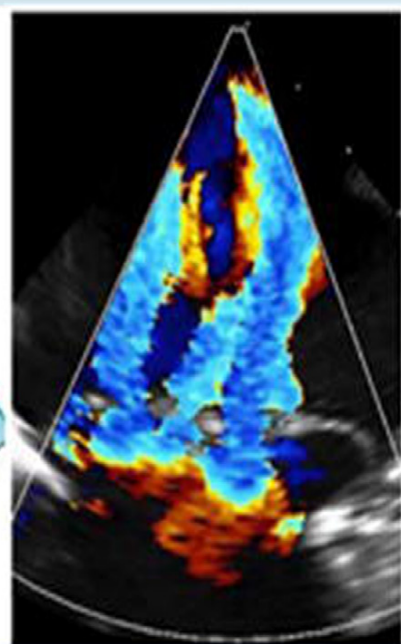
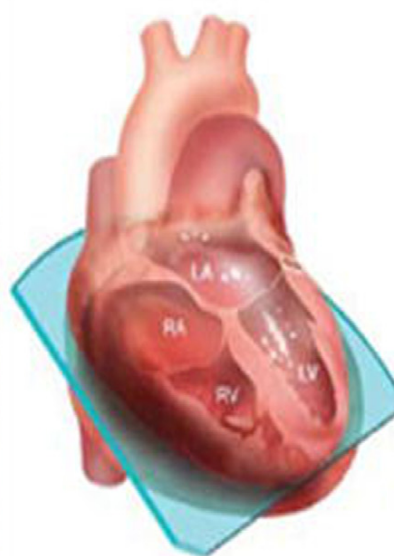
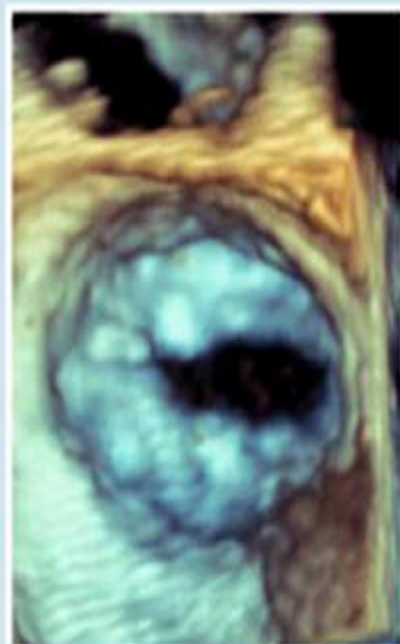


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FIFTH EDITION



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FIFTH EDITION

TEXTBOOK *of* CLINICAL ECHOCARDIOGRAPHY

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PREFACE

Echocardiography is an integral part of clinical cardiology with important applications in diagnosis, clinical management, and decision making for patients with a wide range of cardiovascular diseases. In addition to examinations performed in the echocardiography laboratory, ultrasound imaging is now used in a variety of other clinical settings, including the coronary care unit, intensive care unit, operating room, emergency department, catheterization laboratory, and electrophysiology laboratory, both for diagnosis and for monitoring the effects of therapeutic interventions. There continues to be expansion of echocardiographic applications, given the detailed and precise anatomic and physiologic information that can be obtained with this technique at a relatively low cost and with minimal risk to the patient.

This textbook on general clinical echocardiography is intended to be read by individuals new to echocardiography and by those interested in updating their knowledge in this area. The text is aimed primarily at cardiology fellows on their basic echocardiography rotation but also will be of value to residents and fellows in general internal medicine, radiology, anesthesiology, and emergency medicine, and to cardiac sonography students. For physicians in practice, this textbook provides a concise and practical update.

The *Textbook of Clinical Echocardiography* is structured around a clinical approach to echocardiographic diagnosis. First, a framework of basic principles is provided with chapters on ultrasound physics, normal tomographic transthoracic and transesophageal views, intracardiac flow patterns, indications for echocardiography, and evaluation of left ventricular systolic and diastolic function. A chapter on advanced echocardiographic modalities introduces the concepts of 3D echocardiography, myocardial mechanics, contrast echocardiography, and intracardiac echocardiography. Clinical use of these modalities is integrated into subsequent chapters as appropriate. This framework of basic principles then is built upon in subsequent chapters, organized by disease category (for example, cardiomyopathy or valvular stenosis), corresponding to the typical indications for echocardiography in clinical practice.

In each chapter, basic principles for echocardiographic evaluation of that disease category are reviewed, the echocardiographic approach and differential diagnosis are discussed in detail, limitations and technical considerations are emphasized, and

alternate diagnostic approaches are delineated. Schematic diagrams are used to illustrate basic concepts; echocardiographic images and Doppler data show typical and unusual findings in patients with each disease process. Transthoracic and transesophageal images, Doppler data, and advanced imaging modalities are used throughout the text, reflecting their use in clinical practice. Tables are used frequently to summarize studies validating quantitative echocardiographic methods.

A special feature of this book that grew out of my experience teaching fellows and sonographers is The Echo Exam section at the end of the book. This section serves as a summary of the important concepts in each chapter and provides examples of the quantitative calculations used in the day-to-day clinical practice of echocardiography. The information in The Echo Exam is arranged as lists, tables, and figures for clarity. My hope is that The Echo Exam will also serve as a quick reference guide when a review is needed and in daily practice in the echocardiography laboratory.

In the fifth edition, the text of all the chapters has been revised to reflect recent advances in the field, the suggested readings have been updated, and the majority of the figures have been replaced with recent examples that more clearly illustrate the disease process. The use of 3D and transesophageal imaging now is explicitly integrated into each chapter. Additional tables providing clinical-echocardiographic correlation have been added to several chapters. New artist drawn illustrations provide a clearer understanding of normal and abnormal cardiac anatomy. Updated guidelines for the use of echocardiography and recommendations for image acquisition and analysis are summarized in tables and illustrated in figures in each chapter. The online and electronic versions of the book are further enhanced by videos linked to the figures in each chapter.

A selected list of annotated references is included at the end of each chapter. These references are suggestions for the individual who is interested in reading more about a particular subject. Additional relevant articles can be found in the suggested readings. Of course, an online medical reference database is the best way to obtain more recent publications and to obtain a comprehensive list of all journal articles on a specific topic.

For additional clinical examples, practical tips for data acquisition, and self-assessment questions, the

Echocardiography Review Guide, by Otto, Schwaegler, and Freeman (2nd edition, Elsevier/Saunders, 2011), parallels the information provided in this textbook and provides numerous multiple choice review questions with detailed answers. A more advanced discussion of the impact of echocardiographic data in clinical medicine is available in a larger reference book, *The Practice of Clinical Echocardiography*, 4th edition (Otto [ed], 2012), also published by Elsevier/Saunders, with online cases, video images, and interactive multiple choice questions on the Expert Consult web site. Those seeking additional expertise using echocardiography in specific clinical settings should consider the Otto Practical Echocardiography Series (Elsevier/Saunders, 2012) that includes *Advanced Approaches in Echocardiography* (Gillam and Otto), *Intraoperative Echocardiography* (Oxorn), *Echocardiography in Heart Failure* (St John Sutton and Wieggers), and *Echocardiography in Congenital Heart Disease* (Lewin and Stout). Each of these concise books provides practical clinical approaches with numerous illustrations.

It should be emphasized that this textbook (or any book) is only a starting point or frame of reference for learning echocardiography. Appropriate training in echocardiography includes competency in the

acquisition and interpretation of echocardiographic and Doppler data in real time. Additional training is needed for performance of stress and transesophageal examinations. Further, echocardiography continues to evolve so that as new techniques become practical and widely available, practitioners will need to update their knowledge. Obviously, a textbook cannot replace the experience gained in performing studies on patients with a range of disease processes, and still photographs or selected online videos do not replace the need for acquisition and review of real-time data. Guidelines for training in echocardiography, as referenced in Chapter 5, serve as the standard for determining clinical competency in this technique. Although this textbook is not a substitute for appropriate training and experience, I hope it will enhance the learning experience of those new to the field and provide a review for those currently engaged in the acquisition and interpretation of echocardiography. Every patient deserves a clinically appropriate and diagnostically accurate echocardiographic examination; each of us needs to continuously strive toward that goal.

Catherine M. Otto, MD



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Many people have provided input to each edition of the *Textbook of Clinical Echocardiography*, and the book is immeasurably enhanced by their contributions—not all can be individually thanked here but my gratitude extends to all of you. My special thanks go to the cardiac sonographers at the University of Washington for the outstanding quality of their echocardiographic examinations and for our frequent discussions of the details of image acquisition and the optimal echocardiography examination. Their skill in obtaining superb images provides the basis of many of the figures in this book. My thanks to Pamela Clark, RDCS; Sarah Curtis, RDCS; Caryn D’Jang, RDCS; Michelle Fujioka, RDCS; Carol Kraft, RDCS; Yelena Kovolenko, RDCS; Carol Kraft, RDCS; Chris McKenzie, RDCS; Amy Owens, RDCS; Joanna Shephard, RDCS; Becky Schwaegler, RDCS; Yu Wang, RDCS; and Todd Zwink, RDCS.

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Many thanks to my editor at Elsevier, Dolores Meloni, for providing the support needed to write this edition, and to Joan Ryan, Brandilyn Flagg, Michael Fioretti, and the production team for all the detail-oriented hard work that went into making this book and online videos a reality.

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GLOSSARY

Abbreviations Used in Figures, Tables, and Equations

- 2D = two-dimensional
 3D = three-dimensional
 A-long = apical long-axis
 A-mode = amplitude mode (amplitude versus depth)
 A = late diastolic ventricular filling velocity with atrial contraction
 A' = diastolic tissue Doppler velocity with atrial contraction
 A2C = apical two-chamber
 A4C = apical four-chamber
 AcT = acceleration time
 A_{dur} = transmitral A -velocity duration
 a_{dur} = pulmonary vein a -velocity duration
 AF = atrial fibrillation
 AMVL = anterior mitral valve leaflet
 ant = anterior
 Ao = aortic or aorta
 AR = aortic regurgitation
 AS = aortic stenosis
 ASD = atrial septal defect
 ATVL = anterior tricuspid valve leaflet
 AV = atrioventricular
 AVA = aortic valve area
 AVR = aortic valve replacement

 BAV = bicuspid aortic valve
 BP = blood pressure
 BSA = body surface area

 c = propagation velocity of sound in tissue
 CAD = coronary artery disease
 CPB = cardiopulmonary bypass
 cath = cardiac catheterization
 C_m = specific heat of tissue
 cm/s = centimeters per second
 cm = centimeters
 CMR = cardiac magnetic resonance imaging
 CO = cardiac output
 cos = cosine
 CS = coronary sinus
 CSA = cross-sectional area
 CT = computed tomography
 CW = continuous-wave
 Cx = circumflex coronary artery

 D = diameter
 DA = descending aorta
 dB = decibels
 dP/dt = rate of change in pressure over time
 dT/dt = rate of increase in temperature over time

 DT = deceleration time
 $\text{dyne} \cdot \text{s} \cdot \text{cm}^{-5}$ = units of resistance
 D-TGA, complete transposition of the great arteries

 E = early-diastolic peak velocity
 E' = early-diastolic tissue Doppler velocity
 ECG = electrocardiogram
 echo = echocardiography
 ED = end-diastole
 EDD = end-diastolic dimension
 EDV = end-diastolic volume
 EF = ejection fraction
 endo = endocardium
 epi = epicardium
 EPSS = E-point septal separation
 ES = end-systole
 ESD = end-systolic dimension
 ESV = end-systolic volume
 ETT = exercise treadmill test

 Δf = frequency shift
 f = frequency
 FL = false lumen
 F_n = near field
 F_o = resonance frequency
 F_s = scattered frequency
 FSV = forward stroke volume
 F_T = transmitted frequency

 HCM = hypertrophic cardiomyopathy
 HPRF = high pulse repetition frequency
 HR = heart rate
 HV = hepatic vein
 Hz = Hertz (cycles per second)

 I = intensity of ultrasound exposure
 IAS = interatrial septum
 ID = indicator dilution
 inf = inferior
 IV = intravenous
 IVC = inferior vena cava
 IVCT = isovolumic contraction time
 IVRT = isovolumic relaxation time

 kHz = kilohertz

 l = length
 LA = left atrium
 LAA = left atrial appendage
 LAD = left anterior descending coronary artery
 LAE = left atrial enlargement
 lat = lateral