiology is the study of the cause of a disease. Common agents that cause diseases include viruses, bacteria, trauma, heat, chemical agents, and poor nutrition. At the molecular level, a genetic abnormality of a single protein may also serve as the etiologic basis for some diseases. Proper infection control practices are important in a health care environment to prevent hospital-acquired **nosocomial** disease. Staphylococcal

infection that follows hip replacement surgery is an example of a nosocomial disease, that is, one acquired from the environment. The cause of the disease, in this case, could be poor infection-control practices. **Iatrogenic** reactions are adverse responses to medical treatment itself (e.g., a collapsed lung that occurs in response to a complication that arises during arterial line placement). If no causative factor can be identified, a disease is termed **idiopathic**.

The length of time over which the disease is displayed may vary. **Acute** diseases usually have a quick onset and last for a short period, whereas **chronic** diseases may manifest more slowly and last for a very long time. An example of an acute disease is pneumonia, and multiple sclerosis is considered a chronic condition. An acute illness may be followed by lasting effects termed **sequelae**—for example, a stroke, or cerebrovascular accident, resulting in long-term neurologic deficits. Similarly, chronic illnesses often manifest in acute episodes, for example, an individual diagnosed with diabetes mellitus experiencing hypoglycemia or hyperglycemia.

Two additional terms refer to the identification and outcome of a disease. A **diagnosis** is the identification of a disease an individual is believed to have, and the predicted course and outcome of the disease is called a **prognosis**.

The structure of cells or tissue is termed **morphology.** Pathologic conditions may cause morphologic changes that alter normal body tissues in a variety of ways. Sometimes, the disease process is destructive, decreasing the normal density of a tissue. This occurs when tissue composition is altered by a decrease in the atomic number of the tissue or the compactness of the cells or by changes in tissue thickness, for example, atrophy from limited use. Such disease processes are radiographically classified as *subtractive*, *lytic*, or *destructive* and require a decrease in the exposure technique. Conversely, some pathologic conditions cause an increase in the normal density of a tissue, resulting in a higher atomic number or increased compactness of cells. These are classified as *additive* or *sclerotic* disease processes and require an increase in the exposure technique. It is important for the radiographer to know common pathologic conditions that require an alteration of the exposure technique so that high-quality radiographs can be obtained to assist in the diagnosis and treatment of the disease.

Government agencies compile statistics annually with regard to the incidence, or rate of occurrence, of disease. **Epidemiology** is the investigation of disease in large groups. Health care epidemiology is grounded in the belief that the distributions of health states (good health, disease, disability, and death) are not random within a population and are influenced by multiple factors, including biologic, social, and environmental factors. Health care epidemiologists conduct research primarily by working with medical statistics, data associations, and large cohort studies. The **prevalence** of a given disease refers to the number of cases found in a given population. The **incidence** of disease refers to the number of new cases found in a given period. Diseases of high prevalence in an area where a given causative organism is commonly found are said to be *endemic* to that area. For example, histoplasmosis is a fungal disease of the respiratory system endemic to the Ohio and Mississippi River valleys. It is not uncommon to see a relatively high prevalence of this disease in these areas. Its appearance in great numbers in the western United States, however, could represent an epidemic.

MONITORING DISEASE TRENDS

Over the past century, life expectancy in the United States has continued to increase. The majority of children born at the beginning of the twenty-first century are expected to live well into their eighth decade (Fig. 1-1). Over the past 100 years, the principal causes of death have shifted from acute infections to chronic diseases. These changes have occurred as a result of biomedical and pharmaceutical advances, public health initiatives, and social changes over the past century (Fig. 1-2). But experts disagree about the trend of increased life expectancy

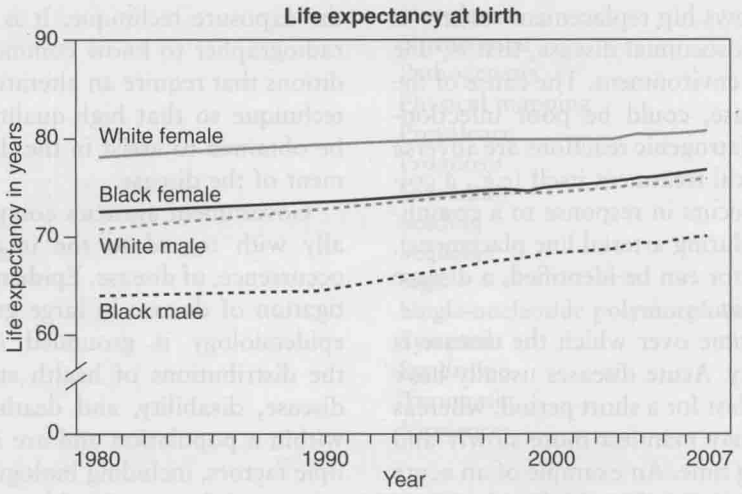
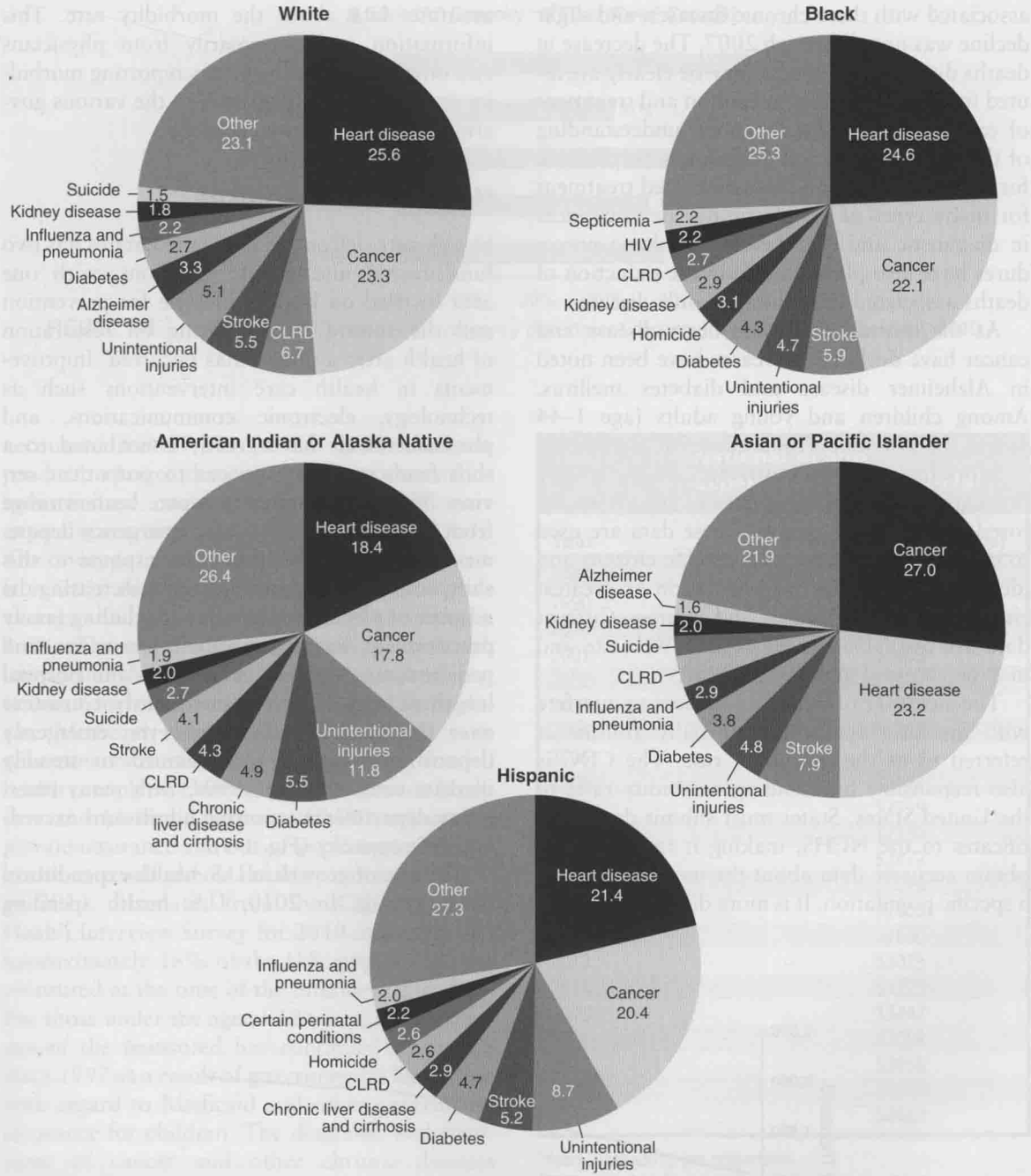


FIGURE 1-1 Life expectancy at birth.

continuing into the twenty-first century. Some believe that increased knowledge of disease etiology and continued development of medical technology in combination with screening, early intervention, and treatment of disease could have positive results. However, many experts express concern about the quality of life of older adults. In other words, the possibility of older adults spending their added years in declining health and lingering illness, instead of being active and productive, is a concern.

The **mortality rate** is the average number of deaths caused by a particular disease in a population. Death certificates are collected by each state, forwarded to the NCHS, and subsequently processed and published as information on mortality statistics and trends. The NCHS and the U.S. Department of Health and Human Services (USDHHS) monitor and report mortality rates in terms of leading causes of death according to gender, race, age, and specific causes of death such as heart disease or malignant neoplasia. Trends in these mortality patterns are identified by age, gender, and ethnic origin and tracked to help identify necessary interventions. For instance, the age-adjusted death rate for heart diseases has steadily decreased for both women and men in the United States. This trend demonstrates a 30% to 40% decline over the past 20 years resulting, in part, from health education and changes in lifestyle behaviors. Because mortality information is gathered from death certificates, changes in the descriptions and coding of "cause of death" and the amount of information forwarded to the NCHS may alter these statistics. For instance, changes in the way deaths were recorded and ranked in terms of the leading causes of death occurred between 1998 and 1999. Since 1999, mortality data and cause-of-death statistics have been gathered and classified according to the *Tenth Revision, International Classification of Diseases* (ICD-10), and in 2007 additional ICD-10 codes were added to clarify the underlying causes of death.

Chronic diseases continue to be the leading causes of death in the United States for adults age 45 years and older. Heart diseases and malignant neoplasia remained the top two causes of deaths in 2007 for both males and females, responsible collectively for 48.6% of all deaths. The third, fourth, and fifth top causes of death in 2007 were stroke, chronic lower respiratory diseases, and accidents, respectively. Alzheimer disease continues to increase and was ranked as the sixth leading cause of death in 2007. Emphasis has been placed on reducing the deaths



NOTES: CLRD is Chronic lower respiratory diseases; HIV is Human Immunodeficiency virus disease. Values show percentage of total deaths. ICD–10 code J09 (Influenza due to avian influenza virus) was added to the influenza and pneumonia category in 2007; no deaths occurred from this cause in 2007.)
SOURCE: CDC/NCHS, National Vital Statistics System, Mortality.

FIGURE 1-2 National Vital Statistics Report of the 10 leading causes of death by race and ethnicity: United States, 2007.

associated with these chronic diseases, and slight decline was noted through 2007. The decrease in deaths due to heart disease may be clearly attributed to advances in the prevention and treatment of cardiac disease. An increased understanding of the genetics of cancer is certainly responsible for better screening and individualized treatment for many types of neoplastic disease. Advances in diagnostic and therapeutic radiologic procedures have also played a role in the reduction of deaths associated with these chronic diseases.

As the mortality rate for heart disease and cancer have declined, increases have been noted in Alzheimer disease and diabetes mellitus. Among children and young adults (age 1–44 years), injury remains the leading cause of death.

Mortality rates from any specific cause may fluctuate from year to year, so trends are monitored over a 3-year period. These data are used to evaluate the health status of U.S. citizens and identify segments of the population at greatest risk from specific diseases and injuries. Current data are available on the NCHS Web site and may be accessed at www.cdc.gov/.

The incidence of sickness sufficient to interfere with an individual's normal daily routine is referred to as the **morbidity rate**. The CDC is also responsible for trending morbidity rates in the United States. States must submit death certificates to the NCHS, making it fairly easy to obtain accurate data about the mortality rate of a specific population. It is more difficult to obtain accurate data about the morbidity rate. This information comes primarily from physicians and other health care workers reporting morbidity statistics and information to the various governmental and private agencies.

Health Care Resources

Health care delivery in the United States has two fundamental and diverse functions, with one area focused on healthy lifestyle for prevention and the second area focusing on restoration of health after a disease has occurred. Improvements in health care interventions such as technology, electronic communications, and pharmaceuticals have greatly contributed to a shift from inpatient services to outpatient services (Fig. 1-3). Ambulatory care centers range from hospital outpatient and emergency departments to physicians' offices. In response to this shift, emphasis has been placed on increasing the number of physician generalists, including family practitioners, internal medicine physicians, and pediatricians. Inpatient admissions and hospital length of stay have remained fairly consistent over the past 10 years; however, emergency department visits have continued to steadily increase since the late 1990s, with many emergency departments reporting admissions exceeding their capacity (Fig. 1-4).

The rate of growth in U.S. health expenditures is staggering. In 2010, U.S. health spending

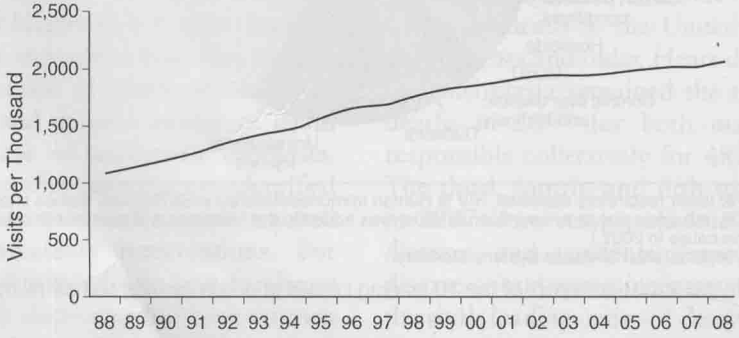


FIGURE 1-3 Number of outpatient hospital visits per 1000 persons during 1988 to 2008.

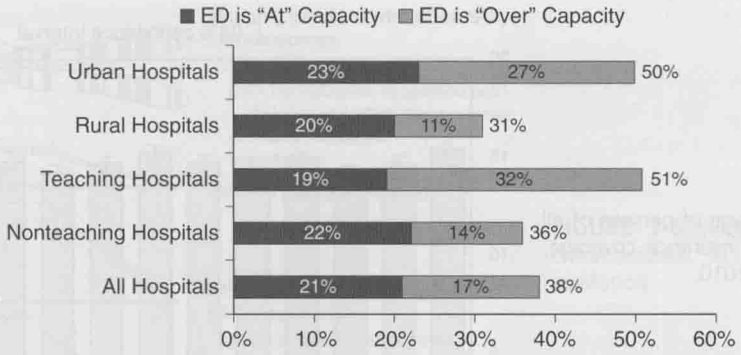


FIGURE 1-4 Percent of hospitals reporting emergency department capacity issues by type of hospital, 2010.

accounted for 17.3% of the gross domestic product, a larger share than in any other major industrialized country, with U.S. health care expenditures totaling $2.6 trillion (Table 1-1). The average annual health spending increase from 2010 through 2020 is projected to outpace average annual growth in the overall economy by 4.7%. The major sources of funding for health care include Medicare, funded by the federal government for older adults and disabled individuals; Medicaid, funded by federal and state governments for the poor; and privately funded health care plans. However, the Centers for Medicare and Medicaid Services (CMS) project that private insurance and out-of-pocket spending on health care will almost double to a rate of 4.8% in 2013. Estimates from the CDC National Health Interview Survey for 2010 indicated that approximately 16% of the U.S. population was uninsured at the time of the interview (Fig. 1-5). For those under the age of 18 years, the percentage of the uninsured has continued to decline since 1997 as a result of governmental legislation with regard to Medicaid and other government insurance for children. The diagnosis and treatment of cancer and other chronic diseases consume enormous financial and other resources in health care. Therefore, emphasis on wellness and disease prevention must continue to reduce these costs. Studies have shown that it is much more cost-effective to provide preventive care than to wait until a disease has progressed.

TABLE 1-1 National Health Expenditures,[1] 1980–2019[2]

Year	Expenditures (Billions)
1980	$253
1990	$714
2000	$1353
2001	$1469
2002	$1602
2003	$1735
2004	$1855
2005	$1983
2006	$2113
2007	$2239
2008	$2339
2009	$2472
2010	$2570
2011	$2703
2012	$2850
2013	$3025
2014	$3225
2015	$3442
2016	$3684
2017	$3936
2018	$4204
2019	$4483

[1]Years 2009–2019 are projections.
[2]CMS completed a benchmark revision in 2006, introducing changes in methods, definitions, and source data that are applied to the entire time series (back to 1960). For more information on this revision, see http://www.cms.hhs.gov.
From Centers for Medicare & Medicaid Services, Office of the Actuary. Data released February 4, 2010.

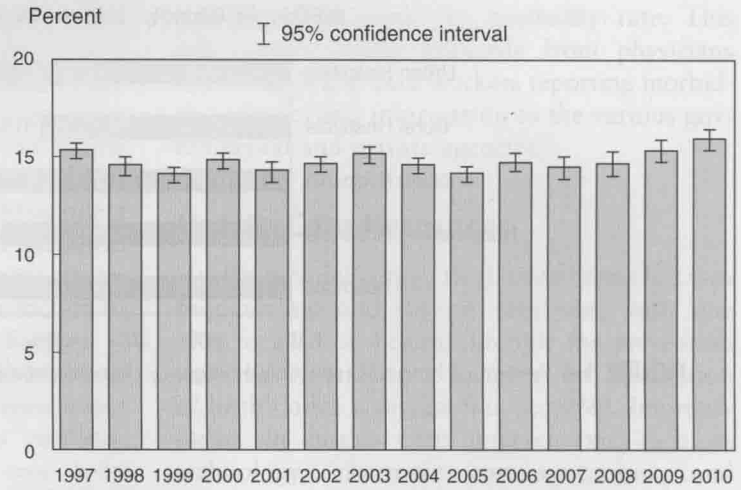


FIGURE 1-5 Percentage of persons of all ages without health insurance coverage, United States, 1997–2010.

HUMAN GENETIC TECHNOLOGY

The Human Genome Project was a 13-year (1990–2003) project coordinated by the U.S. Department of Energy and the National Institutes of Health. The goals of the project were to identify the 30,000 genes in the human deoxyribonucleic acid (DNA); to determine the sequences of the three billion chemical base pairs that make up the human DNA; to electronically store the data; to improve tools for data analysis; and to address ethical, legal, and social issues that arose from the project.

With the exception of reproductive cells, each cell in the human body contains 22 pairs of autosomal chromosomes, 2 sex chromosomes (XX or XY), and the small chromosome found in each mitochondria within the cell. Collectively, this is known as a **genome.** The genome contains between 50,000 to 100,000 genes that are located on approximately three billion base pairs of DNA and forms the basic unit of genetics. Genetics play a significant role in the diagnosis, monitoring, and treatment of disease; thus, it is imperative that radiologic science professionals have a basic understanding of the role of genetics and genetic markers in the development and treatment of disease.

The genome project resulted in the identification of thousands of DNA sequence landmarks and the development of two types of gene maps (Fig. 1-6). **Physical maps** are used to determine the physical location of a particular gene on a specific chromosome. **Genetic maps** are used to assign the distance between the genetic markers, that is, mapping or linking DNA fragments, to a specific chromosome. Genetic linkage maps are useful in tracking inheritance of traits and diseases that are transmitted from parent to child because genetic markers that are in proximity increase the probability that the genes will be inherited together.

As more information was discovered through the Human Genome Project, researchers determined that the genome sequence was 99.9% identical for all humans, leaving only a small percentage of variation among people. However, this 0.1% variation greatly affects an individual's predisposition to certain diseases and his or her response to drugs and toxins. Researchers were able to identify common DNA pattern sequences and common patterns of genetic variations of single DNA bases termed **single-nucleotide polymorphisms** (SNPs). This led to the development of haplotype mapping, often referred to as the *Hap Map*. A **haplotype** comprises closely linked SNPs on a single chromosome, and it is a very important resource in identifying specific DNA sequences affecting disease, response to pharmaceuticals, and response to environmental factors.