Fourth Edition

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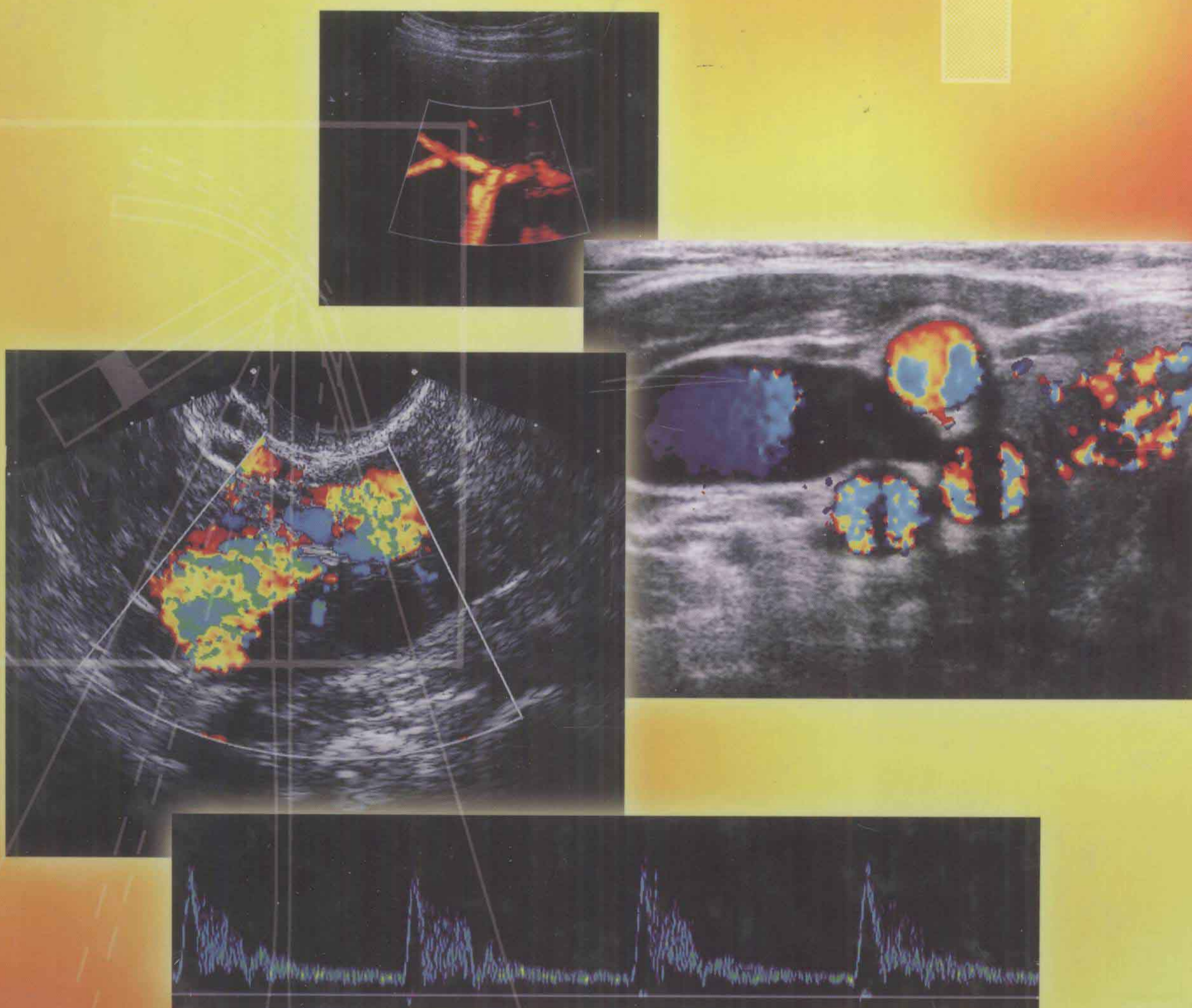
ULTRASOUND PHYSICS AND INSTRUMENTATION



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ULTRASOUND PHYSICS AND INSTRUMENTATION

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ULTRASOUND PHYSICS AND INSTRUMENTATION

In memory of

Mary Mihelcic-Jones

A woman of compassion, intelligence, grace, and beauty

ULTRASOUND PHYSICS AND INSTRUMENTATION

Preface

This new edition continues to present ultrasound physics in an easy-to-understand and comprehensive manner for diagnostic medical ultrasonography students and radiology residents. It will also benefit physicians and technologists in many medical specialties, including obstetrics, cardiology, vascular surgery, urology, general surgery, and veterinary medicine. In addition, medical physicists will find the principles of ultrasound physics and instrumentation that they need to know for clinical practice.

The field of medical diagnostic ultrasound has expanded rapidly over the past decade. Although the basic physical principles are unchanged, significant advances in instrumentation have resulted in increased clinical utilization of ultrasound in medicine. If individuals who perform and/or interpret ultrasound scans are to obtain the highest quality of diagnostic information, they must understand the underlying physical principles and instrumentation.

In the last few years the technical evolution has had an impact on computer processing techniques, PACS, Doppler imaging, tissue harmonic imaging, spatial compounding, frequency compounding, extended field of view, coded excitation, elasticity imaging, contrast agents, beam formation, broadband transducers, 1.5D and 2D transducers, and 3D ultrasound. The text has been revised and expanded to reflect these and other advances in medical diagnostic ultrasound instrumentation.

NEW CONTENT AND ORGANIZATION

Now divided into 25 chapters, the book opens with a detailed presentation of the basic physical principles of ultrasound. Chapter 1 is vitally important because the physical principles it presents form the basis for understanding all ultrasonic scanning modes. These principles are dramatically different from those that apply to diagnostic x-ray imaging. Chapter 2 discusses attenuation in tissue with some mathematical detail. Computer fundamentals are introduced in Chapter 3, followed later by digital processing techniques (Chapter 10) and computer networks (Chapter 20). Chapters 4 and 5 present single-element transducer design, pulse generation, and echo reception, which have application to multielement array transducers. Static imaging modes (A-mode, static B-mode, gated, and transmission) are discussed in Chapter 6. These instruments have been almost totally replaced with real-time scanners, which are described in Chapters 7 through 12, including separate chapters on image quality (Chapter 11) and image artifacts (Chapter 12). Hemodynamics is presented in Chapter 13 before the treatment of Doppler ultrasound (Chapters 14 through 16). Chapter 17 examines M-mode scanning. Contrast agents are discussed in Chapter 18. The usual end product of ultrasonic scanning is an image recorded on film or other media. An overview of image recording devices is presented in Chapter 19. As with other imaging techniques, ultrasound deposits energy into the body and thus has the potential for causing biological effects. Ultrasound exposure is quantified by intensity for which multiple descriptors are possible (Chapter 21). Chapter 22 reviews the literature concerning the biological effects of ultrasound. Clinical safety concerns associated with medical diagnostic ultrasound are addressed in Chapter 23. Image quality must be maintained at a high level via an appropriate quality control program as set forth in Chapter 25. Quality control has been completely revised and separated from performance testing, which is discussed in Chapter 24.

FEATURES

This text fully prepares the reader, not only by explaining the necessary principles but also by using analogies, incorporating sample problems throughout, presenting key terms, and providing review questions at the end of each chapter with answers in the back of the book. An extensive glossary of ultrasonic terms is included. Appendix A contains a comprehensive mathematics review, and Appendix B contains a short discussion of Fourier analysis, a computer processing technique in Doppler ultrasound. A separate practice exam can be found on Evolve's learning resources for students.

Problem solving is an integral part of the learning process in physics and is necessary for passing registry and certification examinations. The comprehensive examination will thoroughly test the working knowledge of readers in the physics and instrumentation of ultrasound, thus helping them prepare for examinations given by the American Registry of Diagnostic Medical Sonographers. All the learning tools integrated within this text help make comprehension easier and more successful.

EVOLVE—ONLINE COURSE MANAGEMENT

Evolve is an interactive learning environment designed to work in coordination with *Ultrasound Physics and Instrumentation.* Instructors may use Evolve to provide an Internet-based course component that reinforces and expands on the concepts delivered 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 allows instructors to post examinations and manage their grade book online. For more information, visit ***http://www.evolve.elsevier.com/Hedrick/ultrasound*** or contact an Elsevier sales representative.

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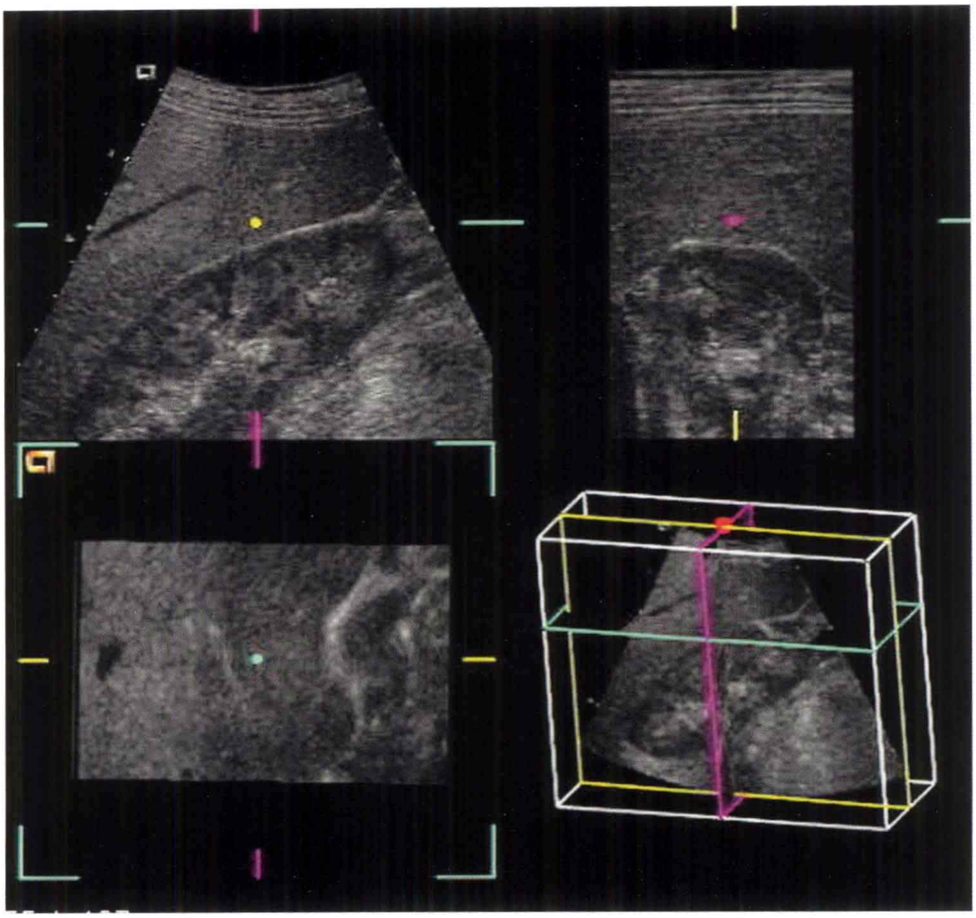
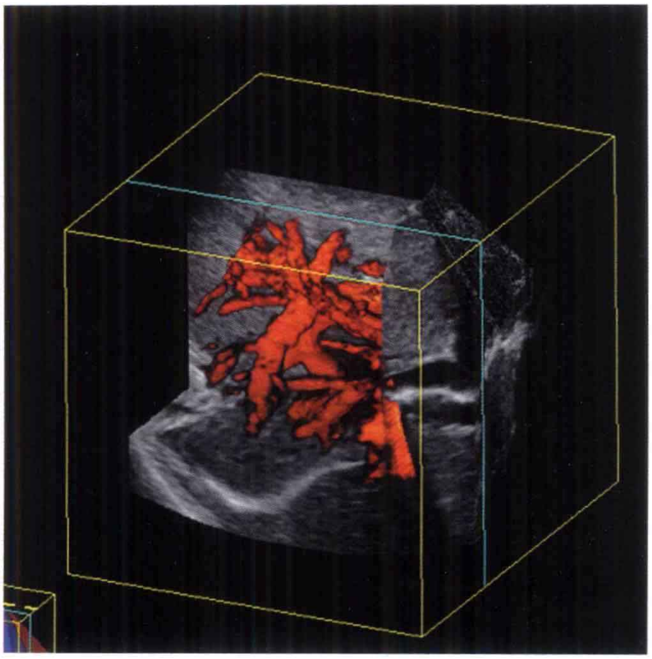
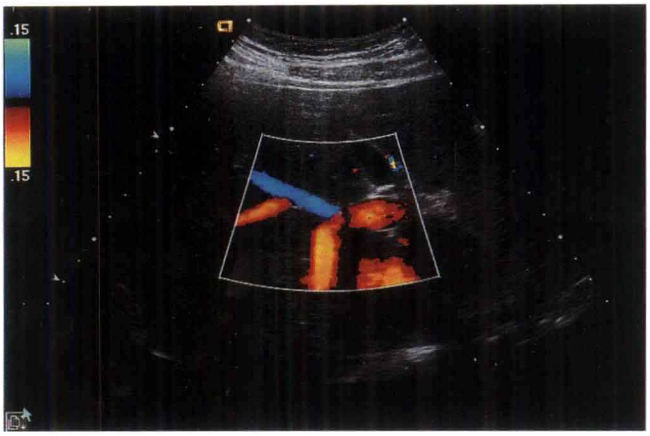


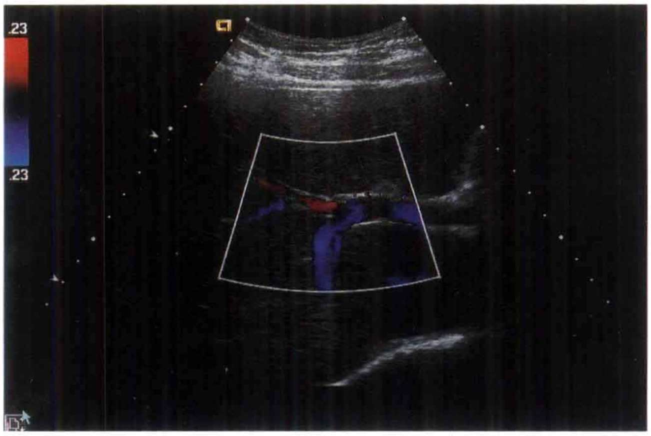
Color Plate 1 Three-dimensional multiformat. Three orthogonal planes through the kidney are displayed. The reference image denotes the orientation. (See Fig. 9-51.) (Courtesy Siemens Medical Solutions USA, Inc., Ultrasound Division, Malvern, Penn.)



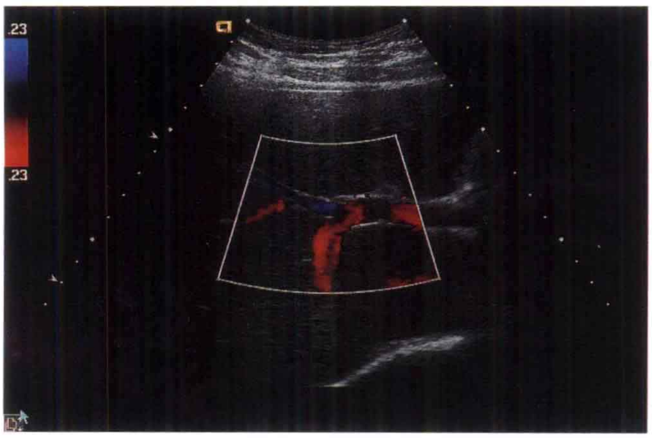
Color Plate 2 Three-dimensional polyhedron image display showing liver vasculature in a child. (See Fig. 9-52.) (Courtesy Siemens Medical Solutions USA, Inc., Ultrasound Division, Malvern, Penn.)



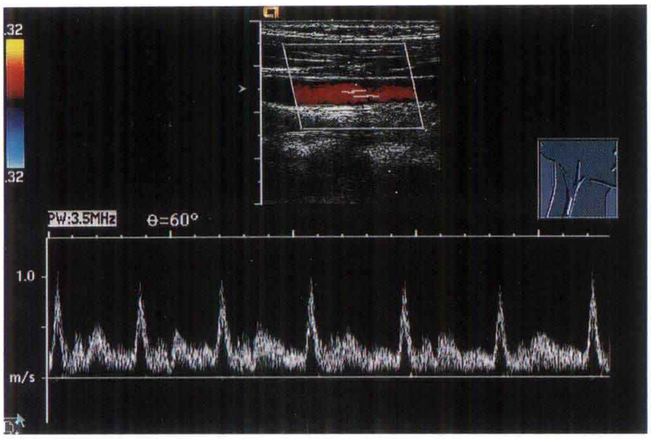
Color Plate 3 Doppler imaging of the portal vein. Flow in the anterior right portal vein and the posterior right portal vein is shown using a rainbow color map. (See Fig. 16-2.) Color Plates 4 and 5 show a color map depicting flow toward the transducer in red and blue, respectively.



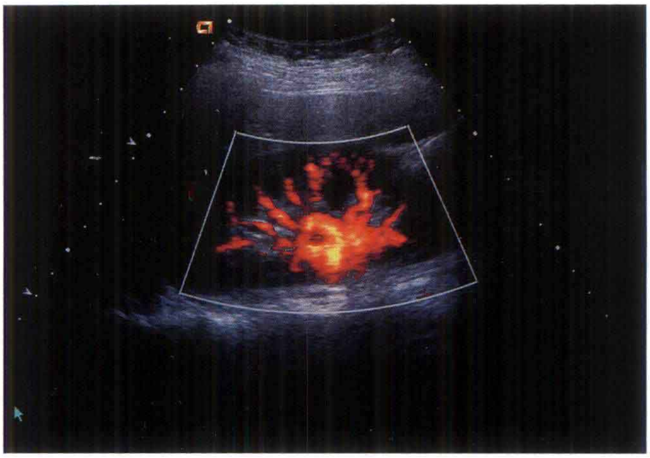
Color Plate 4 Doppler imaging of the portal vein. Flow in the anterior right portal vein and the posterior right portal vein is shown using a saturation color map. (See Fig. 16-2.) Flow toward the transducer is depicted in red.



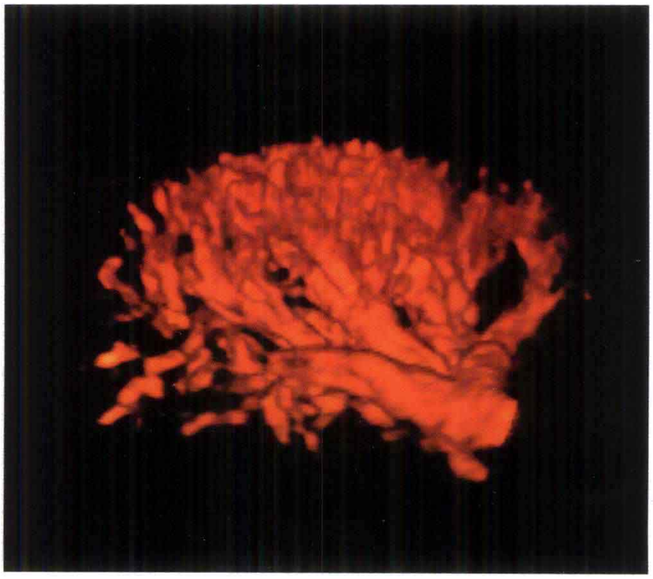
Color Plate 5 Doppler imaging of the portal vein. Flow in the anterior right portal vein and the posterior right portal vein is shown using a saturation color map. (See Fig. 16-2.) Flow toward the transducer is depicted in blue.



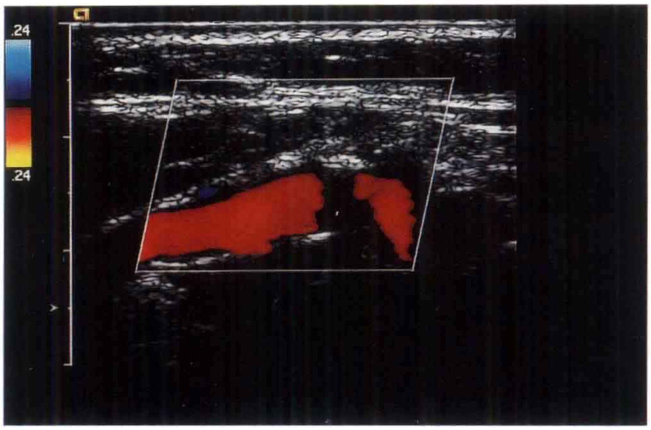
Color Plate 6 Combined Doppler mode. The color Doppler image with the sampled region identified is shown with the Doppler spectral analysis. (See Fig. 16-22.)



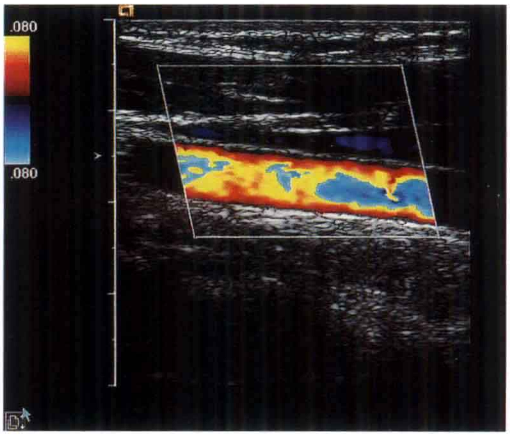
Color Plate 7 Power Doppler image of the kidney. (See Fig. 16-23.)



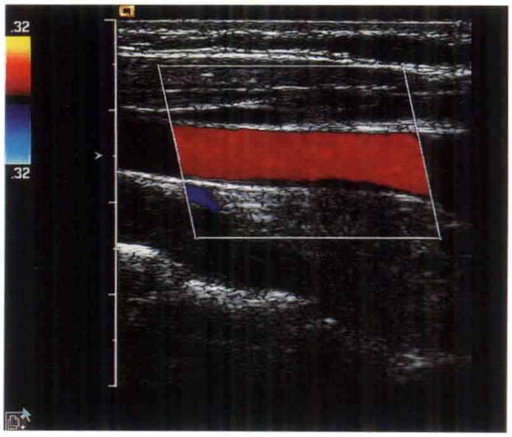
Color Plate 8 Three-dimensional power Doppler image of the kidney. (See Fig. 16-24.) (Courtesy Siemens Medical Solutions USA, Inc., Ultrasound Division, Malvern, Penn.)



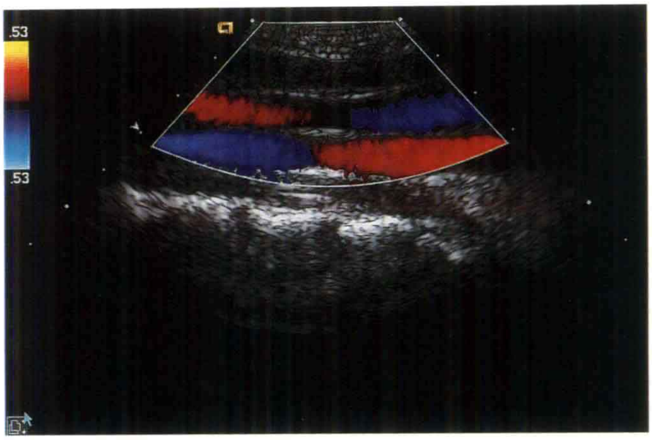
Color Plate 9 Shadowing by a calcified plaque obscures flow in the common carotid artery. (See Fig. 16-25.)



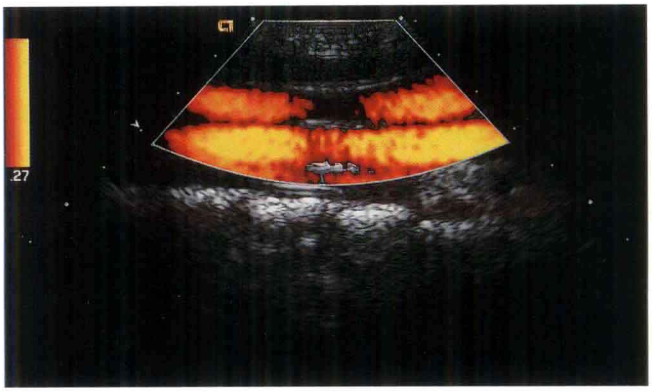
Color Plate 10 Color Doppler aliasing. Note the improper color progression—red to yellow to green to blue. If reverse flow were present, red and blue would be separated by a black region. (See Fig. 16-26.)



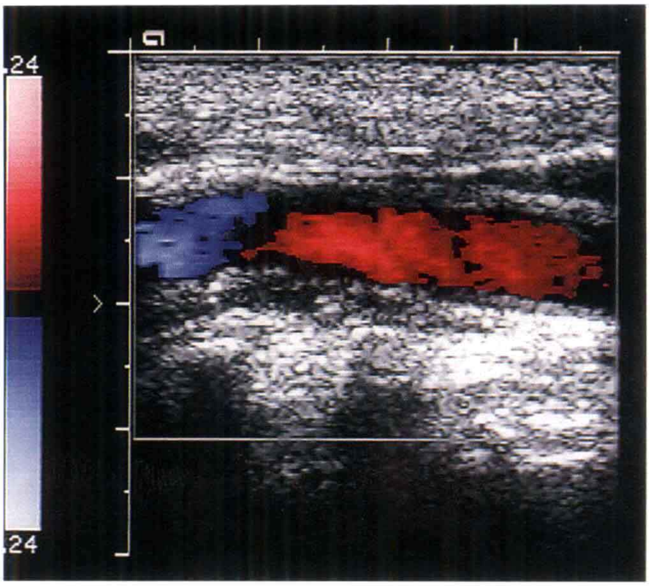
Color Plate 11 Increasing the velocity range removes the aliasing artifact in Fig. 16-26. (See Fig. 16-27.)



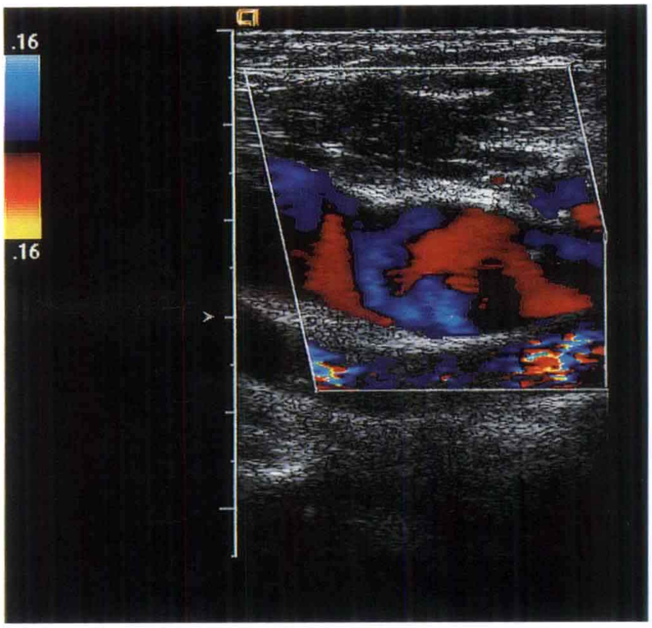
Color Plate 12 Color Doppler image of two vessels acquired with a vector transducer. (See Fig. 16-30.)



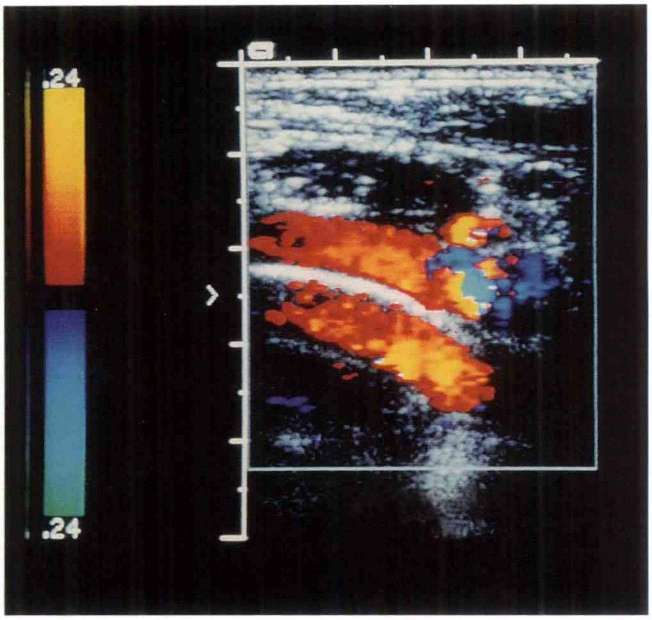
Color Plate 13 Power Doppler image of two vessels acquired with a vector transducer. (See Fig. 16-31.)



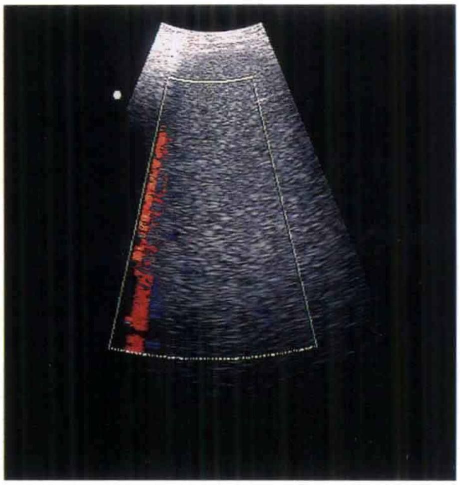
Color Plate 14 A tortuous vessel with unidirectional flow is depicted in changing colors, which suggests a reversal of flow. (See Fig. 16-32.)



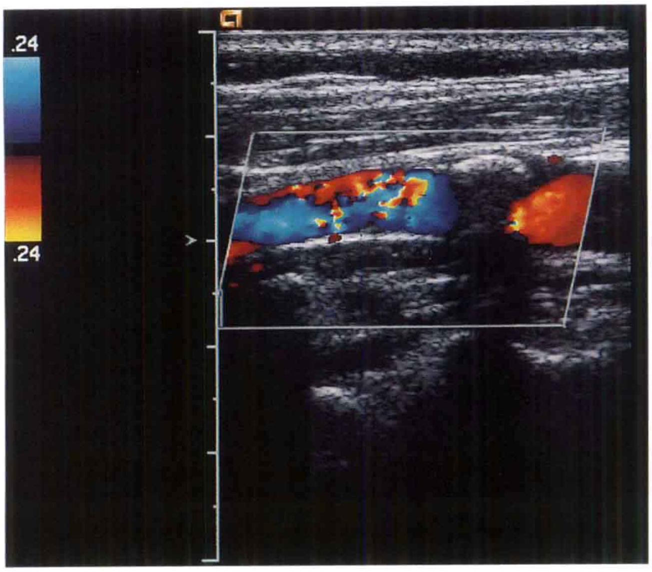
Color Plate 15 Flow reversal. (See Fig. 16-33.)



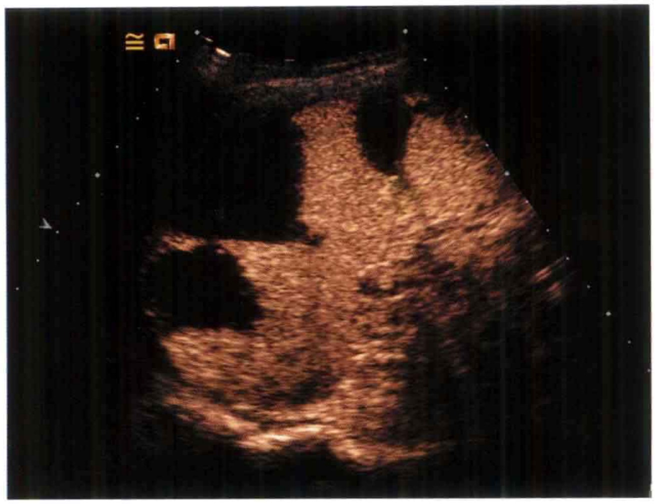
Color Plate 16 Color Doppler mirror image artifact of the subclavian artery. (See Fig. 16-34.) (Courtesy Rob Steins.)



Color Plate 17 Flash artifact. Color is improperly assigned to stationary tissue (phantom material) caused by movement of the transducer. (See Fig. 16-35.)

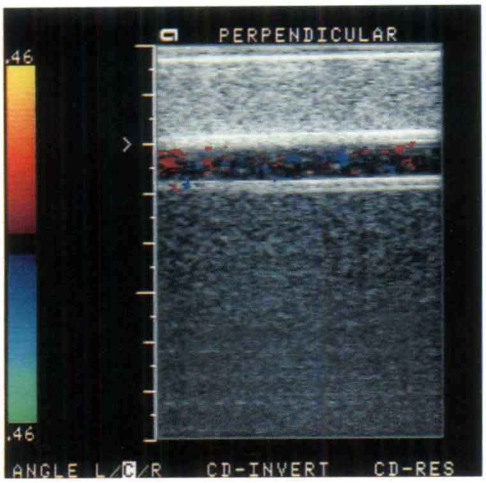


Color Plate 18 In this color flow image the internal carotid shows turbulence distal to the stenosis. (See Fig. 16-36.)

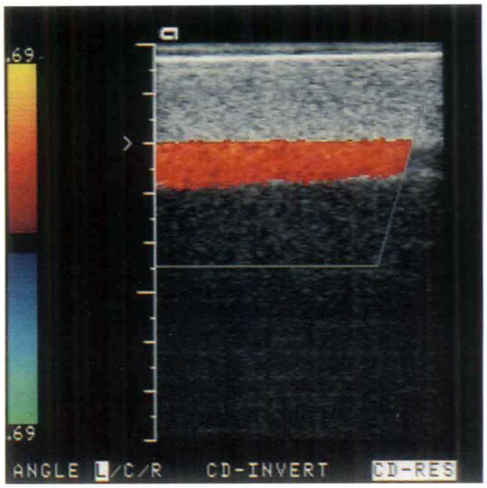


Color Plate 19 Sonogram of the liver showing the distribution of contrast agent. Three lesions that failed to accumulate contrast agent are present. (See Fig. 18-4.) (Courtesy Siemens Medical Solutions USA, Inc., Ultrasound Division, Malvern, Penn.)

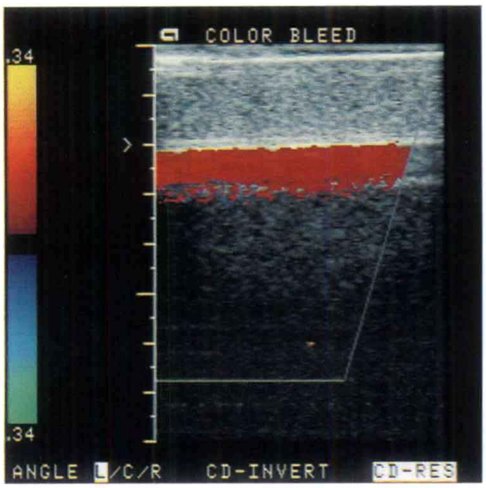
Color Plate 20 Sonogram of the liver showing the distribution of contrast agent. A mass with enhanced signal content is observed. (See Fig. 18-5.) (Courtesy Siemens Medical Solutions USA, Inc., Ultrasound Division, Malvern, Penn.)



Color Plate 21 Color Doppler image of the vessel in the flow phantom obtained with a 90-degree Doppler angle. (See Fig. 24-50.)



Color Plate 22 Color Doppler image of the vessel in the flow phantom obtained with a reduced Doppler angle. (See Fig. 24-51.)



Color Plate 23 Color bleed artifact generated at high power and color gain with a Doppler flow phantom. (See Fig. 24-52.)

Color Plate 24 Color Doppler image of a fetus.