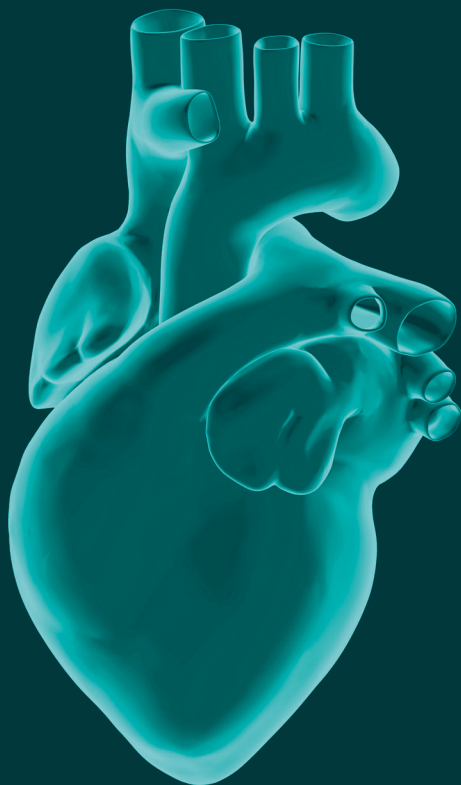
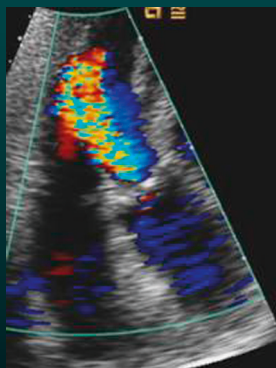
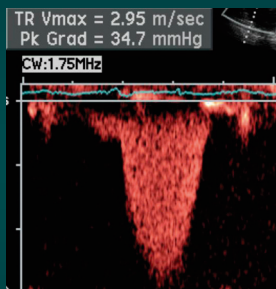
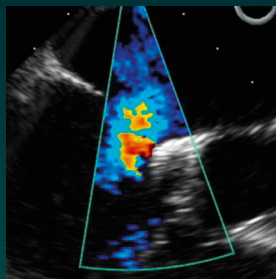


Practical Manual of Echocardiography in the Urgent Setting

Edited by Vladimir Fridman
and Mario J. Garcia



 WILEY-BLACKWELL

Practical Manual of Echocardiography in the Urgent Setting

To:

– Dr Balendu Vasavada, whose knowledge and dedication to echocardiography has been the basis of this textbook. Many of the images in this book are a direct result of his leadership at the echocardiography laboratory of Long Island College Hospital.

– Dr Steven Bergmann, who served as a great mentor throughout my training and clinical practice. His tremendous assistance and dedication to cardiology have made my career possible.

– Dr Cesare Saponieri, who is responsible for all I know about the practice of clinical cardiology. His pursuit of providing great care to patients is truly an inspiration.

– Of course, Dr Mario Garcia for spending countless hours going through all the text, figures, and tables in this book. Without him, this book would not be possible.

– All of my cardiology colleagues who made this book a reality.

Thank you.

Practical Manual of Echocardiography in the Urgent Setting

EDITED BY

Vladimir Fridman, MD

Cardiovascular Diseases
Brooklyn, NY, USA

Mario J. Garcia, MD

Professor, Department of Medicine (Cardiology)
Professor, Department of Radiology
Chief, Division of Cardiology
Co-Director, Montefiore Einstein Center for Heart and Vascular Care
New York, NY, USA

 **WILEY-BLACKWELL**

A John Wiley & Sons, Ltd., Publication

This edition first published 2013, © 2013 by John Wiley & Sons, Ltd.

Wiley-Blackwell is an imprint of John Wiley & Sons, formed by the merger of Wiley's global Scientific, Technical and Medical business with Blackwell Publishing.

Registered Office

John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK.

Editorial Offices

9600 Garsington Road, Oxford, OX4 2DQ, UK

The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

111 River Street, Hoboken, NJ 07030-5774, USA.

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell.

The right of the author to be identified as the author of this work has been asserted in accordance with the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book. This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold on the understanding that the publisher is not engaged in rendering professional services. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

The contents of this work are intended to further general scientific research, understanding, and discussion only and are not intended and should not be relied upon as recommending or promoting a specific method, diagnosis, or treatment by physicians for any particular patient. The publisher and the author make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of fitness for a particular purpose. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of medicines, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each medicine, equipment, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. Readers should consult with a specialist where appropriate. The fact that an organization or Website is referred to in this work as a citation and/or a potential source of further information does not mean that the author or the publisher endorses the information the organization or Website may provide or recommendations it may make. Further, readers should be aware that Internet Websites listed in this work may have changed or disappeared between when this work was written and when it is read. No warranty may be created or extended by any promotional statements for this work. Neither the publisher nor the author shall be liable for any damages arising herefrom.

ISBN: 9780470659977

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover Design: Modern Alchemy LLC

Cover image: Mike Austin

Set in 9/12pt Palatino by SPi Publisher Services, Pondicherry, India

Printed and bound in Singapore by Ho Printing Singapore Pte Ltd

Contents

Contributors, x
Preface, xiv

1 Ultrasound physics, 1

Vladimir Fridman

Ultrasound generation, 7
Image formation, 9
Doppler ultrasound, 15
Summary and key points, 22
References, 22

2 The transthoracic examination, 23

Vladimir Fridman and Dennis Finkelstein

Performing the echocardiogram, 33
Using the transducer, 35
Steps involved in a comprehensive transthoracic echocardiogram, 37
References, 40

3 Transesophageal echocardiography, 41

Salim Baghdadi and Balendu C. Vasavada

Preparation of the patient, 42
Acoustic windows and standard views, 45
Clean-up and maintenance, 54
References, 56

4 Ventricles, 57

Deepika Misra and Dayana Eslava

Left ventricle, 57

Right ventricle, 66

Atria, 72

Contrast echocardiography, 74

References, 77

5 Left-sided heart valves, 79

Muhammad M. Chaudhry, Ravi Diwan, Yili Huang, and Furqan H. Tejani

Aortic valve, 79

Mitral valve, 94

References, 111

6 Right-sided heart valves, 113

Michael J. Levine and Vladimir Fridman

Tricuspid valve, 113

Pulmonic valve, 122

Q_p/Q_s : Pulmonary to systemic flow ratio, 127

References, 127

7 Prosthetic heart valves, 129

Karthik Gujja and Vladimir Fridman

Echocardiographic approach to prosthetic heart valves, 132

Approach to suspected valve dysfunction, 134

References, 140

8 The great vessels, 141

Vladimir Fridman and Hejmadi Prabhu

Aorta, 141

Pulmonary artery, 147

D-septal shift, 151

References, 152

9 Evaluation of the pericardium, 153

Chirag R. Barbhaiya

Pericardial effusions, 153

Cardiac tamponade, 154

Echo-guided pericardiocentesis, 159

- Constrictive pericarditis, 161
- Differentiation of constrictive pericarditis and restrictive cardiomyopathy, 163
- Effusive–constrictive pericarditis, 165
- References, 165

10 Speciality echocardiographic examinations, 167

Cesare Saponieri

- TTE in a VAD patient, 167
- Intracardiac echocardiography, 169
- TEE in the operating room, 171
- Echocardiography to guide percutaneous closure devices placement, 172
- References, 173

11 Common artifacts, 174

Padmakshi Singh, Moinakhtar Lala, and Sapan Talati

- References, 182

12 Hypotension and shock, 183

Sheila Gupta Nadiminti

- Determination of central venous pressure, stroke volume, cardiac output, and vascular resistance, 183
- Hypovolemia, 184
- Septic shock, 188
- Cardiogenic shock due to left ventricular failure, 189
- Cardiogenic shock due to right ventricular failure, 189
- Cardiogenic shock due to acute valvular insufficiency or shunt, 190
- Acute pulmonary hypertension/pulmonary embolism, 190
- References, 193

13 Chest pain syndrome, 195

Sandeep Dhillon and Jagdeep Singh

- Myocardial Infarction, 195
- Aortic dissection, 198
- Pulmonary embolus, 199
- Other causes, 201
- References, 202

14 Cardiac causes of syncope and acute neurological events, 204

Erika R. Gehrie

- Hypovolemia, 205
- Arrhythmias, 205
- Aortic stenosis, 207
- Cardiac tamponade, 207
- Pacemaker malfunction, 207
- Endocarditis, 207
- Pulmonary embolism, 208
- Stroke and transient ischemic attacks, 208
- Cardiac masses, 212
- References, 215

15 Acute dyspnea and heart failure, 216

Mariusz W. Wysoczanski

- Echocardiogram in “heart failure”, 216
- Intracardiac pressures, 217
- Echocardiographic approach to dyspnea with hypoxemia, 222
- Differential diagnosis for cardiac induced dyspnea, 223
- Algorithm for treatment, 223
- References, 225

16 Evaluation of a new heart murmur, 226

Vinay Manoranjan Pai

- Acute valvular regurgitation, 226
- Intracardiac shunts, 231
- Pericardial effusion, 232
- Post myocardial infarction, 232
- References, 233

17 Infective endocarditis, 234

Luis Aybar

- Diagnosis and diagnostic accuracy, 234
- Guidelines for use of echocardiography to diagnose endocarditis, 236
- Appearance on echocardiography, 236
- Complications and risk stratification, 238

Prosthetic valve endocarditis, 239

Cardiac device-related infective endocarditis, 240

References, 241

18 Post-procedural complications, 244

Vladimir Fridman

Noncardiac procedures, 244

Cardiac procedures, 245

References, 247

19 “Quick echo in the emergency department”: What the EM physician needs to know and do, 248

Dimitry Bosoy and Alexander Tsukerman

Goal of FOCUS, 248

Clinical use of FOCUS, 250

References, 252

Index, 253

Contributors

Luis Aybar, MD

Cardiovascular Diseases
Beth Israel Medical Center
New York, NY, USA

Salim Baghdadi, MD

Department of Cardiology
Long Island College Hospital
New York, NY, USA

Chirag R. Barbhaiya, MD

Cardiology Fellow
Beth Israel Medical Center
New York, NY, USA

Dimitry Bosoy, MD

Clinical Teaching Attending
Department of Emergency Medicine
Maimonides Medical Center
Brooklyn, NY, USA

Muhammad M. Chaudhry, MD

Cardiology Fellow
Beth Israel Medical Center
New York, NY, USA

Sandeep Dhillon, MD, FACC

Cardiovascular Diseases
Beth Israel Medical Center
New York, NY, USA

Ravi Diwan, MD

Beth Israel Medical Center
New York, NY, USA

Dayana Eslava, MD

St Luke's Roosevelt Hospital
Columbia University College of Physicians and Surgeons
New York, NY, USA

Dennis Finkelstein, MD, FACC, FASE

Director, Ambulatory Cardiology
Program Director, Cardiovascular Diseases Fellowship
Beth Israel Medical Center, New York, NY, USA
Assistant Professor of Medicine
Albert Einstein College of Medicine
New York, NY, USA

Karthik Gujja, MD, MPH

Division of Cardiology
Department of Internal Medicine
Long Island College Hospital
New York, NY, USA

Erika R. Gehrie, MD, FACC

Medical Director, Echocardiography
Preferred Health Partners,
Brooklyn, NY, USA

Yili Huang, DO, FACC

Beth Israel Medical Center
New York, NY, USA

Moinakhtar Lala, MD

Fellow in Cardiovascular Diseases
Cardiovascular Diseases
Beth Israel Medical Center
New York, NY, USA

Michael J. Levine, MD

Cardiovascular Diseases
NYU Langone Medical Center
New York, NY, USA

Vinay Manoranjan Pai, MBBS, MD

Fellow, Cardiovascular Medicine
Beth Israel Medical Center and Long Island College Hospital
New York, NY, USA

Deepika Misra, MBBS, FACC

Beth Israel Medical Center
New York, NY, USA

Sheila Gupta Nadiminti, MD

Department of Cardiology
Beth Israel Medical Center
New York, NY, USA

Hejmadi Prabhu, MD

Cardiovascular Diseases
Wyckoff Heights Medical Center
Brooklyn, NY, USA

Cesare Saponieri, MD, FACC

Electrophysiology and Cardiovascular Diseases
Brooklyn, NY, USA

Jagdeep Singh, MBBS

Cardiovascular Diseases
Beth Israel Medical Center
New York, NY, USA

Padmakshi Singh, MD

Fellow in Cardiovascular Diseases
Cardiovascular Diseases
SUNY Downstate Medical Center
Brooklyn, NY, USA

Sapan Talati, MD

Fellow in Cardiovascular Diseases
SUNY Downstate Medical Center
Brooklyn, NY, USA

Furqan H. Tejani, MD, FACC, FSCCT

Associate Professor of Medicine
Director, Advanced Cardiovascular Imaging
Director, Nuclear Cardiology and Electrocardiography Laboratories
State University of New York
Downstate Medical Center
University Hospital of Brooklyn at Long Island College Hospital
Brooklyn, NY, USA

Alexander Tsukerman, MD, FACEP

Attending, Emergency Medicine
Partner, Emergency Medical Associates
Staten Island, New York, NY, USA

Balendu C. Vasavada, MD, FACC

Director of Echocardiography and Chief of Cardiology Service
University Hospital of Brooklyn at Long Island College Hospital
SUNY Downstate Medical Center
New York, NY, USA

Mariusz W. Wysoczanski, MD

Fellow, Cardiovascular Diseases
Beth Israel Medical Center
Albert Einstein College of Medicine
New York, NY, USA

Preface

There will be times when you will need to read a comprehensive echocardiography textbook. However, there will be also times when you will need to access quick reference information to help you manage a crashing patient in an urgent situation. This reference guide will provide you everything you need to establish a differential and accurate diagnosis that will lead you to best manage a cardiovascular patient in an emergent situation.

With the first part devoted to basic instrumentation and image acquisition and the second part focusing on the different clinical situations that often require evaluation by echocardiography in the urgent setting, this book is the ideal companion to the physician who needs to implement rapid life and death decisions.

You should use this book as a quick reference guide to echocardiography in the urgent setting. It is designed to help in situations where seconds and minutes can really make a difference in the lives of patients. Even one extra saved life will justify the large amount of work that the authors have put into this work.

Vladimir Fridman and Mario Garcia

Ultrasound physics

Vladimir Fridman

Cardiovascular Diseases, New York, NY, USA

CHAPTER 1

Echocardiography is one of the most valuable diagnostic tests for the evaluation of patients with suspected cardiovascular disease in the acute setting. Even though echocardiography has become more widely available, its performance and interpretation require practice and knowledge of the principles of image formation. Although the physical principles and instrumentation of ultrasound can be quite complex, there are a few basic concepts that every echocardiographer and interpreting physician must understand to maximize the diagnostic utility of this test and avoid misinterpretations. These key concepts are covered in this chapter.

The echocardiogram machine (Figure 1.1) is made up of few distinct components:

- 1 Monitor
- 2 CPU (central processing unit), responsible for all functions of the echocardiogram
- 3 Transducer
- 4 Keyboard/controls
- 5 Printer

The control panel of any echocardiogram looks similar to that shown in Figure 1.2a. The panel is shown in more detail in Figures 1.2b–d, with the important controls labeled. Although slight changes in control positions are noted between machines from different companies, all machines have the key controls that are shown in these images.

The panel from above image, is split into three frames, and the important controls are labeled below.

Practical Manual of Echocardiography in the Urgent Setting, First Edition.

Edited by Vladimir Fridman and Mario J. Garcia.

© 2013 John Wiley & Sons, Ltd. Published 2013 by John Wiley & Sons, Ltd.

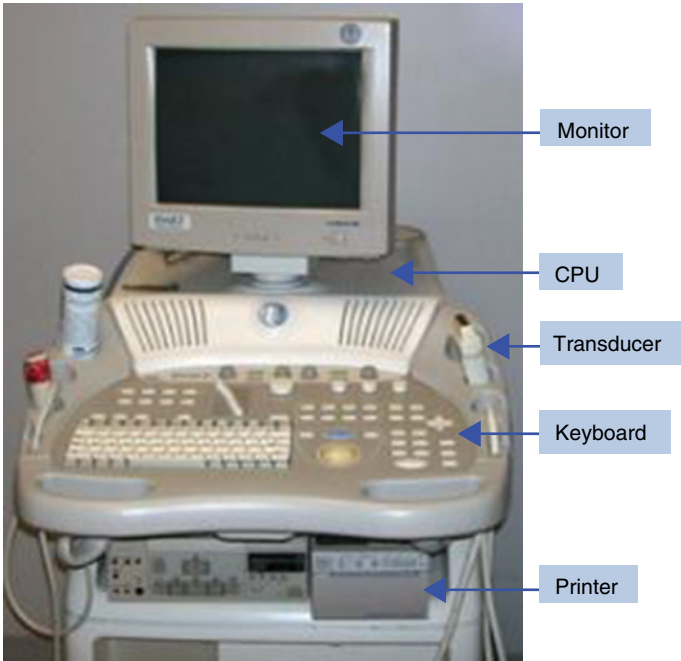


Figure 1.1 Echocardiogram machine.

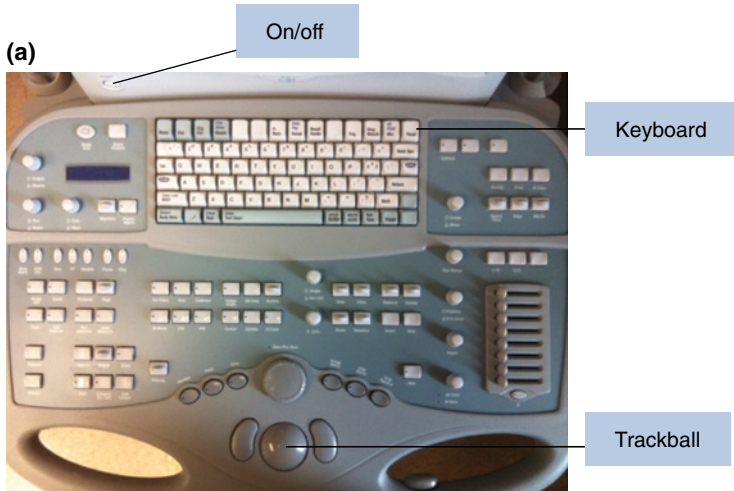


Figure 1.2 Typical echocardiogram control panel.

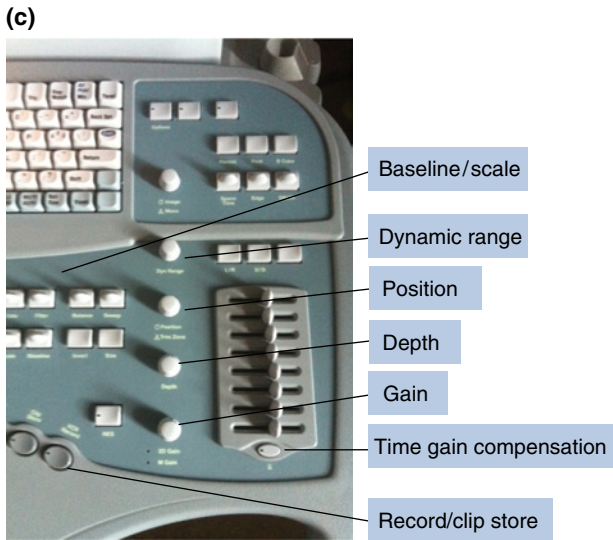
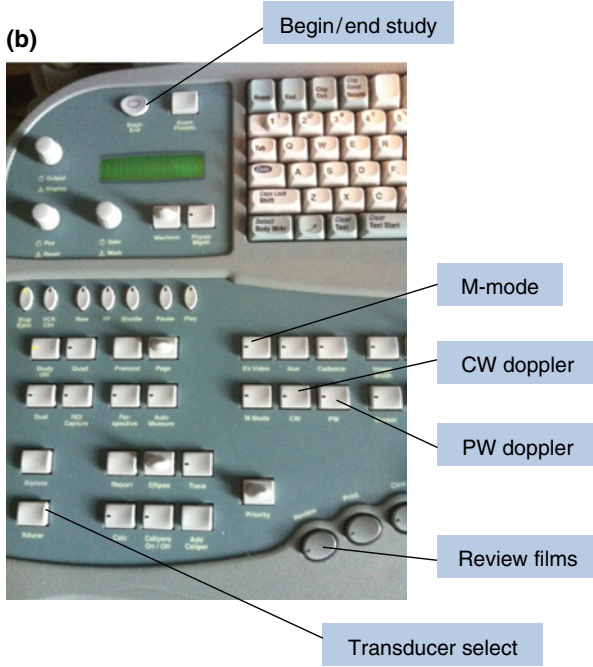


Figure 1.2 (Cont'd)

(d)

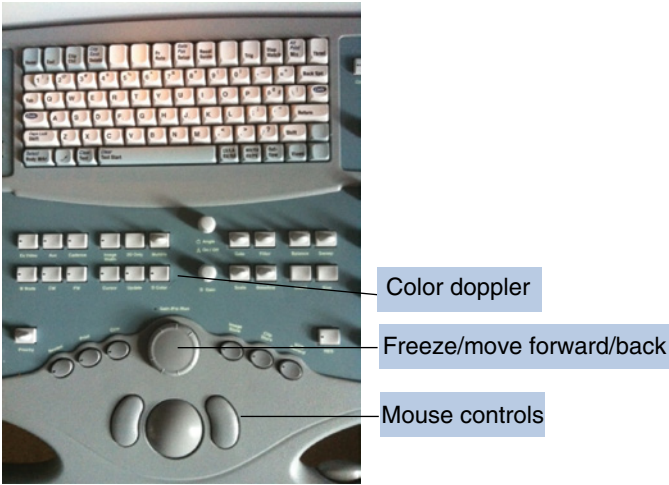


Figure 1.2 (Cont'd)

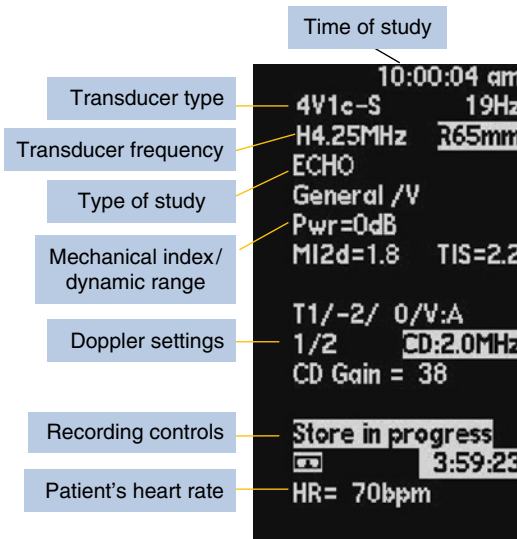


Figure 1.3 Echocardiography settings.

The important echocardiographic settings as displayed on the monitor of most ultrasound machines are shown in Figure 1.3. These settings can be changed, as needed, to adjust the image quality.

The different echocardiographic modes that are available, which are described later in this book, are:

- M-mode: a graphic representation of a specific line of interest of a two-dimensional image (Figure 1.4).

- 2D: a two-dimensional view of cardiac structures that can be visualized as time progresses (Figure 1.5).
- Color Doppler: a color representation of blood flow velocities superimposed on a two-dimensional image (Figure 1.6).
- CW/PW Doppler: the representation of flow velocities as plotted with time on the x axis and velocity on the y axis (Figure 1.7).
- Tissue Doppler: the measurement of tissue velocities (Figure 1.8).

The controls, as shown in the figures, switch between the different modes of echocardiography. However, before moving on to performing and

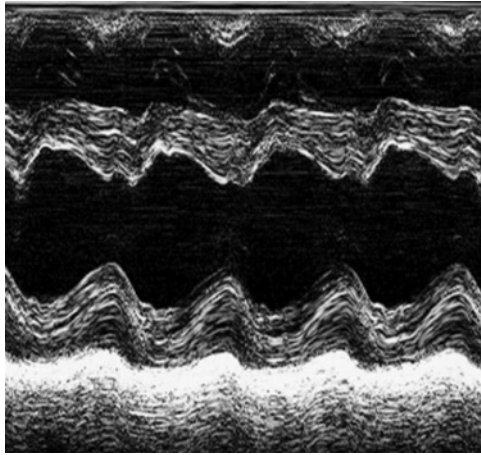


Figure 1.4 M-Mode: a graphic representation of a specific line of interest of a two-dimensional image.



Figure 1.5 2D: a two-dimensional view of cardiac structures that can be visualized as time progresses.

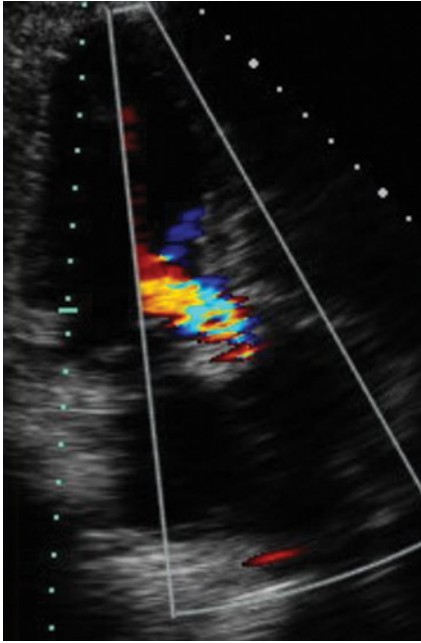


Figure 1.6 Color Doppler: a color representation of blood flow velocities superimposed on a two-dimensional image.

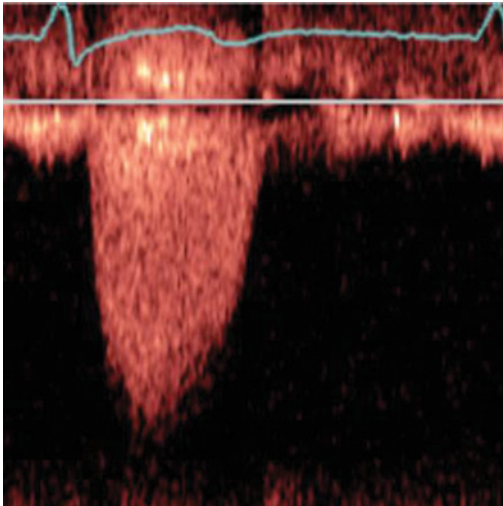


Figure 1.7 CW/PW Doppler: the representation of flow velocities as plotted with time on the x axis and velocity on the y axis.

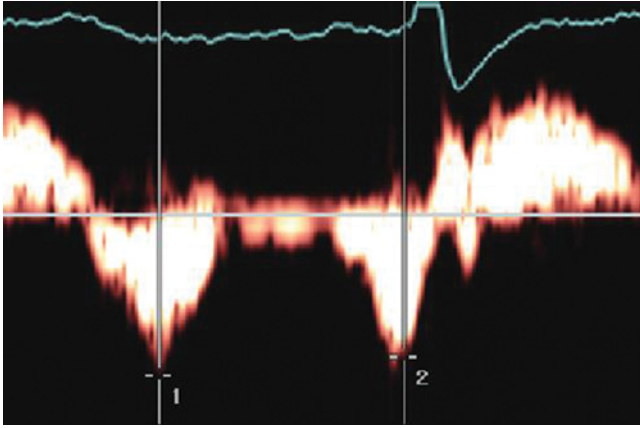


Figure 1.8 Tissue Doppler: the measurement of tissue velocities.

interpreting echocardiograms, it is necessary to be aware of the physics behind this imaging modality.

Ultrasound generation

Ultrasound is a cyclic sound pressure waveform whose frequency is greater than the limit of human hearing. This number is generally considered to be 20kHz, or 20 000Hz (Hertz). Echocardiography usually relies on sound waves ranging from 2 to 8MHz. The echocardiograph, or any other medical ultrasound machine, produces these high frequency sound waves using transducers that contain a piezoelectric crystal.

A piezoelectric crystal (such as quartz or titanate ceramics) is a special material that compresses and expands as electricity is applied to it. This compression and expansion generates the ultrasound wave. The rate (frequency) of compression and expansion is based on the current that the ultrasound machine applies to the piezoelectric signal, which in turn is based on the settings the operator has selected on the machine.

An ultrasound wave, as all sound waves, has some basic physical properties (Figure 1.9). These are:

- Cycle – the sum of one compression and one expansion of a sound wave.
- Frequency (f) – the number of cycles per second.
- Wavelength (λ) – the length of one complete cycle of sound.
- Period (p) – the time duration of one cycle.
- Amplitude – the maximum pressure change from baseline of a sound wave.
- Velocity (v) – speed at which sound moves through a specific medium.

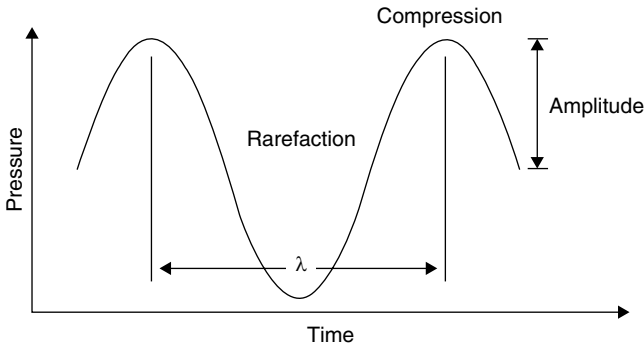


Figure 1.9 A sound wave is made up of varying pressure cycles formed by repeating of compression and rarefaction. The distance between similar points in a wave is called the wavelength (λ) [1].

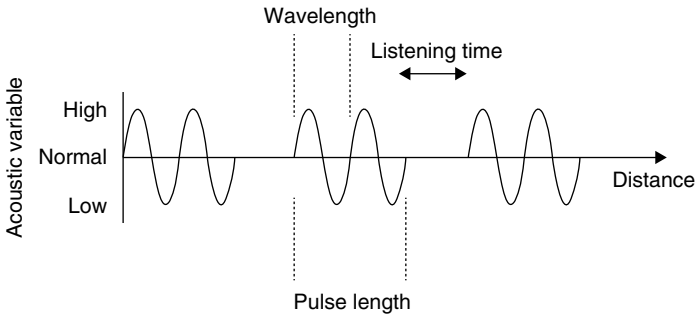


Figure 1.10 A pulse can consist of multiple wavelengths of a sound wave. In this figure, three pulses are shown, each the length of two wavelengths (Reproduced from Case [2], with permission from Elsevier).

A basic property of all sound waves is: $\text{Velocity} = \text{Frequency } (f) \times \text{Wavelength } (\lambda)$. This formula shows that frequency and wavelength are inversely related, since the velocity of a sound wave depends on the density of the medium the wave is traveling in.

In an echocardiogram machine, current is applied to the piezoelectric crystal, which then emits ultrasound energy into human tissue. The ultrasound is emitted in pulses that usually consist of several consecutive cycles of a sound wave with the same frequency separated by a pause (Figure 1.10). An extremely important concept for ultrasound is the frequency of pulses that the ultrasound emits; this is called the Pulse Repetition Frequency (PRF). The inverse of PRF is the Pulse Repetition Period (PRP), which is the time from the beginning of one ultrasound pulse to the next:

$$\text{PRF} = 1 / \text{PRP}$$

The actual length of the pulse – the spatial pulse length (SPL) – is equal to the wavelength multiplied by the number of cycles in a pulse.

Once an ultrasound pulse is emitted from the transducer, the entire mechanism enters the “listening” phase. At this time, the ultrasound machine is waiting to receive back the pulse it emitted after it was reflected from distant structures. It is important to know that the ultrasound machine spends almost 99% of the time listening for, and 1% of the time generating, a signal.

Image formation

As the ultrasound wave exits the echocardiogram probe, it enters the human tissue. When the ultrasound waves encounter a change in tissue density, such as the endocardium–blood interphase, some of them will be reflected back while others will penetrate deeper into the tissue. Thus, ultrasound energy is greater near the transducer and is progressively lost as it penetrates into the tissue. The ultrasound systems typically compensate by amplifying more the signals that are received from the far field to make the image homogeneous. The interaction of ultrasound with human tissue is also very complex. However, it is important to know that within soft tissue the velocity of ultrasound is fairly constant at 1540 m/s. In fact, it is usually assumed that this is the velocity of sound in human tissue. However, it is not always the truth. The velocities of ultrasound in various human tissues are shown in Table 1.1.

This concept is extremely important, since the ultrasound machine is not able to recognize whether the ultrasound it receives back from the body traveled mainly through bone, through soft tissue, through air, or any combination of the above structures. As such, it computes the distance the ultrasound traveled based on a velocity of 1540 m/s. Therefore, objects can be misplaced on an ultrasound image because of this velocity assumption, which is built into the ultrasound machine. This explains

Table 1.1 Velocity of ultrasound in various human tissues.

| Medium | Velocity (m/s) |
|--------------------|----------------|
| Air (the slowest) | 330 |
| Soft tissue | 1540 |
| Blood | 1570 |
| Muscle | 1580 |
| Bone (the fastest) | 4080 |

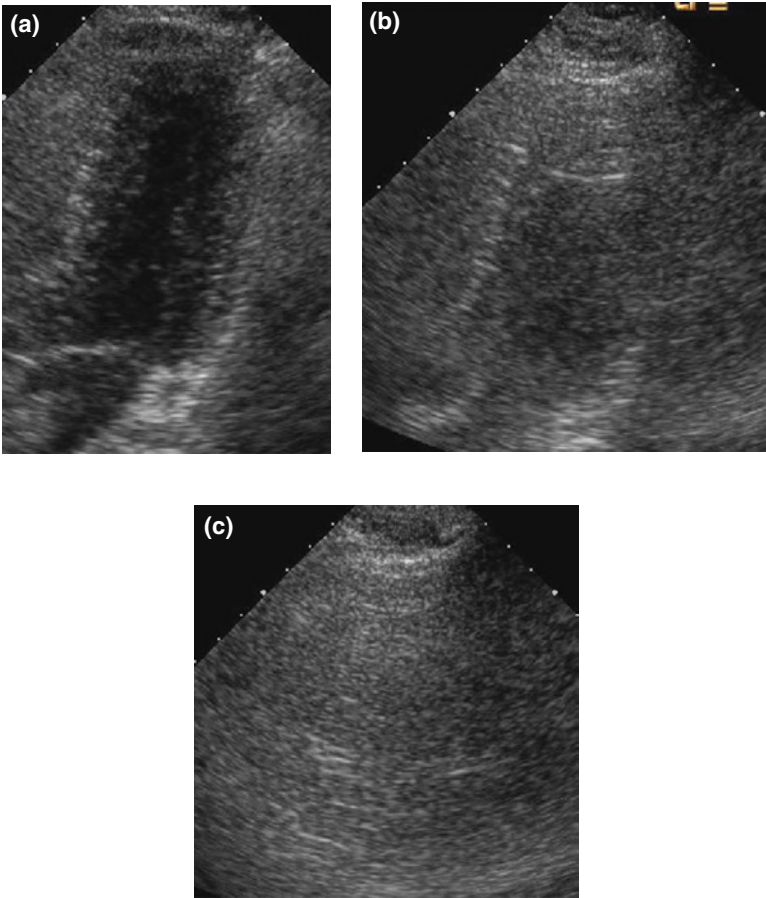


Figure 1.11 An apical four-chamber view of the same patient when the patient has exhaled (a), as the patient is inhaling (b), and as the patient is fully inhaled (c). As clearly seen, the quality of the myocardial image declines acutely as more air enters the lung of the patient, to a point where no myocardium is seen in full inhalation (c).

why interposition of ribs or lung tissue between the transducer and the heart will produce severe imaging artifacts and make part of the image uninterpretable (Figure 1.11).

Another important point to remember is the behavior of the ultrasound beam as it emerges from the transducer (Figure 1.12). The ultrasound beam is initially parallel and cylindrical (near zone). However, after its narrowest point, the focal zone, it begins to diverge and acquires a cone shape (far zone). For reasons outside the scope of this book, the imaging is much better if the object of interest is located near the focal zone. The near zone length is calculated via: $\text{near field} = (\text{radius of transducer})^2 / \text{wavelength of ultrasound}$. The location of the focal zone can be adjusted electronically.

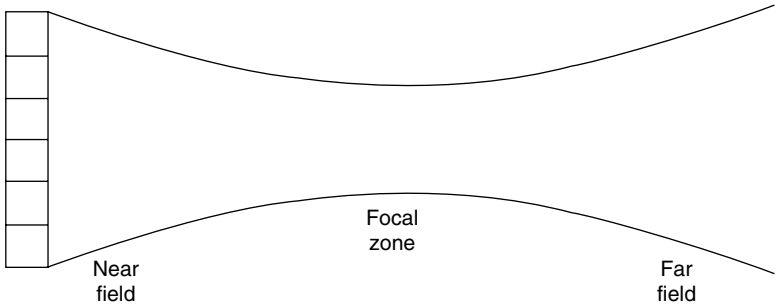


Figure 1.12 Behavior of an ultrasound beam as it comes out of the ultrasound probe (Reproduced from [2] Case, TD. Ultrasound Physics and Instrumentation. Surg Clin N Am. 1998;78(2):197–217).

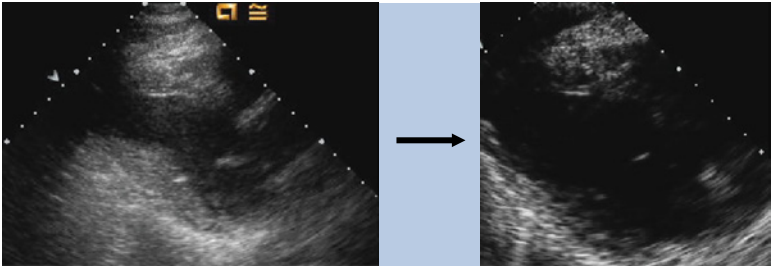


Figure 1.13 Image changes with a decrease in ultrasound frequency.

Resolution versus penetration

The behavior of the beam within tissue determines the lateral resolution of the ultrasound, or the ability to distinguish two objects located side by side on an ultrasound image. The axial resolution, or the ability to distinguish two objects one in front of the other, on an ultrasound image is determined by ultrasound transducer frequency ($1/\text{wavelength}$). At higher frequency, axial resolution increases. However, since the ultrasound signal is attenuated as it travels through the tissues, more attenuation occurs. In general, high frequency is preferred for imaging structures that are closer to the transducer and lower frequency for those that are far. In the case shown in Figure 1.13, a parasternal long axis view loses its definition as the transducer frequency is changed from 4.0MHz to 2.0MHz.

As the ultrasound comes back to the transducer, the same piezoelectric properties of crystal that allow the ultrasound waves to be made allow the conversion of the received ultrasound waves into electrical signals. A typical 2D ultrasound transducer has 128 or 256 individual crystal-electronic interphases. In M-mode imaging, the ultrasound beam is emitted and received only at 90° . By alternating the time and sequence in

which these are stimulated, the ultrasound beam can be steered at almost any angle. By steering rapidly while emitting and receiving at sequential angles a two-dimensional image is formed (Figure 1.14).

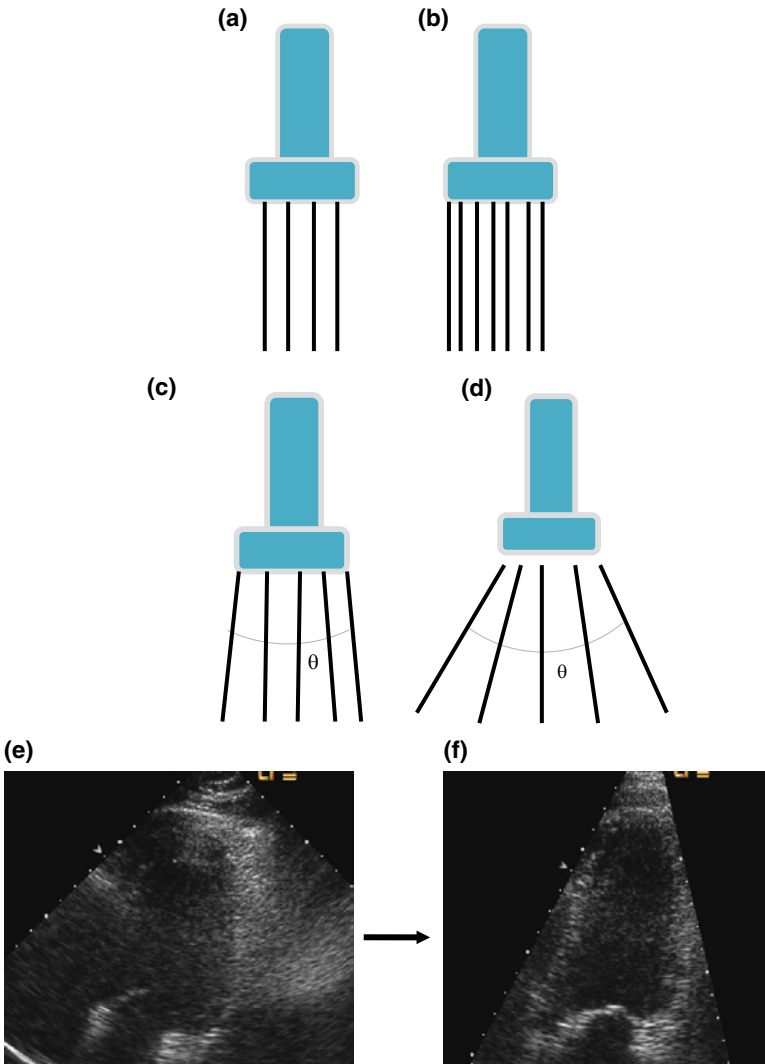


Figure 1.14 As the scan line density increases (a→b), the accuracy and resolution of the image increase. As the sector angle (θ) increases (c→d), more structures are noted as the area being interrogated by the ultrasound beam increases. However, going to a narrower angle (e→f) increases resolution, as is seen in this set of images where a wider view (e) shows multiple structures, while the same view with a narrower sector angle (f) more clearly shows the endocardial definition of the left ventricle.