Emergency Echocardiography
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Foreword

Echocardiography has certainly become the mostly used non-invasive imaging technology in the assessment of cardiac function. Several technical refinements over the years have made it a superb diagnostic tool in different clinical settings, including the intensive (ICU, intensive care unit)/emergency (ER, emergency room) care atmosphere. The ability to perform transesophageal studies, to use contrast or three dimensional echo and fully assess the hemodynamics at bedside in a reliable way, or use a hand-held device, among others, has added significant value and accuracy to the way patients are currently managed in the ICU/ER. It is also a reality that echocardiography has expanded beyond the boundaries of cardiology, which is unavoidable (and maybe even desirable). It is, however, important to strongly underline the need of proper knowledge and training in order to make it a useful and reliable method. This encompasses a whole set of different approaches, including practical training and adequate sources of information and study. This book by Adrian Chenzbraun certainly fulfils this goal in several ways. In opposition to the conventional classical books, sometimes with too many theoretical details that make the reader a bit lost, in this book there was great care in making it a useful bedside tool with very practical tips, profuse illustrations demonstrating the main uses, pitfalls, and tricks of echocardiography in the emergency setting. With great wit the author provides very practical algorithms for the different clinical situations. Consequently, this is a book not only for the ones who are starting to use the technique but also will certainly be a great help for the experienced echocardiologist or intensivist. Certainly, the extensive experience of the author in the field helped in crafting this book and turning it into a real practical advisor.
I will finish with a quote 2,400 years old from Hippocrates, which I think applies perfectly to this book: “Everyone has a doctor in him or her; we just have to help it in its work.” *Emergency Echocardiography* will certainly be a great help for all of those who will use it for their clinical work.

Fausto J. Pinto  
Professor of Cardiology, Lisbon University, Portugal  
Past President of European Association of Echocardiography (EAE)  
Lisbon, September 25, 2008
The idea of writing this book arose from frequent encounters with cardiologists in training and intensivist colleagues who highlighted the contribution of echocardiographic studies to the evaluation of difficult cases. In this, our experience only mirrored the growing role of echocardiography in the immediate management of hemodynamically unstable or acutely ill patients, as increasingly acknowledged in the literature.\textsuperscript{1-3}

Echocardiography is the most versatile cardiac imaging technology readily available today at the patient’s bedside. Its superb diagnostic input relates to the ability to identify any hemodynamic condition and cardiac pathology that implies a morphologic and/or a flow pattern change. Impressive technological advances over the last half century (Table I.1) and the advent of small, portable, and yet powerful echocardiographic machines pushed this technique in the frontline of diagnostic strategies when dealing with critically ill patients. Indeed, we are witnessing a change of medical practice, whereby, the management of hemodynamically unstable patients relies less on invasive data and increasingly more on the noninvasive assessment immediately obtainable with echocardiography.

It is the aim of this book to be a step-by-step, how- and what-to-do, easy to use guide for the benefit of cardiology and intensive care doctors and sonographers faced with critically ill patients for whom major therapeutic decisions could depend on the information provided by a timely and accurate echocardiographic examination. It tries to address what was perceived to be the practical needs of cardiology trainees and of intensivists faced with the increased use of echocardiography in an acute care setting. Because of the intended dual audience of this book, both pure “cardiological” topics such as aortic pathology, valvular emergencies, mechanical complications of myocardial infarction, or tamponade and more “intensive care” or “mixed” situations such as pulmonary embolism, resuscitation, sepsis, and the need for filling status assessment are covered.
The users of this guide should have an echocardiography expertise roughly equivalent to at least level 1, that is, able to understand echocardiographic studies and information and ideally level 2. A special case, however, is that of acute and intensive care doctors for whom a more basic and targeted understanding of echocardiographic practice may be adequate to address a few major and well-defined pathologies in a focused way.

The book starts with an opening chapter dedicated to the essentials of echocardiographic technology, standard imaging, newer techniques and practical, and “don’t forget to …” tips to perform a study with diagnostic value. Evolving technologies which are yet to be adopted into routine clinical practice such as three-dimensional echocardiography or speckle tracking are not discussed. Beginning with fundamental concepts and then reviewing the main controls and settings of an echocardiographic machine, this section was written having in mind the less-experienced echocardiographer, possibly not a cardiologist, who nevertheless may have to perform an urgent study at a time when no one more skilled is available for help and advice. However, this chapter addresses the basic concepts only and, thus, is to be seen as an aid, and in no way as a substitute for a proper training in performing a basic echocardiographic examination. Also, any information

Table I.1  Echocardiographical historical landmarks

<table>
<thead>
<tr>
<th>Year</th>
<th>Development</th>
<th>Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954</td>
<td>First M-mode study</td>
<td>3D echocardiography</td>
</tr>
<tr>
<td>1970s</td>
<td>2D technology</td>
<td>Second harmonic and contrast echocardiography</td>
</tr>
<tr>
<td>1980s</td>
<td>Spectral and color Doppler</td>
<td>Tissue Doppler echocardiography</td>
</tr>
<tr>
<td>1990s and 2000s</td>
<td>Techniques</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stress echocardiography</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intraoperative echocardiography</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intravascular echocardiography</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intracardiac echocardiography</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hand-held echocardiography</td>
<td></td>
</tr>
</tbody>
</table>

2D two-dimensional, 3D three-dimensional, TEE transesophageal echocardiography
or guideline provided by this book should be individualized and selectively applied in a given case, using clinical judgment and the advice of a more experienced colleague, if needed.

The various applications of echocardiography in critically ill patients are discussed in the following sections, trying to strike the right balance between a didactic approach and a practical one; whereby, a clinical scenario is used to raise the questions which should be answered by an echocardiographic study. More specialized topics and practical issues are summarized in appendixes to be found at the end of the book. Essential indexed references are provided at the end of each chapter and they are supplemented by a list of general references and resources in Appendix H.

Unless mentioned otherwise, all figures are from the author’s personal collection.

The possible mentioning or identification of echocardiographic equipment throughout the text should in no way be seen as an endorsement of the particular brand involved.

References


Acknowledgments

This book would not have been possible without the hard work and support of sonographers at the Royal Liverpool University Hospital and the Liverpool Heart and Chest Hospital.

Special thanks to friends and colleagues who reviewed the manuscript and whose suggestions have been incorporated in the final text.
Dr. Adrian Chenzbraun was trained in echocardiography at Stanford University, CA. He has authored numerous articles in peer-reviewed medical journals. Presently, he is a consultant cardiologist and clinical lead in echocardiography at the Royal Liverpool University Hospital and the Liverpool Heart and Chest Hospital.
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Symbols and Abbreviations

2D two dimensional
3D three dimensional
ACS acute coronary syndrome
AD aortic dissection
AF atrial fibrillation
AMI acute myocardial infarction
AML anterior mitral leaflet
AO aorta
APM anterolateral papillary muscle
AR aortic regurgitation
AS aortic stenosis
ASD atrial septal defect
AV aortic valve
AVA aortic valve area
AVR aortic valve replacement
AVSR acute ventricular septal rupture
BP blood pressure
CAUSE Cardiac Arrest Ultrasound Examination
CBV central blood volume
CE contrast echocardiography
CMP cardiomyopathy
COLD chronic obstructive lung disease
CPR cardiopulmonary resuscitation
CRT cardiac resynchronization therapy
CSA cross-sectional area
CT computed tomography
CVP central venous pressure
CW continuous wave
DA descending aorta
DT deceleration time
EDV end-diastolic volume
EGALS Echo Guided Advanced Life Support
EMEA European Medicines Agency
EROA effective regurgitant orifice area
ESV    end-systolic volume
FAST   Focused Assessment by Sonography in Trauma
FDA    Food and Drugs Administration
FEER   Focused Echocardiographic Evaluation in Resuscitation
FL     false lumen
FPS    frames per second
HCU    hand-carried ultrasound
IABP   intraaortic balloon pump
IAS    interatrial septum
IE     infective endocarditis
IMET   Immediate Echocardiographic Triage
IMH    intramural hematoma
IP     intrapericardial pressure
ICU    intensive care unit
IVC    inferior vena cava
IVS    interventricular septum
LA     left atrium
LAA    left atrial appendage
LAD    left anterior descending coronary artery
LBBB   left bundle branch block
LCA    left carotid artery
LCC    left coronary cusp
LCx    left circumflex coronary artery
LMCA   left main coronary artery
LSA    left subclavian artery
LUPV   left upper pulmonary vein
LV     left ventricle
LVAD   left ventricular assist device
LVAW   left ventricle anterior wall
LVEDP  left ventricular end-diastolic pressure
LVEF   left ventricular ejection fraction
LVIW   left ventricle inferior wall
LVLW   left ventricular lateral wall
LVO    left ventricle opacification
LVOT   left ventricle outflow tract
LVPW   left ventricular posterior wall
LVT    left ventricular thrombus
MI     myocardial infarction
MPA    main pulmonary artery
MR     mitral regurgitation
MRI    magnetic resonance imaging
MS     mitral stenosis
MV     mitral valve
MVA  mitral valve area
NCC  non-coronary cusp
P$_{1/2}T$  pressure half-time
PAP  pulmonary artery pressure
PCI  percutaneous coronary intervention
PCWP  pulmonary capillary-wedged pressure
PDA  posterior descending artery
PE  pulmonary embolism
PEA  pulseless electrical activity
PF  pericardial fluid
PFO  patent foramen ovale
PHT  pulmonary hypertension
PISA  proximal isovelocity surface area
PML  posterior mitral leaflet
PPM  posteromedial papillary muscle
PSLA  parasternal long axis
PSSA  parasternal short-axis view
PV  pulmonic valve
PW  pulsed wave
RA  right atrium
RAA  right atrial appendage
RAP  right atrial pressure
RCA  right coronary artery
RCC  right coronary cusp
RF  regurgitant fraction
RPA  right pulmonary artery
RV  right ventricle
RVOT  right ventricle outflow tract
RVSP  right ventricular systolic pressure
SAM  systolic anterior motion
SBP  systolic blood pressure
SPW  subxyphoid pericardial window
SV  stroke volume
SVC  superior vena cava
TC  Takotsubo cardiomyopathy
TD  tissue Doppler
TEE  transesophageal echocardiography
TGC  time gain controls
TIA  transient ischemic attack
TL  true lumen
TR  tricuspid regurgitation
TTE  transthoracic echocardiography
TV  tricuspid valve
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>US</td>
<td>ultrasound</td>
</tr>
<tr>
<td>VC</td>
<td>vena contracta</td>
</tr>
<tr>
<td>VF</td>
<td>ventricular fibrillation</td>
</tr>
<tr>
<td>VSD</td>
<td>ventricular septal defect</td>
</tr>
<tr>
<td>VTI</td>
<td>velocity time integral</td>
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</table>
Chapter 1
Getting Ready for the Study

The amount and complexity of possible controls of an echocardiographic machine and the involved physical principles can be bewildering without full technical training. This chapter deals with basic theoretical assumptions and the mastering of those controls, which are necessary to perform a clinically useful study. Suggestions for controls optimization are provided in a practical manner, as well as tips to avoid frequent artifacts. Increasingly popular techniques, such as tissue Doppler and contrast echocardiography, are explained with an emphasis on practical aspects of their use. All standard echocardiographic views are presented, using a rich iconography, and highlighting the potential clinical information provided.

1.1 ULTRASOUND SYSTEMS BASICS
From the simplest to the most sophisticated, any echocardiography system will consist of the following basic components:

- Transducer(s)
- Computing system to process the ultrasound signal
- Screen display
- Analogic (VCR tape recorder) and/or digital (optical disk/DVD) storage capacity

Among the numerous technical parameters and concepts related to the use of ultrasound for medical diagnostic purposes, the following represents a minimum to be fully understood even
by “occasional” users, if they are to obtain a diagnostic quality study. For more in-depth presentation of the physics of ultrasound imaging, the reader is referred to available general echocardiography textbooks (Appendix H).

1.2 ULTRASOUND FREQUENCY AND WAVELENGTH

*FIG. 1.1*

By definition, ultrasound has a frequency above 20,000 Hz, which is the upper limit of the audible spectrum of the human ear. The usual range of frequencies for cardiology diagnostic purposes is much higher: 1.5–5.0 MHz for transthoracic (TTE) studies, 5–7 MHz for transesophageal studies, and 7–10 MHz for intracardiac studies. As opposed to first-generation mechanical transducers, present phased array ones have a small footprint so they can be used even with a narrow intercostal space and are able to deliver several frequencies, which can be selected with the appropriate controls.

The actual frequency is displayed along with other technical data on the machine screen (Fig. 1.2). For a given propagation velocity (around 1,500 m/s in soft tissues), these high frequencies ensure wavelengths <1 mm, which are suitable for the visualizations of cardiac structures. The concept of wavelength is important since it defines image resolution (see below).

*FIG. 1.1. Schematic representation of an ultrasound wave.*
Fig. 1.2. Screen snapshot (*in this example a Philips IE 33 machine*) displaying main settings and imaging characteristics. The transducer frequencies in harmonic imaging are displayed on the left side with a triangle symbol (*dotted arrow*); the lower number is the emitted frequency and the higher one, the received harmonic frequency. The frame rate (Hz) and the image depth (cm) are displayed in the left upper corner (*thick arrow*). A thin line with a central *dot* shows the position of the focal zone, where ultrasound energy is maximal. 

**a** Large sector width. **b** Narrow sector width. Note the increase in frame rate from 56 Hz to 134 Hz when using a narrow sector.
1.3 INTERACTION OF ULTRASOUND WITH TISSUES AND IMAGE FORMATION (FIG. 1.3)

1.3.1 Reflection
The ultrasound image is generated when the main ultrasound beam is reflected by the targeted structure and thus redirected toward the transducer. Reflection occurs at interfaces between media of different acoustic impedance, that is, with different densities and ultrasound propagation velocities. When the differences in impedance are high, such as for pericard, bone, air, heavily calcified structures, or prosthetic material, the intensity of the reflected signal is high as well, while the blood-myocardium interface is a much weaker reflector and will return a small amount of the incident signal. Strong reflectors may totally block the ultrasound signal distal to them (the so-called “shadowing” noted with prosthetic valves) or induce artifacts whereby the ultrasound signal “travels” back and forth between the transducer and an anatomical structure.

![Fig. 1.3. Schematic representation of ultrasound interaction with targets of different sizes (See text for details).]