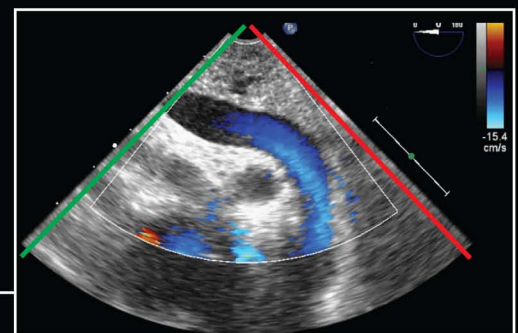
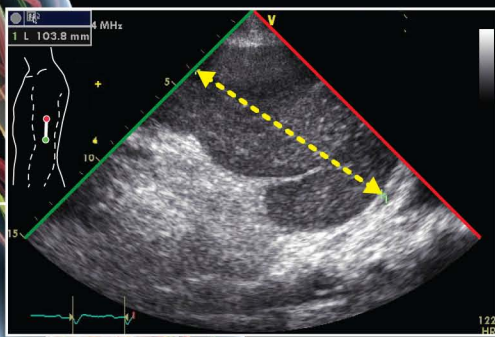
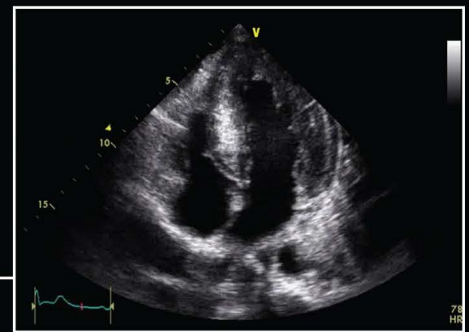
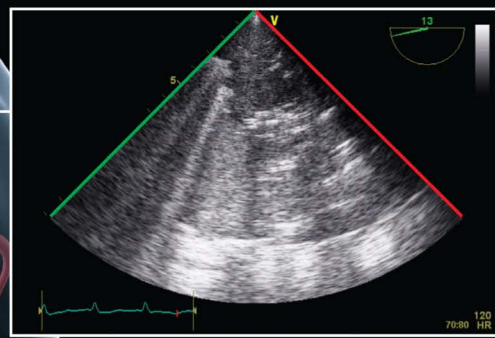
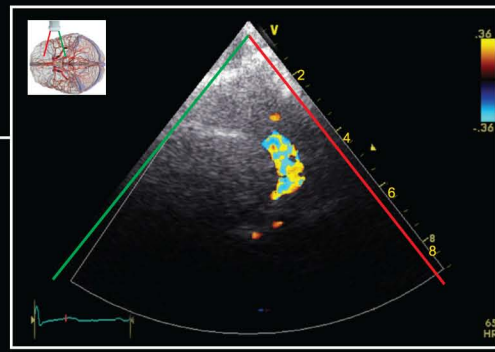


BASIC TRANSESOPHAGEAL AND CRITICAL CARE ULTRASOUND



EDITED BY
ANDRÉ Y. DENAULT
ANNETTE VEGAS
YOAN LAMARCHE
JEAN-CLAUDE TARDIF
PIERRE COUTURE



BASIC
**TRANSESOPHAGEAL
AND CRITICAL CARE**
ULTRASOUND



Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>

BASIC
**TRANSESOPHAGEAL
AND CRITICAL CARE**
ULTRASOUND

EDITED BY
ANDRÉ Y. DENAULT
Institut de Cardiologie de
Montréal, Québec, Canada

ANNETTE VEGAS
Toronto General Hospital
Ontario, Canada

YOAN LAMARCHE
Institut de Cardiologie de Montréal
and Hôpital du Sacré-Coeur de
Montréal, Québec, Canada

JEAN-CLAUDE TARDIF
Research Center at the Montreal
Heart Institute, Québec, Canada

PIERRE COUTURE
Institut de Cardiologie de
Montréal, Québec, Canada



CRC Press

Taylor & Francis Group

Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

© 2018 by Taylor & Francis Group, LLC
CRC Press is an imprint of Taylor & Francis Group, an Informa business

No claim to original U.S. Government works

Printed on acid-free paper

International Standard Book Number-13: 978-1-4822-3712-2 (Pack – Book + eBook)

This book contains information obtained from authentic and highly regarded sources. While all reasonable efforts have been made to publish reliable data and information, neither the author[s] nor the publisher can accept any legal responsibility or liability for any errors or omissions that may be made. The publishers wish to make clear that any views or opinions expressed in this book by individual editors, authors or contributors are personal to them and do not necessarily reflect the views/opinions of the publishers. The information or guidance contained in this book is intended for use by medical, scientific or health-care professionals and is provided strictly as a supplement to the medical or other professional's own judgement, their knowledge of the patient's medical history, relevant manufacturer's instructions and the appropriate best practice guidelines. Because of the rapid advances in medical science, any information or advice on dosages, procedures or diagnoses should be independently verified. The reader is strongly urged to consult the relevant national drug formulary and the drug companies' and device or material manufacturers' printed instructions, and their websites, before administering or utilizing any of the drugs, devices or materials mentioned in this book. This book does not indicate whether a particular treatment is appropriate or suitable for a particular individual. Ultimately it is the sole responsibility of the medical professional to make his or her own professional judgements, so as to advise and treat patients appropriately. The authors and publishers have also attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, please access www.copyright.com (<http://www.copyright.com/>) or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. CCC is a not-for-profit organization that provides licenses and registration for a variety of users. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

Visit the Taylor & Francis Web site at
<http://www.taylorandfrancis.com>

and the CRC Press Web site at
<http://www.crcpress.com>

Visit Companion Website: www.crcpress.com/cw/denault

Dedication

This book is dedicated to:

My wife Denise Fréchette and my children Jean-Simon, Gabrielle, and Julien who have supported me with love and patience (André Y Denault)

My parents, Patrick and Lena, and my brother Derek, who have always been supportive (Annette Vegas)

Maude and Julien for their support and inspiration (Yoan Lamarche)

Michèle, Jean-Daniel and Pier-Luc (Jean-Claude Tardif)

Frédéric and Noémie (Pierre Couture)

And above all, our patients for whom we believe that knowledge in the use of bedside ultrasound will improve their care.

The editors would like to thank sincerely Dora and Avrum Morrow and the Richard I Kaufman Endowment Fund in Anesthesia and Critical Care.



Avrum Morrow



Richard I Kaufman



Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>

List of contributors

Martin Albert, MD, FRCPC Associate Professor of Medicine, Internist and Intensivist, Department of Medicine and Critical Care, Hôpital du Sacré-Coeur de Montréal Research Center and Intensivist, Department of Surgery, Institut de Cardiologie de Montréal, Université de Montréal, Montréal, Québec, Canada

Christian Ayoub, MD, B.Pharm, FRCPC Clinical Assistant Professor, Department of Cardiac Anesthesiology, Institut de Cardiologie de Montréal, Department of Anesthesiology, Maisonneuve-Rosemont Hospital, Université de Montréal, Montréal, Québec, Canada

Mustapha Belaidi, MD Department of Cardiac Anesthesiology, Centre Hospitalier Universitaire (CHU) de Nantes, Nantes, France

François M. Carrier, MD, FRCPC Clinical Assistant Professor, Department of Anesthesiology and Division of Critical Care, Department of Medicine, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montréal, Québec, Canada

D. Catalina Casas Lopez, MD Department of Anesthesia and Perioperative Medicine, London Health Sciences and St. Joseph's Health Care, University of Western Ontario, London, Ontario, Canada

Yiorgos Alexandros Cavayas, MD, FRCPC Critical Care Fellow, Université de Montréal, Montréal, Québec, Canada

David-Olivier Chagnon, MD, FRCPC Department of Radiology, Hôpital Pierre-Boucher, Longueuil, Québec, Canada

Carl Chartrand-Lefebvre, MD, FRCPC Clinical Professor, Department of Radiology, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montréal, Québec, Canada

Robert Chen, MD, FRCPC Assistant Professor of Anesthesia, Cardiac Anesthesia and Intensive Care, University of Ottawa Heart Institute, University of Ottawa, Ottawa, Ontario, Canada

Anne S. Chin, MD, FRCPC Assistant Professor, Department of Radiology, Cardiothoracic Section, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montréal, Québec, Canada

Jennifer Cogan, MD, M.Epid, FRCPC Associate Professor, Department of Anesthesiology, Institut de Cardiologie de Montréal, Université de Montréal, Montréal, Québec, Canada

Geneviève Côté, MD, MSc, FRCPC Assistant Professor, Pediatric Cardiac Anesthesiologist, Department of Pediatric Anesthesia, Centre Hospitalier Universitaire (CHU) Mère-Enfant Sainte-Justine, Université de Montréal, Montréal, Québec, Canada

Pierre Couture, MD, FRCPC Clinical Associate Professor, Cardiac Anesthesiology Department, Institut de Cardiologie de Montréal, Department of Anesthesiology, Université de Montréal, Montréal, Québec, Canada

André Y. Denault, MD, PhD, FRCPC, FASE, ABIM-CCM, FCCS Professor, Critical Care Ultrasound Training Program Director, Department of Cardiac Anesthesiology and Division of Critical Care of the Department of Cardiac Surgery, Institut de Cardiologie de Montréal and Division of Critical Care of the Department of Medicine, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montréal, Québec, Canada

Georges Desjardins, MD, FRCPC, FASE Associate Professor of Anesthesiology, Director of Perioperative Echocardiography, Department of Anesthesiology, Institut de Cardiologie de Montréal, Université de Montréal, Montréal, Québec, Canada

Vinay K. Dhingra, MD, FRCPC Clinical Associate Professor of Medicine, Medical Director Quality Critical Care Vancouver Acute Clinical Lead, Department of Medicine, Division of Critical Care, Vancouver General Hospital, University of British Columbia, Vancouver, British Columbia, Canada

Jean-Nicolas Dubé, MD, MA, FRCPC Clinical Instructor, Department of Internal Medicine, Division of Critical Care, Centre intégré universitaire de santé et de services sociaux de la Mauricie-et-du-Centre-du-Québec, Université de Montréal, Trois-Rivières, Québec, Canada

Ashraf Fayad, MD, MSc, FRCPC, FCARCSI, FACC, FASE Associate Professor, Director of Perioperative Hemodynamic Echocardiography, Department of Anesthesiology, University of Ottawa, Ottawa, Ontario, Canada

Gordon N. Finlayson, BSc, MD, FRCPC (Anesth and CCM) Clinical Assistant Professor, Division of Critical Care, Department of Anesthesiology and Perioperative Care, Vancouver General Hospital, University of British Columbia, Vancouver, British Columbia, Canada

Annie Giard, MD, FRCPC Emergency Room Physician, Responsible for Echography Training in Emergency Medicine and Family Medicine, Université de Montréal, ARDMS, Local Manager for the Training of Independent Practitioner of CEUS, Department of Emergency Medicine, CIUSS du Nordde-l'Île-de-Montréal, Installation Hôpital du Sacré-Coeur de Montréal, Montréal, Québec, Canada

Martin Girard, MD, FRCPC Clinical Associate Professor, Department of Anesthesiology, Division of Critical Care of the Department of Medicine, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montréal, Québec, Canada

Donald E.G. Griesdale, MD, MPH, FRCPC Assistant Professor, Department of Anesthesiology, Pharmacology and Therapeutics, Department of Medicine, Division of Critical Care Medicine, Chair, Vancouver Medical Advisory Council, Vancouver General Hospital, University of British Columbia, Vancouver, British Columbia, Canada

Han Kim, MD, FRCPC Assistant Professor, Department of Anesthesia, St. Michael's Hospital, University of Toronto, Toronto, Ontario, Canada

Manoj M. Lalu, MD, PhD, FRCPC Clinical Scholar, Department of Anesthesiology, The Ottawa Hospital, Regenerative Medicine Program, The Ottawa Hospital Research Institute, Ottawa, Ontario, Canada

Yoan Lamarche, MD, MSc, FRCSC Assistant Professor of Surgery, Cardiac Surgeon and Intensivist, Department of Cardiac Surgery, Institut de Cardiologie de Montréal and Hôpital du Sacré-Coeur de Montréal, Université de Montréal, Montréal, Québec, Canada

Moishe Liberman, MD, PhD Associate Professor of Surgery, Director, CHUM Endoscopic in Tracheobronchial and Oesophageal Center (C.E.T.O.C.), Marcel and Rolande Gosselin Chair in Thoracic Surgical Oncology, Scientist, Research Center, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montréal, Québec, Canada

Feroze Mahmood, MD, FASE Associate Professor of Anesthesia, Harvard Medical School, Director Vascular Anesthesia and Perioperative Echocardiography, Beth Israel Deaconess Medical Center, Boston, U.S.A.

Ramamani Mariappan, DA, MD, Dip.NB Professor, Christian Medical College, Vellore, India

Serge McNicoll, MD, CSPQ Cardiologist, Chief of Cardiology Department of the Department of Medicine, Hôpital Régional de St-Jérôme, Université de Montréal, Montréal, Québec, Canada

Massimiliano Meineri, MD Associate Professor of Anesthesia, Staff Anesthesiologist, Director Perioperative Echocardiography, Toronto General Hospital, University of Toronto, Toronto, Ontario, Canada

Scott J. Millington, MD, FRCPC Assistant Professor, Department of Critical Care Medicine, The Ottawa Hospital, University of Ottawa, Ottawa, Ontario, Canada

Blandine Mondésert, MD Assistant Professor, Cardiologist, Division of Cardiac Electrophysiology, Department of Medicine, Adult Congenital Heart Disease Center, Institut de Cardiologie de Montréal, Université de Montréal, Montréal, Québec, Canada

Céline Odier, MD, FRCPC Assistant Clinical Professor, Department of Neurosciences, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montréal, Québec, Canada

Sarto C. Paquin, MD, FRCPC Assistant Professor, Department of Medicine, Division of Gastroenterology, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montréal, Québec, Canada

Eric Piette, MD, MSc, FRCPC Clinical Assistant Professor, Emergency Room Physician, Department of Family Medicine and Emergency Medicine, Hôpital du Sacré-Coeur de Montréal, CIUSS Nord de l'Île de Montréal, Université de Montréal, Montréal, Québec, Canada

Wilfredo Puentes, MD Assistant Professor, Department of Anesthesia and Perioperative Medicine, London Health Sciences and St. Joseph's Health Care, University of Western Ontario, London, Ontario, Canada

Andrea Rigamonti, MD Assistant Professor, Director, Trauma-Neuro Anesthesia and Critical Care Fellowship Program, Departments of Anesthesia and Critical Care, St. Michael's Hospital, Department of Anesthesia and Interdepartmental Division of Critical Care Medicine, University of Toronto, Toronto, Ontario, Canada

Antoine G. Rochon, MD, FRCPC Assistant Professor, Department of Anesthesiology, Cardiac Anesthesiology Fellowship Program Director, Perioperative Transesophageal Echocardiography Training Program Director, Institut de Cardiologie de Montréal, Université de Montréal, Montréal, Québec, Canada

Andrew Roscoe, MB ChB, FRCA Consultant in Anaesthesia and Intensive Care Medicine, Papworth Hospital, Cambridge, U.K.

Karim Serri, MD, FRCPC Associate Professor, Department of Medicine, Critical Care Division, Hôpital du Sacré-Coeur de Montréal, Université de Montréal, Montréal, Québec, Canada

Ying Tung Sia, MD, MSc, FRCPC Clinical Assistant Professor, Department of Medicine, Division of Cardiology, Centre Hospitalier Régional de Trois-Rivières and Division of Critical Care, Institut de Cardiologie de Montréal, Université de Montréal, Montréal, Québec, Canada

Jean-Claude Tardif, CM, MD, FRCPC, FACC, FAHA, FESC, FCAHS Professor, Director of the Research Center, Department of Medicine, Division of Cardiology, Institut de Cardiologie de Montréal, Université de Montréal, Montréal, Québec, Canada

Annette Vegas, MD, FRCPC, FASE Associate Professor, Staff Anesthesiologist, Department of Anesthesiology, Toronto General Hospital, University of Toronto, Toronto, Ontario, Canada

Claudia H. Viens, MD, FRCPC Assistant Professor, Department of Anesthesiology, Institut de Cardiologie de Montréal, Université de Montréal, Montréal, Québec, Canada

Kim-Nhien Vu, MD Diagnostic Radiology Resident, Department of Radiology, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montréal, Québec, Canada

Contents

Forewordxi
Prefacexiii
Abbreviations	xv
How To Use Image	xxii
List of Videos	xxiii

Part I

Chapter 1	Ultrasound Imaging: Acquisition and Optimization	1
Chapter 2	Patient Safety and Imaging Artifacts	15
Chapter 3	Normal Cardiac Anatomy and TEE Imaging Planes	29
Chapter 4	Extra-Cardiac Transesophageal Ultrasonography	41
Chapter 5	Assessment of Global Ventricular Function, Pericardium, and Cardiomyopathy	65
Chapter 6	Basic Regional Ventricular Systolic Function	87
Chapter 7	Basic Valve Diseases	103
Chapter 8	Intra-cavitary Contents	131
Chapter 9	Basic Hemodynamic Assessment	157
Chapter 10	Related Diagnostic Imaging Modalities	177
Chapter 11	Simple Congenital Heart Disease in Adults	195
Chapter 12	Echocardiography in Non-Cardiac Procedures and Trauma	205

Part II

Chapter 13	Critical Care Ultrasound Examination of the Nervous System	229
Chapter 14	Critical Care Examination of the Respiratory System	249
Chapter 15	Critical Care Examination of the Cardiovascular System	271
Chapter 16	Critical Care Examination of the Abdomen	293
Chapter 17	Ultrasound for Critical Care Procedures	321
Chapter 18	Ultrasound-Guided Vascular Access and Examination	333
Chapter 19	Training Guidelines and Simulation	365
Chapter 20	Mock Transesophageal Echocardiography Examination (On-Line)	
	Mock Critical Care Ultrasound Examination (On-Line)	
Appendix 1	Recommended Views in Transesophageal Echocardiography	381
Index		403

Foreword

Since I first trained in Critical Care Medicine (CCM) in the mid-1980s at the University of Pittsburgh, where André Denault then followed, the intensive care unit (ICU) has changed dramatically with regards to the acuity, severity and complexity of the patient population. As clinicians at the bedside, the questions we ask are increasingly complex and the answers we seek are more precise. Non-invasive monitoring is more refined and ultrasound (US) technology has become the modern clinician's stethoscope. US monitoring has gone from echocardiography being performed by a cardiologist in the occasional ICU patient two decades ago, to the intensivist obtaining either a focused or comprehensive echocardiogram and performing US examination of the thoracic and abdominal contents, as well as guiding vascular access and monitoring neurological status. Since all the organs of interest to the CCM physician are accessible by US imaging, the scope of practice is rapidly growing in popularity. This is matched only by the challenge we face in mastering the technology, recognizing the limits, interpreting the results and teaching ultrasound to our students, residents, fellows and colleagues.

It is with these objectives in mind that this textbook on US imaging was wonderfully conceived by the team of experts that André has put together. The chapters proceed in more or less the same fashion as US imaging has progressed through the last decades. From basic principles and image acquisition, the reader evolves to transesophageal echocardiography (TEE) and assessing intra-cardiac and extra-cardiac structures and function, as well as all other organs accessible to the TEE platform. The reader then proceeds to transthoracic echocardiography and focused US imaging of the pulmonary and abdominal contents, with a welcome addition regarding

brain monitoring. Perioperative and ICU assessments are well dealt with, as are ICU procedures and vascular access in the critically ill patient. Each chapter is rigorously structured and very well referenced with diagrams, intra-operative photographs, illustrations and videos to optimize interactive learning for both the novice, as well as the experienced clinician. Tables and figures abound throughout the text in pragmatic support and as a reminder of concepts, classifications and equations. Last but not least are the chapters dedicated to simulation training and examination, which are of the utmost importance to those involved in structuring US teaching programs and in abiding by society guidelines and recommendations.

Dr Denault and his team are to be complimented for this comprehensive and rigorous effort in mastering US imaging whether in the operating room or the ICU. It is a reflection of where US imaging has come from and where it is going. However, for US imaging to evolve, we must make certain it is well performed, interpreted and leads to appropriate decision making. This book strives to achieve these goals.

Our CCM training program at the University of Montreal believes US imaging is now an obligatory skill to be mastered during fellowship training. Our fellows go through a 3-month structured US training program in order to become proficient in basic US imaging of the heart and other organs through TEE, TTE and focused US examination. This book recreates how our fellows are being trained and as such, is our textbook of reference. Years of clinical observation and correlation with US imaging by clinicians have gone into this book and I am extremely proud of what it has become and what it will achieve.

Jean-Gilles Guimond MD, FRCPC, FCCP
Program Director, Critical Care Medicine
Université de Montréal, Quebec, Canada



Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>

Preface

In 2005, we published our first Transesophageal Echocardiography Multimedia Manual,¹ which was followed in 2011 by a second edition.² These manuals were written to help prepare practising anesthesiologists and trainees in cardiothoracic anesthesia and critical care for the National Board of Echocardiography (NBE) Examination of Special Competence in Advanced Perioperative Transesophageal Echocardiography (TEE). In the second edition, several chapters were dedicated to the role of TEE in non-cardiac surgical applications and in the intensive care unit (ICU). The field of TEE has matured significantly over the last decade. In addition, with the widespread availability of ultrasound, there is a growing interest for the applications of bedside ultrasound in the ICU, non-cardiac operating room, and emergency medicine. Furthermore, training guidelines in basic TEE³ and in critical care ultrasound were published.^{4,5} Certification in both modalities through the NBE and the American College of Chest Physicians (ACCP) have also become available.

The goal of this manual also remains simple: to prepare anesthesiologists, critical care physicians, fellows, and residents for the NBE Basic Perioperative TEE examination and ACCP critical care ultrasonography certification. This book, whose editors and the majority of its authors are from Canadian universities, also covers the Canadian recommendations for critical care ultrasound training and competency.⁶ It is the opinion of the editors that all critical care physicians and general anesthesiologists will eventually become trained in both basic TEE and critical care ultrasound. At the Université de Montréal in 2013, the Critical Care Program Director, Dr Jean-Gilles Guimond asked me to initiate comprehensive ultrasound training for all our fellows. This is the manual that we will be using.

The manual is divided in two parts. **Part I** consisting of **Chapters 1 to 12** is dedicated to basic TEE. **Part II** relates to focused bedside ultrasound and includes **Chapters 13 to 19**. In **Chapter 20**, two mock exams inspired by the NBE Basic TEE and the ACCP exam are presented, and additional materials are available from the CRC website: <http://www.crcpress.com/product/isbn/9781482237122> In **Part I**, we introduce for the first time a chapter on extra-cardiac TEE. In addition, in **Part II**, there is a chapter on ultrasound of the brain. These unconventional areas will become more important in the future as clinicians evaluate not only the etiology of hemodynamic instability, but also the impact on multiple organs such as the kidney, liver, splanchnic perfusion, and brain. This manual is unique because the editors and authors represent several different fields of clinical practice in anesthesia, internal medicine, emergency medicine, and surgery. General anesthesiologists, cardiothoracic anesthesiologists and neuro-anesthesiologists have shared

their unique expertise alongside critical care physicians, cardiologists, gastroenterologists, neurologists, emergency medicine specialists, abdominal and thoracic radiologists, and cardiac and thoracic surgeons. I sincerely thank all the authors who have taken the time to contribute to this work.

Such a manual would not have been possible without the support of my four editors. I am very grateful for their contributions. Dr Annette Vegas is a cardiothoracic anesthesiologist with a critical care appointment at the Toronto General Hospital. Annette has been an editor since 2009 and has continuously raised the quality and pertinence of our educational material. She has already published several books in TEE that are carried by ultrasound trainees worldwide. She has contributed to an outstanding free educational website in ultrasound translated into several languages (<http://pie.med.utoronto.ca>). Her dedication to this manual has been unsurpassed and is remarkable, as it was for the second edition of the TEE manual. Dr Yoan Lamarche is a cardiac surgeon, additionally certified in critical care medicine and TEE, working at both the Montreal Heart Institute (MHI) and Hôpital du Sacré-Coeur. He is the director of the MHI Cardiac Surgical ICU. Yoan's natural leadership, educational skills, common sense, and surgical experience gave this manual clarity and a unique perspective. Dr Jean-Claude Tardif is a cardiologist and the director of the MHI Research Center. Since the perioperative anesthesia TEE program started in 1999 at the MHI, Jean-Claude has strongly supported the Anesthesiology Department in TEE development and expertise. Dr Tardif has played an important role participating in developing our manuals and has also made available the MHI research environment in order to improve the care of our patients in the operating room and the ICU. I met Dr Pierre Couture in 1993 when he returned from Paris after completing his cardiac anesthesia fellowship. We shared a common passion for ultrasound applications and have been working and publishing together ever since. Pierre was our former Chief of Cardiac Anesthesia at the MHI. He has been helping me in all aspects of the manual, completely rewriting some chapters in order to offer the best to our students and readers. His generosity, kindness, amazing TEE knowledge, and teaching skills are well appreciated in our institution.

Several individuals have played a significant role in the creation of this manual. Mr Denis Babin is the webmaster of the Department of Anesthesiology of the Université de Montréal and my research assistant since 1998. I am fortunate to have such an amazing assistant. His diverse talents in computer science, graphic design, database management, and communication provide the key elements that have made all our manuals so appealing. There is not a single figure or video that Denis has not

touched, improved or converted ... I often say, "Denis, would you mind 'babinising' this?" Special thanks for the support and advice of my current Chief of Cardiac Anesthesia at the MHI must go to Dr Alain Deschamps. I also thank all my colleagues, anesthesiologists, critical care physicians, cardiac surgeons, and cardiologists at the MHI who have supported and alerted me to interesting cases. Likewise, I thank my critical care colleagues in the ICU of the Centre Hospitalier de l'Université de Montréal.

This work would not have been possible without financial support. I would like to thank especially Dora and Avrum Morrow. Meeting Mr Avrum Morrow in Old Montreal and seeing the Avmor Collection was an unforgettable moment in my life. In 2014, I had the privilege of being chosen for the Richard I Kaufman Endowment Fund in Anesthesia and Critical Care. This support will allow us to continue our educational and research activities for the coming years. My gratitude to the Kaufman family is beyond words. All this support has been completely dependent on the MHI Foundation and its director Mélanie LaCouture. The MHI Foundation has been supporting me every year since 1999 and played a key role in contacting those who are supporting this manual and our future development. Special thanks to Josée Darche from the MHI Foundation. In addition, my appreciation goes to MHI director Dr Denis Roy and to Dr Annie Dore who is responsible for all MHI educational activities, as both have also believed in our initiatives. I am also indebted to the Fondation de l'Association des Anesthésiologistes du Québec and president Dr Gilles Plourde and Mr Joseph Bestravos from Sonosite/Fuji for their generous support. Credit must also be given to Mr Fainman for his generous donation that allowed us to buy the first X-Porte ultrasound system from Sonosite/Fuji in Canada. Several figures in this book came from this equipment.

Dr Robert Amyot, staff cardiologist at the Hôpital du Sacré-Coeur has been an author in our two previous TEE manuals. In 2014 Robert became the president of CAE Healthcare. We acknowledge his support in allowing us to enhance many figures in this manual by extensively using the Vimedix simulator (CAE, Healthcare Canada) to obtain

anatomic illustrations and videos. In addition, physicians in Canada have free institutional access to Anatomy.tv powered by Primal Picture (info@primalpictures.com) through Wolters Kluwer Health. This educational site allows clinicians to learn and teach anatomy from a 3D atlas. We are so grateful to both of these companies for allowing us to use their interface throughout the manual.

Finally, many colleagues, residents, and fellows at the MHI have graciously reviewed chapters of this manual, making suggestions and pointing out corrections. I would like to thank all of them which are listed just below.

I hope that you will enjoy reading the 1st Edition of the Basic Transesophageal and Critical Care Ultrasound textbook.

André Denault MD, PhD, FRCPC, FASE, ABIM-CCM, FCCS

Dr William Beaubien-Souigny

Dr Alexandros Cavayos

Dr David Claveau

Dr Joseph Dahine

Dr André Dubé

Dr Roberto Eljaiek

Dr Jessica Forcillo

Dr Caroline Gebhard

Dr Brian Grondin-Beaudoin

Dr Jean-Gilles Guimond

Dr Vincent Lecluyse

Dr Gabrielle Migner-Laurin

Dr Alex Moore

Mrs Antoinette Paolitto

Dr Daniel Parent

Dr Élise Rodrigue

Dr Catalina Sokolof

Dr Francis Toupin

Dr Claudia Viens

Dr Han Ting Wang

REFERENCES

1. Denault AY, Couture P, Tardif JC, Buithieu J. *Transesophageal Echocardiography Multimedia Manual: A Perioperative Transdisciplinary Approach*. New York: Marcel Dekker, 2005.
2. Denault AY, Couture P, Vegas A, Buithieu J, Tardif JC. *Transesophageal Echocardiography Multimedia Manual, Second Edition: A Perioperative Transdisciplinary Approach*. New York: Informa Healthcare, 2011.
3. Reeves ST, Finley AC, Skubas NJ, Swaminathan M, Whitley WS, Glas KE, Hahn RT, Shanewise JS, Adams MS, Shernan SK. Basic perioperative transesophageal echocardiography examination: a consensus statement of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. *J Am Soc Echocardiogr* 2013; **26**: 443–56.
4. Mayo PH, Beaulieu Y, Doelken P, Feller-Kopman D, Harrod C, Kaplan A, et al. American College of Chest Physicians/La Société de Réanimation de Langue Française statement on competence in critical care ultrasonography. *Chest* 2009; **135**: 1050–60.
5. Via G, Hussain A, Wells M, Reardon R, Elbarbary M, Noble VE, et al. International evidence-based recommendations for focused cardiac ultrasound. *J Am Soc Echocardiogr* 2014; **27**: 683.
6. Arntfield R, Millington S, Ainsworth C, Arora R, Boyd J, Finlayson G, et al. Canadian recommendations for critical care ultrasound training and competency. *Can Respir J* 2014; **21**: 341–45.

Abbreviations

2C	two-chamber
2D	two-dimensional
4C	four-chamber
5C	five-chamber
A	amplitude
A	peak late diastolic TMF or TTF velocity
A	atrial contraction
a'	peak late diastolic mitral or tricuspid annular velocity
A dur	duration of TMF A-wave
A4C	apical four-chamber
AA	apical anterior
AA	axillary artery
AAA	abdominal aortic aneurysm
AAL	anterior axillary line
AC	attenuation coefficient
ACA	anterior cerebral artery
ACC	American College of Cardiology
ACCP	American College of Chest Physicians
ACES	Abdominal Cardiac Evaluation with Sonography in Shock
ACGME	Accreditation Council for Graduate Medical Education
ACLS	advanced cardiac life support
ACoA	anterior communicating artery
Adr	adrenal
Adre	adrenaline
AHA	American Heart Association
AIN	apical inferior
AJV	anterior jugular vein
AL	apical lateral / anterolateral
AL	area-length method
Am	peak late diastolic MAV
AMVL	anterior mitral valve leaflet

Ant	anterior
Ao	aorta
AoV	aortic valve
AP	anterior–posterior
AR	atrial reversal
AR	aortic regurgitation
AR dur	atrial reversal pulmonary venous flow velocity duration
ARDS	acute respiratory distress syndrome
AS	apical septal / anteroseptal
ASA	American Society of Anesthesiologists
aSAH	aneurysmal subarachnoid hemorrhage
Asc Ao	ascending aorta
ASD	atrial septal defect
ASE	American Society of Echocardiography
Asr	late diastolic strain rate
At	peak late diastolic tricuspid annular velocity
AV	axillary vein / aortic valve
AVA	aortic valve area
AVC	aortic valve closure
AVM	arteriovenous malformation
AW	anterior window
BA	basal anterior
BA	basilar artery
BAL	basal anterolateral
BART	Blue Away Red Towards (common color map)
BAS	basal anteroseptal
BHI	breath holding index
BIN	basal inferior
BIL	basal inferolateral
BIS	basal inferoseptal
BSA	body surface area
C	carotid segments
C	propagation speed

CA	carotid artery
CAD	coronary artery disease
CAE	Canadian Aviation Electronics
CAS	carotid angioplasty and stenting
CBF	cerebral blood flow
CBFV	cerebral blood flow velocity
CCA	cerebral circulatory arrest
CCCS	Canadian Critical Care Society
CCE	critical care echocardiography
CCS	Canadian Cardiovascular Society
CCTA	coronary computed tomography angiography
CEA	carotid endarterectomy
CFD	color flow Doppler
CFS	cerebrospinal fluid
CHD	congenital heart disease
cm	centimeter
CME	continuing medical education
CMR	cardiovascular magnetic resonance
CO	cardiac output
CO ₂	carbon dioxide
CPB	cardiopulmonary bypass
CPP	cerebral perfusion pressure
CPR	cardiopulmonary resuscitation
CS	coronary sinus
CSA	cross-sectional area
CSE	Canadian Society of Echocardiography
CT	celiac trunk
CT	computed tomography
CTA	computed tomography angiogram
CTP	computed tomography perfusion
CVC	central venous catheters
CVP	central venous pressure
CW	continuous wave

CWD	continuous wave Doppler
CXR	chest radiography
d	diameter
D	diastolic PVF or HVF velocity
D	diastolic
D1	first diagonal
D2	second diagonal
DAP	diastolic arterial pressure
db	decibel
DBP	diastolic blood pressure
DCI	delayed cerebral ischemia
DE-CMR	delayed enhanced cardiovascular magnetic resonance
Des Ao	descending aorta
DF	duty factor
DT	deceleration time
DVT	deep venous thrombosis
E	early diastolic TMF or TTF velocity
E	early filling
e'	peak early diastolic mitral or tricuspid annular velocity
ECA	external carotid artery
ECG	electrocardiogram or electrocardiographic
ECMO	extracorporeal membrane oxygenation
EDA	end-diastolic area
EDV	end-diastolic velocity
EF	ejection fraction
eFAST	extended FAST
EI	eccentricity index
EIV	external iliac vein
Em	early diastolic MAV
ER	emergency room
ERO	effective regurgitant orifice
ESA	end-systolic area

ESLD	end-stage liver disease
Esr	early diastolic strain rate
ET	ejection time
Et	peak early diastolic tricuspid annular velocity
ETCO₂	end-tidal carbon dioxide
ETT	endotracheal tube
EUS	endoscopic ultrasound scanning
EV	eustachian valve
EVAR	endovascular repair of aortic aneurysm
f	frequency (Hz)
FA	femoral artery
FAC	fractional area change
FAST	Focused Assessment with Sonography in Trauma
Fd	Doppler frequency shift
FL	false lumen
FO	foramen ovale or fossa ovalis
FP	foramen primum
FS	foramen secundum
FV	femoral vein
FVd	end-diastolic flow velocity
FVm	mean flow velocity
FVR	flow velocity ratio
FVs	systolic flow velocity
FW	frontal window
g	gram
GCCUS	General Critical Care Ultrasound
GE	gastroesophageal
GI	gastrointestinal
GLS	global longitudinal strain
H	horizontal
HAF	hepatic artery flow
HAV	hemiazygos vein
HCM	hypertrophic cardiomyopathy
HITS	hyperintensity thromboembolic signal
HR	heart rate
HU	Hounsfield unit

HV	hepatic vein
HVF	hepatic venous flow
HVLT	half value layer thickness
IN	inferior
IAS	interatrial septum
IA	innominate artery
IABP	intra-aortic balloon pump
ICA	internal carotid artery
ICCU	Imaging Curriculum in Critical Care Ultrasound
ICM	intercostal muscle
ICP	intracranial pressure
ICU	intensive care unit
IJV	internal jugular vein
IL	inferolateral
IMA	internal mammary arteries
IN	inferior
In-Out	inflow-outflow
IOA	index of autoregulation
IRC	intensity reflection coefficient
IS	inferoseptal
IVC	inferior vena cava
IVCT	isovolumic contraction time
IVRT	isovolumic relaxation time
IVS	interventricular septum
IVUS	intravascular ultrasound
J	joules
L	lateral
LA	left atrium
LAA	left atrial appendage
LACA	left anterior cerebral artery
LAD	left anterior descending
LAFB	left atrio-femoral bypass
LAP	left atrial pressure
LAX	long-axis
LCC	left coronary cusp
LCCA	left common carotid artery

LCX	left circumflex artery
LGC	lateral gain control
LGE	late-gadolinium-enhancement
LH	left heart
LHV	left hepatic vein
LIJV	left internal jugular vein
LK	left kidney
LLL	left lower lobe
LM	left main
LMCA	left middle cerebral artery
LPV	left portal vein
LSCA	left subclavian artery
LSVC	left-sided superior vena cava
LT	liver transplantation
LTICA	left terminal internal carotid artery
L-to-R	left-to-right
LUL	left upper lobe
LUPV	left upper pulmonary vein
LV	left ventricle or left ventricular
LVD	left ventricular minor-axis diameter
LVEDA	left ventricle end-diastolic area
LVEDD	left ventricle end-diastolic diameter
LVEDP	left ventricular end-diastolic pressure
LVEDV	left ventricle end-diastolic volume
LVEF	left ventricular ejection fraction
LVESA	left ventricular end-systolic area
LVESP	left ventricular end systolic pressure
LVIDd	left ventricular internal diameter at end-diastole
LVOT	left ventricular outflow tract
LVOTO	left ventricular outflow tract obstruction
m	meter
MA	mid-anterior
MAL	mid-anterolateral
MAS	mid-anteroseptal
MAV	mitral annular velocity
Max	maximal

MCA	middle cerebral artery
ME	mid-esophageal
MFV	mean flow velocity
MHV	middle hepatic vein
MI	mechanical index
Mid	middle
MIL	mid-inferolateral
MIN	mid-inferior
MIS	mid-inferoseptal
MLS	midline shift
mm	millimeter
mmHg	millimeter of mercury
M-mode	motion mode
Mn	mean
MOC	maintenance of competence
MOD	method of disk
MPA	main pulmonary artery
MPI	myocardial performance index
MR	mitral regurgitation
MRI	magnetic resonance imaging
ms	millisecond
MS	mitral stenosis
MV	mitral valve
MVA	mitral valve area
MVO	mitral valve opening
MW	middle window
NBE	National Board of Echocardiography
NCC	non-coronary cusp
NL	nipple line
Norad	noradrenaline
NS	not specified
OA	ophthalmic artery
ONSD	optic nerve sheath diameter
OR	operating room
P	power
P	pressure

P1	posterior leaflet
PA	pulmonary artery
PAC	pulmonary artery catheter
PaCO₂	arterial carbon dioxide tension
PAEDP	pulmonary artery end-diastolic pressure
PAL	posterior axillary line
Pan	pancreas
PaO₂	arterial oxygen tension
Par	systolic radial blood pressure
PASP	pulmonary artery systolic pressure
PC	pericardial cyst
PCA	posterior cerebral artery
PCoA	posterior communicating artery
PCWP	pulmonary capillary wedge pressure
PD	pulse duration
PE	pericardial effusion
PE	pulmonary embolism
PEA	pulseless electrical activity
PecM	pectoralis muscle
PEEP	positive end-expiratory pressure
PFO	patent foramen ovale
PG	pressure gradient
PHT	pressure half-time
PI	pulsatility index
PICC	peripherally inserted central catheter
PISA	proximal isovelocity surface area
PM	papillary muscle
PMD	power mode Doppler
Pms	mean systemic venous pressure
PMV	prosthetic mitral valve
POCUS	point-of-care ultrasound
Post	posterior
PoVF	portal venous flow
Ppa	pulmonary artery pressure
Ppl	pleural pressure
PR	pulmonary regurgitation

Pra	right atrial pressure
PREDV	pulmonary regurgitation end-diastolic velocity
PRF	pulse repetition frequency
PRI	pulmonary regurgitation index
PRP	pulse repetition period
P_{RV}	right ventricular pressure
PSL	parasternal line
PT	pulmonary trunk
PTE	Perioperative Transesophageal Echocardiography
PV	pulmonic valve
PV	pressure–volume
PVAC	pulmonic valve anterior cusp
PVF	pulmonary venous flow
PVLC	pulmonic valve left cusp
PVR	pulmonary vascular resistance
PW	pulsed-wave
PWD	pulsed-wave Doppler
PWT	posterior wall thickness
PWTd	posterior wall thickness diameter
Py	pylorus
Qp	pulmonary flow
Qs	systemic flow
R	radius
RA	right atrium or right atrial
RAA	right atrial appendage
RACA	right anterior cerebral artery
RAP	right atrial pressure
RCA	right carotid artery
RCA	right coronary artery
RCC	right coronary cusp
RH	right heart
RHV	right hepatic vein
RI	resistance index
RIJV	right internal jugular vein
RLPV	right lower pulmonary vein

RMCA	right middle cerebral artery
RML	right middle lobe
ROSC	return of spontaneous circulation
RPA	right pulmonary artery
RPV	right portal vein
R-to-L	right-to-left
RUL	right upper lobe
RUPV	right upper pulmonary vein
RUSH	Rapid Ultrasound for Shock and Hypotension
RV	right ventricle or right ventricular
RVD	right ventricular diameter
RVEF	right ventricular ejection fraction
RVOT	right ventricular outflow tract
RVOTO	right ventricular outflow tract obstruction
Rvr	resistance to venous return
RVSP	right ventricular systolic pressure
RWMA	regional wall motion abnormalities
RWT	relative wall thickness
S	septal
S	systolic
S	systolic pulmonic or hepatic venous flow velocity
s'	systolic tricuspid annular velocity
S wave	inflow during systole
SAM	systolic anterior motion
SaO₂	oxygen saturation
SAP	systolic arterial pressure
SAX	short-axis
SBP	systolic blood pressure
SC	subcostal
SCA	Society of Cardiovascular Anesthesiologists
SCA	subclavian artery
SCA	Society of Cardiovascular Anesthesiologists
SCD	sickle cell disease
ScO₂	brain saturation
SCT	subcutaneous tissue
SCV	subclavian vein

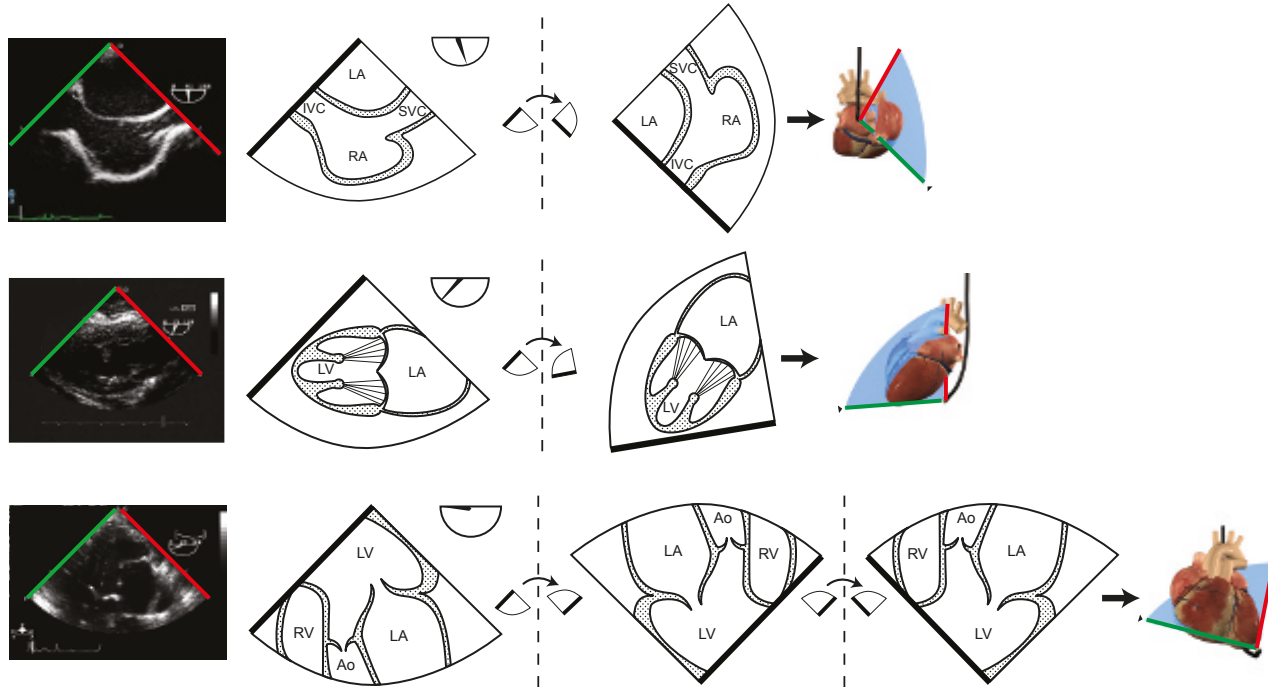
SD	standard deviation
sec	second
SEC	spontaneous echo contrast
SIRS	systemic inflammatory response syndrome
SL	strain longitudinal
SMA	superior mesenteric artery
SP	septum primum
SPECT	single photon emission computer tomography
SPL	spatial pulse length
SPTA	spatial peak temporal average
SR	strain rate
SS	septum secundum
Ssr	peak systolic strain rate
STJ	sinotubular junction
SV	stroke volume
SVC	superior vena cava
SVF	splenic venous flow
SWT	septal wall thickness
SWTd	septal wall thickness in diastole
SX	sub xyphoid
T	period
TAAA	thoraco-abdominal aortic aneurysm
TAMV	time-averaged mean velocity
TAPSE	tricuspid annular plane systolic excursion
TAV	tricuspid annular velocity
TCCS	transcranial color-coded duplex sonography
TCD	transcranial Doppler
TD	thermodilution
TDI	tissue Doppler imaging
TEE	transesophageal echocardiography
TEVAR	thoracic endovascular aortic repair
TG	transgastric
TGC	time gain compensation
Th	wall thickness
TICA	terminal internal carotid artery
TL	true lumen

TMF	transmitral flow
TPR	total peripheral resistance
TR	tricuspid regurgitation
TS	tricuspid stenosis
TTE	transthoracic echocardiography
TTF	transtricuspid flow
TV	tricuspid valve
TVA	tricuspid valve area
TVAL	tricuspid valve anterior leaflet
TVPL	tricuspid valve posterior leaflet
UE	upper esophageal
US	ultrasound
V	vertical
VA	vertebral arteries
Vaso	vasopressin
VC	vena contracta
Vel	velocity

VIRTUAL	Visual Interactive Resource for Teaching, Understanding and Learning
V_{max}	maximum jet velocity
V_{mv}	mitral valve regurgitant velocity
V_p	flow propagation velocity
V_{peak}	peak velocity
VR	venous return
VSD	ventricular septal defect
V_{t_{1/2}}	velocity at the pressure half-time point
VTI	velocity time integral
V_{TR}	peak tricuspid regurgitant velocity
W	watts
WMA	wall motion abnormalities
WMSI	regional wall motion score index
Z	impedance
σ	stress
λ	wavelength

How to Use

Sketch and 3D icon correlation and superposition



This symbol used in the legend indicates the presence of additional video in relation to the figure available on the Web.



The human body icon indicates how the patient was positioned when images or videos were obtained.



<http://goo.gl/bba15t>

In order to see the video related to the figure, use an application to scan the QR code or with the mouse, click on short URL to view video. The letter(s) before URL address is in relation to which part of the figure, the video is associated.

List of Videos

- Video title and figure number**
- Chapter 2**
 Mechanical and thermal indices **2.6b**
 Mechanical and thermal indices **2.6e**
 Reverberation **2.7i**
 Reverberation **2.7ii**
 Comet tail and ring down artifacts **2.8a**
 Refraction **2.9a**
 Edge shadowing **2.10a**
 Side lobe artifact **2.11a**
 Side lobe artifact **2.11c**
 Range ambiguity **2.12a**
 Acoustic shadowing **2.13c**
 Enhancement and dropout artifacts **2.14a**
 Near-field clutter **2.15a**
- Chapter 3**
 TEE probe manipulation **3.2**
 ME 4CH view **3.4a**
 ME 4CH view **3.4c**
 ME two-chamber view **3.5a**
 ME LAA view **3.6a**
 ME LAA view **3.6c**
 ME LAA view **3.6i**
 ME long-axis view **3.7**
 LVOT obstruction **3.8a & b**
 LVOT obstruction **3.8d & e**
 Asc Ao views **3.9a**
 Asc Ao views **3.9c**
 Asc Ao views **3.9e**
 ME Asc Ao short-axis view **3.10a**
 ME Asc Ao short-axis view **3.10d**
 ME AoV short-axis view **3.11a**
 ME right ventricular inflow/outflow view **3.12a**
 ME bicaval view **3.13a**
 Transgastric mid short-axis view **3.14a**
 Desc thoracic Ao views **3.15a**
 Desc thoracic Ao views **3.15c**
- Chapter 4**
 Pulmonary regions **4.1a & b**
 Pulmonary references points **4.2**
 Left lung examination **4.5a**
 Left lung examination **4.5e**
 Left lung examination **4.5i**
 Right lung examination **4.6a**
 Right lung examination **4.6e**
 Right lung examination **4.6i**
 Complex pleural effusion **4.7a**
 Complex pleural effusion **4.7d**
 Hemothorax **4.8**
 Pleural hematoma **4.9b**
 Pleural hematoma **4.9c**
- Pleural hematoma **4.9d**
 Atelectasis **4.10d**
 Pneumonia after lobectomy **4.11a**
 Pneumonia after lobectomy **4.11b**
 Pneumonia after lobectomy **4.11c**
 Pneumonia after lobectomy **4.11d**
 Subcarinal lymph node **4.14a**
 Azygos and hemiazygos venous system **4.16**
 Azygos vein **4.17a**
 Azygos vein **4.17c**
 Examination of the stomach **4.20d**
 Examination of the stomach **4.20e**
 Examination of the stomach **4.20f**
 Gastric abnormalities **4.21a**
 Gastric abnormalities **4.21b**
 Gastric abnormalities **4.21c**
 Spleen anatomy and position **4.23**
 Spleen **4.24a**
 Spleen **4.24b**
 Spleen **4.24c**
 Spleen **4.24d**
 Left kidney **4.25d**
 Left kidney **4.26a**
 Left kidney **4.26b**
 Liver **4.28**
 Hepatic veins **4.29a**
 Hepatic veins **4.29c**
 Hepatic veins **4.29e**
 Portal vein **4.30a**
 Hepatic artery **4.31a**
 Hepatic artery **4.31b**
 Hepatic pathologies **4.32a**
 Hepatic pathologies **4.32b**
 Hepatic pathologies **4.32c**
 Hepatic pathologies **4.32d**
 Portal hypertension **4.34d**
 Whale tail sign **4.35c**
 Whale tail sign **4.35d**
 Splenic Doppler flow **4.38a**
 Splenic Doppler flow **4.38d**
 Abnormal splenic venous flow **4.39b**
 Abnormal splenic venous flow **4.39e**
- Chapter 5**
 Preload **5.5a & b**
 Preload **5.6a & d**
 Respiratory variation of the SVC **5.7a**
 Respiratory variation of the SVC **5.7c**
 Fractional area change **5.9a & c**
 Eccentricity index **5.12c-d**
 Eccentricity index **5.12e-f**
 TAPSE **5.13**
 Pulmonary vein Doppler **5.15a**
 Pulmonary vein Doppler **5.15d**
 Pericardial effusion **5.18a**
 Cardiac tamponade **5.19b & e**
- Pleural and pericardial effusions **5.20a**
 Hypertrophic cardiomyopathy **5.23a**
 Dilated cardiomyopathy **5.24a**
 Takotsubo **5.26a**
 Takotsubo **5.26b**
 Takotsubo **5.26c**
 Takotsubo **5.26d**
 Takotsubo **5.26e**
 Takotsubo **5.26f**
- Chapter 6**
 LV function **6.2a,b, & e**
 LV function **6.3a,b, & e**
 Left coronary artery **6.4a**
 Left coronary artery **6.4c**
 Right coronary artery **6.5a**
 Right coronary artery **6.5c**
 Right coronary artery **6.5e**
 ECMO **6.6a**
 ECMO **6.6b**
 Radial strain **6.11a**
 LV function **6.13a**
 LV function **6.13b**
 Apical thrombus **6.14a**
 Apical thrombus **6.14d**
 Ruptured papillary muscle **6.15a**
 Inferior LV aneurysm **6.16a**
 Apical ischemic VSD **6.18c**
 Apical ischemic VSD **6.18d**
 Ischemic VSD **6.19b**
 RV ischemia **6.20**
- Chapter 7**
 AoV anatomy **7.1a**
 AoV anatomy **7.1a**
 Ao root anatomy **7.3a**
 Ao stenosis **7.4a & c**
 Bicuspid AoV **7.5a**
 Bicuspid AoV **7.5e**
 Unicuspid unicommissural AoV **7.6a**
 Supraaortic Ao membrane **7.7c**
 TG LAX View **7.8a**
 Deep TG views **7.9a**
 TG views of AoV **7.10a**
 TG views of AoV **7.10e**
 ERO area **7.12a**
 Ao Regurgitation **7.13a**
 Mitral valve (MV) anatomy **7.16e**
 LAA thrombus **7.18a**
 LAA thrombus **7.18c**
 LAA velocities **7.21a**
 TEE assessment of MV **7.23c**
 TEE assessment of MV **7.23e**
 TEE assessment of MV **7.23g**
 TEE assessment of MV **7.23i**
 Rheumatic tricuspid valve (TV) **7.26a**
 Rheumatic tricuspid valve (TV) **7.26c**
 TR **7.27a**
 Pulmonic valve (PV) **7.31a**
 Pulmonic valve (PV) **7.31a**
 Pulmonary artery post-stenotic aneurysm **7.32a**
- Pulmonary artery post-stenotic aneurysm **7.32c**
 Normal pulmonic valve (PV) **7.33b**
 Mechanical heart valves **7.34b**
 Mitral valve (MV) bioprotheses **7.36a**
 Mitral valve (MV) bioprotheses **7.36a**
 Mechanical bileaflet dysfunction **7.37a**
 Mechanical bileaflet dysfunction **7.37c**
 Washing jets **7.38a**
- Chapter 8**
 Persistent LSVc **8.2a**
 Atrial septal aneurysm **8.3a**
 Eustachian valve and Chiari network **8.5a**
 Eustachian valve and Chiari network **8.5c**
 Eustachian valve and Chiari network **8.5d**
 Lipomatous hypertrophy **8.6a**
 Papillary muscle as a pseudomass **8.7a**
 Papillary muscle as a pseudomass **8.7e**
 False tendon **8.8c**
 Moderator band **8.9a**
 Lambl's excrescence **8.10a**
 Endocarditis **8.11a**
 Endocarditis **8.11c**
 Endocarditis **8.11d**
 LV thrombus and hematoma **8.13a**
 Spontaneous echo contrast **8.14a**
 Spontaneous echo contrast **8.14c**
 Paradoxical embolism **8.15a**
 Paradoxical embolism **8.15d**
 Intra-cardiac thrombus **8.18a**
 Intra-cardiac thrombus **8.18e**
 Chronic pulmonary embolism **8.19a**
 Endocarditis **8.20a**
 Endocarditis **8.20b**
 Endocarditis **8.20e**
 Tricuspid valve (TV) endocarditis **8.21a**
 Endocarditis **8.22a**
 Endocarditis **8.22c**
 Left atrial myxoma **8.24a**
 Left atrial myxoma **8.24c**
 Fibroelastoma **8.25d**
 Fibroma **8.26a**
 Fibroma **8.26c**
 Pericardial cyst **8.28a**
 Pericardial cyst **8.28d**
 Renal cell cancer **8.32a**
 Carcinoid heart disease **8.33a**
 Carcinoid heart disease **8.33c**
- Carcinoid heart disease **8.33d**
 IABP catheter **8.34a**
 ECMO cannula **8.35a**
 ECMO cannula **8.35b**
 ECMO cannula **8.35c**
- Chapter 9**
 Brain-heart syndrome **9.7a**
 Brain-heart syndrome **9.7b**
 Brain-heart syndrome **9.7c**
 ECG changes **9.8b**
 Arterial pressure waveforms **9.9a**
 Arterial pressure waveforms **9.9b**
 Arterial pressure waveforms **9.9c**
 Arterial pressure waveforms **9.9d**
 Arterial pressure waveforms **9.9ei**
 Arterial pressure waveforms **9.9eii**
 Capnography and ventilator flow-time waveforms **9.10b**
 V wave **9.11a**
 V wave **9.11a**
 V wave **9.11b**
 V wave **9.11c**
 V wave **9.11c**
 Systolic blood pressure **9.12**
 LVOT obstruction **9.13a**
 LVOT obstruction **9.13d**
 RVOT obstruction **9.14a**
 RVOT obstruction **9.14e**
 RVOT obstruction **9.14f**
 Acute pulmonary emboli **9.15a**
 Acute pulmonary emboli **9.15b**
 Cardiac tamponade **9.16a**
 Cardiac tamponade **9.16c**
 Left-sided pneumothorax **9.17b**
 Compression of the RA **9.18a**
 IVC occlusion during Fontan procedure **9.19a**
 Endocarditis with Ao root abscess **9.20a**
 Endocarditis with Ao root abscess **9.20a**
 Endocarditis with Ao root abscess **9.20c**
 Pneumonia **9.21a**
 Peritoneal bleed **9.22a**
- Chapter 11**
 Patent foramen ovale (PFO) **11.2a & b**
 ASD secundum **11.5a**
 ASD secundum **11.5d**
 Patent Foramen Ovale (PFO) **11.6c**
 Muscular VSD **11.8a**
 Muscular VSD **11.8c**
- Chapter 12**
 TDI for RV function **12.3c**
 Air emboli **12.7a**
 LUPV stenosis **12.8a**
 Transverse Ao **12.11 a & c**

- Left atrio-femoral bypass [12.13a](#)
 Guidewire position [12.15a](#)
 Ao arch vessels [12.16a](#)
 Pleural effusion [12.19b](#)
 Pleural effusion [12.19c](#)
 LVOTO and hypoxemia [12.21a](#)
 LVOTO and hypoxemia [12.21c](#)
 LVOTO and hypoxemia [12.21d](#)
 IVC stenosis [12.22a](#)
 IVC stenosis [12.22b](#)
 IVC stenosis [12.22c](#)
 IVC stenosis [12.22e](#)
 Ao dissection Stanford type A [12.23a](#)
 Ao dissection Stanford type A [12.23c](#)
 Air embolism [12.24a](#)
 Embolus [12.25a](#)
- Chapter 13**
 TCCS [13.3a](#)
 TCCS [13.3c](#)
 Temporal windows [13.7](#)
 Orbital window [13.8b](#)
 Occipital window [13.9](#)
 Vasospasm [13.11a](#)
 Vasospasm [13.11c](#)
 Papilledema [13.16a](#)
 Optic nerve examination [13.17c](#)
 Postcraniotomy [13.21b](#)
 Cerebral hematoma [13.22a](#)
 Cerebral hematoma [13.22b](#)
 Shunts and emboli [13.25f](#)
 Submandibular window [13.10ab](#)
 Submandibular window [13.10cd](#)
- Chapter 14**
 Anatomic correlation [14.2a](#)
 Anatomic correlation [14.2a](#)
 Anatomic correlation [14.2b](#)
 Anatomic correlation [14.2c](#)
 Anatomic correlation [14.2c](#)
 Normal lung sliding [14.5a & b](#)
 Lung pulse [14.6c](#)
 US settings and B lines [14.12a](#)
 US settings and B lines [14.12b](#)
 US settings and B lines [14.12c](#)
 US settings and B lines [14.12d](#)
 E and Z lines [14.13a](#)
 E and Z lines [14.13b](#)
 Subcutaneous emphysema [14.14a](#)
 Congestive heart failure [14.16b](#)
 Congestive heart failure [14.16c](#)
 Congestive heart failure [14.16e](#)
 Congestive heart failure [14.16g](#)
 Air bronchogram [14.20a](#)
 Viral pneumonia [14.21a](#)
 Viral pneumonia [14.21b](#)
 Pulmonary venous thrombosis [14.22a](#)
 Pneumothorax [14.24a](#)
 Pneumothorax [14.25a](#)
 Barcode sign [14.27](#)
 Lung point in M-mode [14.28](#)
 Pleural effusion [14.29](#)
 Empyema [14.31](#)
 Percutaneous tracheostomy [14.34c](#)
- Chapter 15**
 FOCUS exam [15.2a](#)
 FOCUS exam [15.2c](#)
 FOCUS exam [15.2e](#)
 FOCUS exam [15.2h](#)
 Asc Ao aneurysm [15.4a](#)
 Asc Ao aneurysm [15.4b](#)
 Asc Ao aneurysm [15.4c](#)
 RV Dysfunction [15.5a](#)
 RV Dysfunction [15.5g](#)
 RV Dysfunction [15.5e](#)
 Pleural Effusion [15.6a](#)
 Pleural Effusion [15.6c](#)
 RV Dysfunction [15.10a](#)
 RV Dysfunction [15.10c](#)
 RV Dysfunction [15.10e](#)
 RV dysfunction and pulmonary hypertension [15.12a](#)
 IVC Diameter [15.13a](#)
 IVC Diameter [15.13b](#)
 Respiratory variation of the SVC [15.14a](#)
 Cardiac tamponade [15.15a](#)
 Pleural Effusion [15.16a](#)
 Pleural Effusion [15.16c](#)
 Pleural Effusion [15.16d](#)
 Thrombus [15.17a](#)
 Thrombus [15.17b](#)
 Ventricular Septal Defect [15.18a](#)
 Ventricular Septal Defect [15.18b](#)
 Myxoma [15.19a](#)
 Myxoma [15.19b](#)
 Pulmonary Embolism [15.20a](#)
 Pulmonary Embolism [15.20b](#)
 Ao Dissection [15.21a](#)
 Ao Dissection [15.21b](#)
 Takotsubo syndrome [15.22a](#)
 Takotsubo syndrome [15.22b](#)
 Outflow Tract Obstruction [15.23a](#)
 Outflow Tract Obstruction [15.23c](#)
 Outflow Tract Obstruction [15.23e](#)
 LVOT obstruction [15.24a](#)
 LVOT obstruction [15.24a](#)
- Chapter 16**
 Abdominal wall varices [16.2a](#)
 Abdominal wall varices [16.2b](#)
 Normal liver anatomy [16.6](#)
 Right posterior axillary coronal upper and mid abdominal US views [16.7bdf](#)
 Right posterior axillary coronal upper and mid abdominal US views [16.7h](#)
 Gallbladder [16.8d](#)
 Gallbladder [16.8b](#)
 Gallbladder [16.8c](#)
 Kidney [16.9a](#)
 Kidney [16.9b](#)
 Spleen [16.10a](#)
 Spleen [16.10b](#)
 Spleen [16.10b](#)
 Abdominal aorta [16.12b](#)
 Abdominal aorta [16.12c](#)
 Abdominal aorta [16.12d](#)
 Abdominal aorta branches [16.14ace](#)
 Abdominal aorta branches [16.14bdf](#)
 IVC [16.15b](#)
 IVC [16.15c](#)
 IVC [16.15d](#)
 HVF [16.16a](#)
 HVF [16.16b](#)
 PVF [16.17b](#)
 Bladder [16.18a](#)
 Stomach [16.20a](#)
 Stomach [16.20a](#)
 Free fluid [16.21a](#)
 Free fluid [16.21c](#)
 Subdiaphragmatic abscess [16.22a](#)
 Rectosigmoid free fluid [16.23a](#)
 Retroperitoneal hemorrhage [16.24a](#)
 Abnormal kidneys [16.25c](#)
 Ileus [16.26a](#)
 Full stomach [16.27a](#)
 Full stomach [16.27b](#)
 Full stomach [16.27d](#)
 Air in the liver [16.28a](#)
 Air in the liver [16.28c](#)
 Abdominal Ao aneurysm [16.29a](#)
 Abdominal Ao aneurysm [16.29d](#)
 Ao dissection [16.30a](#)
 Ao dissection [16.30b](#)
 IVC [16.31a](#)
 IVC [16.31b](#)
 IVC [16.31c](#)
 IVC [16.31c](#)
 IVC [16.31e](#)
 IVC [16.31f](#)
 Abnormal portal vein vel [16.32a](#)
 Gallstone complications [16.33a](#)
 Abnormal gallbladder [16.34c](#)
 Hydronephosis [16.35e](#)
 Foley catheter [16.36a](#)
 Foley catheter [16.36b](#)
 Foley catheter [16.36c](#)
 Acute colitis [16.37a](#)
 Acute colitis [16.37b](#)
 Abnormal liver [16.38c](#)
 Abnormal spleen [16.39a](#)
 Abnormal spleen [16.39c](#)
- Chapter 17**
 Internal Mammary Artery [17.1a](#)
 Internal Mammary Artery [17.1b](#)
 Effusions [17.3d](#)
 Pericardiocentesis [17.5a](#)
 Pericardiocentesis [17.5b](#)
 Pericardiocentesis [17.5c](#)
 Pericardiocentesis [17.6a](#)
 Pericardiocentesis [17.6b](#)
 Pericardiocentesis [17.6c](#)
 Pericardiocentesis [17.6c](#)
 Pleurocentesis [17.1](#)
 Pleurocentesis [17.11a](#)
 Pleurocentesis [17.11b](#)
 Pneumothorax [17.12b](#)
 Pneumothorax [17.13a](#)
 Pneumothorax [17.13c](#)
 Pneumothorax [17.13c](#)
 Pneumothorax [17.13b](#)
 Pneumothorax [17.13d](#)
 Pneumothorax [17.13d](#)
 Paracentesis [17.16a](#)
 Paracentesis [17.16b](#)
 Paracentesis [17.16c](#)
 Paracentesis [17.17](#)
- Chapter 18**
 Central line kit [18.3](#)
 Internal jugular vein [18.4](#)
 Internal jugular vein [18.9a](#)
 Internal jugular vein [18.9b](#)
 Internal jugular vein [18.9b](#)
 Internal jugular vein [18.9c](#)
 Internal jugular vein [18.9d](#)
 Internal jugular vein [18.10a](#)
 Internal jugular vein [18.10b](#)
 Internal jugular vein [18.10c](#)
 Internal jugular vein [18.10d](#)
 Double tip sign [18.11a](#)
 Double tip sign [18.11a](#)
 Double tip sign [18.11b](#)
 Guidewire position [18.12a](#)
 Guidewire position [18.12c](#)
 Guidewire malpositions [18.13b](#)
 Guidewire malpositions [18.13c](#)
 US of axillary vasculature [18.15b](#)
 US of axillary vasculature [18.15c](#)
 Axillary vein [18.16a](#)
 Axillary vein [18.16b](#)
 Enhanced needle [18.17](#)
 Femoral vessel examination [18.20a](#)
 Femoral vessel examination [18.20c](#)
 Femoral vessel examination [18.20d](#)
 Complications [18.21a](#)
 Complications [18.21b](#)
 Complications [18.21b](#)
 Complications [18.21c](#)
 Complications [18.22a](#)
 Complications [18.22c](#)
 Complications [18.22d](#)
 Complications [18.23b](#)
 Complications [18.23c](#)
 Complications [18.24a](#)
 Complications [18.24c](#)
 Complications [18.24d](#)
 US-guided examination of the upper extremity [18.27](#)
 PICC insertion [18.29a](#)
 PICC insertion [18.29d](#)
 PICC position [18.30a](#)
 PICC insertion [18.32](#)
 Intravascular Doppler tip tracking system [18.33](#)
 Radial artery [18.37a](#)
 Radial artery [18.37d](#)
 Arterial vascular pathologies [18.39a](#)
 Arterial vascular pathologies [18.39b](#)
 Arterial vascular pathologies [18.39c](#)
 US training [18.41d](#)
 US training [18.41d](#)
- Appendix**
 Antero posterior view CT
 Transverse plane view CT
 CT Sagittal plane view CT
 Mid-Esophageal Four-Chamber [A1](#)
 Mid-Esophageal Two-Chamber Mitral Commissural [A2](#)
 Mid-Esophageal Two-Chamber [A3](#)
 Mid-Esophageal Long-Axis [A4](#)
 Mid-Esophageal Left Atrial Appendage [A5](#)
 Mid-Esophageal Left Atrial Appendage [A5](#)
 Mid-Esophageal Right Ventricular Outflow Tract [A6](#)
 Mid-Esophageal Right Ventricular Outflow Tract [A6](#)
 Mid-Esophageal Bicaval [A7](#)
 Mid-Esophageal Aortic Valve Short-Axis [A8](#)
 Mid-Esophageal Aortic Valve Short-Axis [A8](#)
 Mid-Esophageal Aortic Valve Long-Axis [A9](#)
 Mid-Esophageal Ascending Aortic Short-Axis [A10](#)
 Mid-Esophageal Ascending Aortic Long-Axis [A11](#)
 Transgastric Mid-Papillary Short-Axis [B1](#)
 Transgastric Basal Short-Axis [B2](#)
 Transgastric Basal Short-Axis [B2](#)
 Transgastric Two-Chamber [B3](#)
 Transgastric Long-Axis [B4](#)
 Transgastric Right Ventricle [B5](#)
 Transgastric Inferior Vena Cava Long-Axis [B6](#)
 Transgastric Inferior Vena Cava Long-Axis [B6](#)
 Deep Transgastric [C1](#)
 Descending Aortic Short-Axis [D1](#)
 Descending Aortic Long-Axis [D2](#)
 Upper Esophageal Aortic Long-Axis [E1](#)
 Upper Esophageal Aortic Short-Axis [E2](#)