Ninth Edition

Sonography

Principles and Instruments

Frederick W. Kremkau

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Sonography

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To the next generation of professionals—Myra, Donna, Shelley, Cara, and Olivia.

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PREFACE

This book is intended for sonography students, allied-health personnel, and physicians who seek understanding of the principles and instrumentation of diagnostic sonography. Applying these underlying principles in practice improves the quality of medical care involving sonography. The best sonographers and image interpreters understand these principles and apply them in their practice.

The purpose of this book is to explain how contemporary diagnostic sonography works. It serves as a principles textbook in sonography educational programs and helps readers handle artifacts properly, scan safely, and prepare for registry and board examinations. The content of the book is driven by the author's assessment of contemporary technology in the field and his experience in teaching this material in the medical-school classroom and at conferences and seminars. The book does not describe how to perform diagnostic examinations or how to interpret the results. Other Elsevier books cover these topics.

Although this latest edition includes newer developments in the field, the emphasis is on the fundamentals. For the sake of beginners, the text is simplified, yet at the same time it maintains its integrity and usefulness for more experienced users. Although the book is designed for *non*-physicist and *non*-engineering readers, digestion of the material will require some effort. Admittedly, for such readers, the material can be difficult. It cannot be made easy for everyone and still maintain the necessary level for appropriate application in practice. However, 40 years of lecturing and publication experience have convinced the author that the material *can* be understood with reasonable preparation and effort on the part of the student. It is assumed that the student has completed courses in basic physics (including mechanics, waves, and electricity) and mathematics (including algebra, trigonometry, and statistics), which are normal prerequisites in sonography programs. The following topics are *not* covered in this textbook: the history of the development of sonography, therapy applications, and investigational techniques. They are covered in other books and journal articles.

DIFFERENCES WITH EARLIER EDITIONS AND NATIONAL EXAMINATIONS

There are several differences between each new edition compared with earlier editions and compared with the content of registry and specialty-board examinations. This is because this text is up to date with current technology, whereas examinations change more slowly because of the necessarily thorough and time-consuming process, which requires practice surveys; committee decisions; and item generation, review, and approval. Outmoded descriptions of technology and instrument features that are no longer largely present in the field are eliminated with each new edition. Thus the book tends to change more rapidly than the examinations. The philosophy of the book is to be, with each new edition, as consistent as possible with contemporary sonographic technology and usage.

FEATURES

- Comprehensive coverage of the principles of sonography
- Preparation for the ARDMS SPI examination
- Latest developments in commercially available sonographic technology
- Hundreds of color illustrations and images
- Hundreds of exercises with answers
- Comprehensive multiple-choice examination with annotated answers
- Consistent pedagogy, including learning objectives, chapter outlines, and key terms
- Key points set off by icons
- Descriptive subheadings
- Boxes and tables
- Math review
- Glossary

NEW TO THIS EDITION

- New illustrations and images demonstrating the latest and best images from the newest equipment
- Expanded content on volume imaging, shear-wave and acoustic-radiation-force elastography, and sophisticated echo acquisition techniques, keeping students up to date on the latest technology
- The latest instrument output data and official safety statements
- Alignment with the ARDMS examination specifications, making this a useful text for preparing for the SPI examination

FOR THE STUDENT

This book should be read in sequential chapter order, as each chapter builds on material previously presented. Key terms are listed at the beginning of each chapter, are highlighted in **blue** in the chapter, and are defined in the Glossary at the back of the book.

After studying this text, the student should be able to:

- Describe what ultrasound is
- Explain how ultrasound is sent into the body
- Explain how ultrasound detects and locates anatomic structures
- Discuss how echoes are received from the body and processed in the instrument
- Describe how anatomic information is presented on the display

- Explain how ultrasound detects and measures tissue motion and blood flow
- List the ways motion and flow information are presented
- Explain how flow detection is localized to a specific site in tissue
- List the common artifacts that can occur in diagnostic sonography
- Discuss how performance of sonographic instruments is tested
- Describe the risk and safety issues associated with diagnostic sonography

FOR THE INSTRUCTOR

The material in Chapter 4 has been rearranged to enable treatment of more fundamental aspects first, followed by more advanced features.

The following resources are available at *http://evolve.elsevier.com/Kremkau/ultrasound*.

- *Instructor's Electronic Resource* containing an instructor's manual, PowerPoint slides, a test bank, and an image collection
  - The instructor's manual includes outlines and summaries of textbook chapters, visual learning exercises, lab and learning assignments, and review questions.
  - The PowerPoint presentation includes notes for instructors.
  - The test bank, available in Examview or Word, includes over 400 questions.
  - The image collection can be downloaded in PowerPoint or as jpeg files.
- Real-time videos of the following:
  - Use of a sonographic phantom as a patient surrogate
  - Effect of frequency on attenuation and penetration
  - Image formats of various transducer types
  - Impact of output and gain controls on the image
  - Color-Doppler displays and control effects
  - Spectral-Doppler displays and control effects
  - Aliasing artifact and ways to correct it

Any questions?

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CONTENTS

1

Introduction

LEARNING OBJECTIVES

After reading this chapter, the student should be able to do the following:

- Explain the pulse-echo principle used in sonographic imaging.
- Describe the image formats used in sonography.
- Explain how the Doppler effect is applied in sonography.
- List the ways in which Doppler information is presented.

OUTLINE

KEY TERMS

Color-Doppler display
Doppler effect
Gray-scale image
Image
Linear image
Pulse-echo technique
Scan line
Sector image
Sonography
Spectral-Doppler display
Transducer
Ultrasound
Volume imaging

Bats, dolphins, and other animals used **ultrasound** long before humans adopted it for their needs. These animals use ultrasound to detect, locate, determine the motion of, and capture prey; to avoid obstacles; to detect and avoid predators; and to court their mates. One way humans have applied ultrasound techniques is by using **sonography** in diagnostic medicine. Sonography is the use of ultrasound in medical anatomic and flow imaging. Diagnostic ultrasound encompasses sonography and Doppler ultrasound. Doppler ultrasound includes the detection, quantization, and evaluation of tissue motion and blood flow by using the **Doppler effect** with ultrasound. This chapter presents an overview of the principles of sonography and Doppler ultrasound. Here, we are water skiing over the principles. In subsequent chapters we will scuba dive into the details.

SONOGRAPHY

The word *sonography* comes from the Latin *sonus* (sound) and the Greek *graphein* (to write). Diagnostic sonography is medical two-dimensional (2D) and three-dimensional (3D) anatomic and flow imaging with the use of ultrasound. Ultrasound is sound that is higher in pitch than the range of human hearing. Ultrasound imaging is not a passive push-button activity; rather, it is an interactive process that involves a sonographer (an allied health professional who acquires the images), a patient, an ultrasound **transducer**, an instrument, and a sonologist (a physician who interprets the images). Understanding and application of the underlying physical and electronic principles presented in this book will strengthen the expertise of the sonographer and the sonologist, and thus improve the quality of medical care that involves diagnostic sonography.

Medical imaging with ultrasound is called *sonography*.

An **image** (from the Latin term for *imitate*) is a reproduction, representation, or imitation of the physical form of a person or object. An ultrasound image is the visible counterpart of an invisible object, produced in an

electronic instrument by the interaction of ultrasound with the object. Ultrasound provides a noninvasive way of looking inside the human body (Figure 1-1) to image otherwise hidden anatomy. Anatomic imaging with ultrasound is accomplished with a **pulse-echo technique**. Pulses of ultrasound generated by a transducer are sent into the patient (Figure 1-2), where they produce echoes at organ boundaries and within tissues. These echoes return to the transducer, where they are detected and presented on the display of a sonographic instrument. The transducer (Figure 1-3) generates the ultrasound pulses and receives the returning echoes. Sonography requires knowledge of the location of origin of each echo and its strength as it returns from the patient. The ultrasound instrument (Figure 1-4) processes the echoes and presents them as visible dots, which form the anatomic image on the display. The brightness

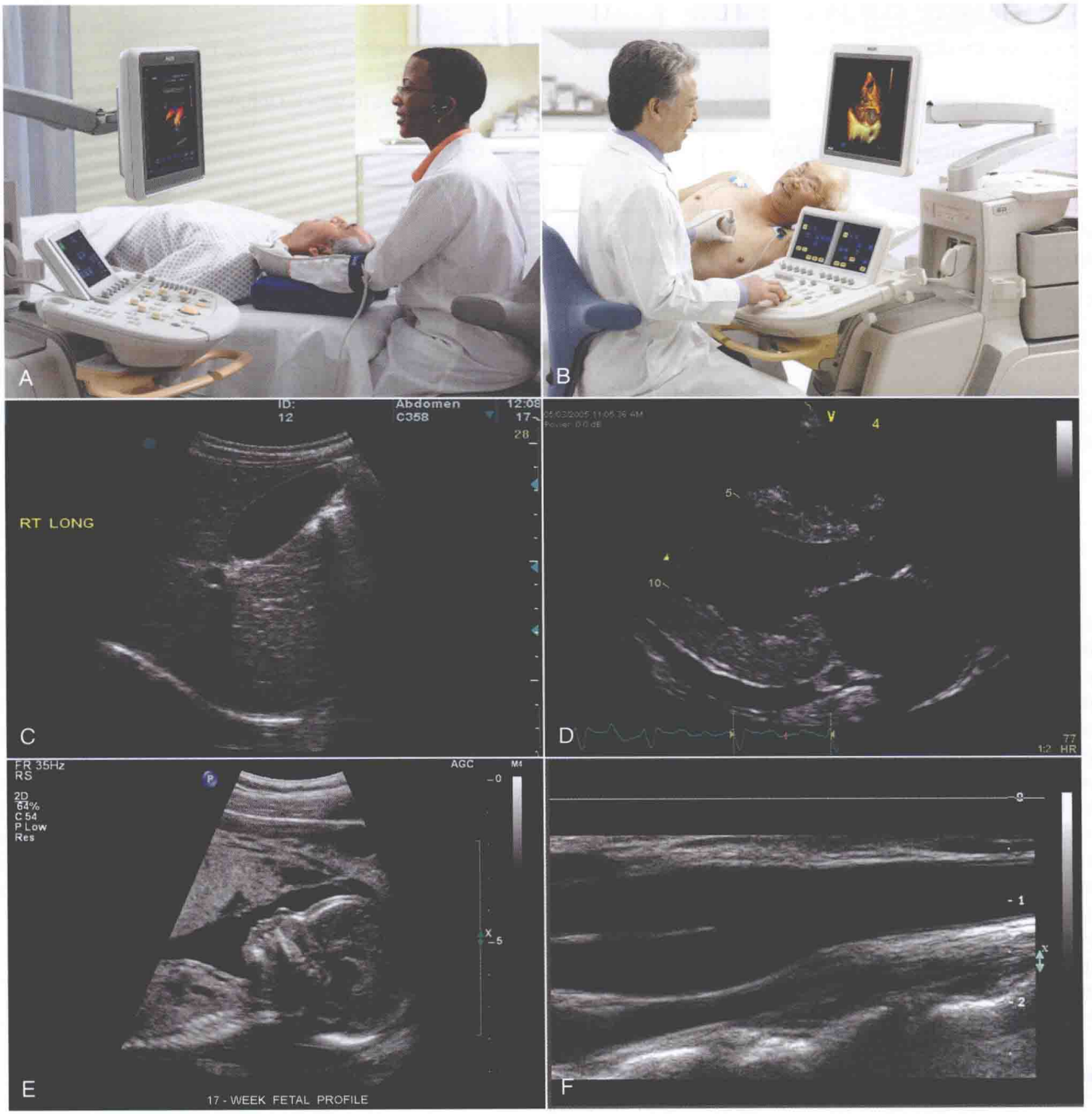

FIGURE 1-1 Ultrasound provides a window into the human body, allowing us to see what would otherwise be hidden from view (A-B). Images shown are as follows: C, abdominal; D, cardiac; E, obstetric, and F, vascular.