Transesophageal Echocardiography

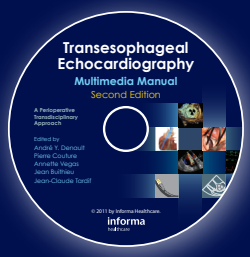
Multimedia Manual

Second Edition

A Perioperative Transdisciplinary Approach

Edited by
André Y. Denault
Pierre Couture
Annette Vegas
Jean Buithieu
Jean-Claude Tardif

DVD Included!



informa
healthcare

Transesophageal Echocardiography Multimedia Manual

This page intentionally left blank

Transesophageal Echocardiography Multimedia Manual

A Perioperative Transdisciplinary Approach

Second Edition

Edited by

André Y. Denault
Montreal Heart Institute
Centre Hospitalier de l'Université de Montréal
Montreal, Quebec, Canada

Pierre Couture
Montreal Heart Institute
Université de Montréal
Montreal, Quebec, Canada

Annette Vegas
Toronto General Hospital
University of Toronto
Toronto, Ontario, Canada

Jean Buithieu
McGill University Health Center
Montreal, Quebec, Canada

Jean-Claude Tardif
Montreal Heart Institute Research Center
Université de Montréal
Montreal, Quebec, Canada

informa
healthcare
New York London

First published in 2005 by Marcel Dekker, Inc. This edition published in 2011 by Informa Healthcare, Telephone House, 69-77 Paul Street, London EC2A 4LQ, UK.
Simultaneously published in the USA by Informa Healthcare, 52 Vanderbilt Avenue, 7th floor, New York, NY 10017, USA.

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

ISBN-13: 978-1-420-08070-4

Orders may be sent to: Informa Healthcare, Sheepen Place, Colchester, Essex CO3 3LP, UK
Telephone: +44 (0)20 7017 5540
Email: CSDhealthcarebooks@informa.com
Website: http://informahealthcarebooks.com/

For corporate sales please contact: CorporateBooksIHC@informa.com
For foreign rights please contact: RightsIHC@informa.com
For reprint permissions please contact: PermissionsIHC@informa.com

Typeset by MPS Limited, a Macmillan Company
Printed and bound in India

This book is dedicated to

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

Frédéric and Noémi (Pierre Couture);

my family Patrick, Lena, and Derek for their unconditional love and encouragement (Annette Vegas);

my wife Véronique and my parents Tuong and Thai (Jean Buithieu);

Michèle, Jean-Daniel, and Pier-Luc, who have been so supportive and so patient with me (Jean-Claude Tardif);

our families and teachers who have prepared us for this work;

our students;

and above all our patients for whom we hope and believe that transesophageal echocardiography and perioperative echocardiography will improve their care.

This page intentionally left blank

Foreword

When it was released in 2005, the first edition of *Transesophageal Echocardiography Multimedia Manual* was instantly praised as one of the most comprehensive pedagogical endeavor into the then-fairly-new field of perioperative echocardiography. So, when they decided, five years later, to undertake the challenge of creating a new and improved version of their work, André Denault and his team had to know that they would be held to the highest standard, the one that they themselves created. To be truly innovative and useful to beginners and experts alike, the new edition would have to include basic echographic notions while encompassing most major advances in the field of transesophageal echocardiography (TEE). Moreover, all this material would have to be showcased in an up-to-date and appealing format using the most advanced pedagogical tools available. Well, we can now state that the challenge has been met successfully and that this second edition of *Transesophageal Echocardiography Multimedia Manual* should become an instant classic for everybody who is seriously interested in TEE and perioperative echocardiography.

Dr. Denault and his fellow editors have been able to assemble a team of experts coming from several countries, giving their work a truly international flavor. Also, since contributors belong to various disciplines, namely anesthesiology, cardiology, surgery, and radiology, their work is uniquely positioned to provide the reader with a truly multidisciplinary approach to perioperative problems. The new edition contains more chapters, figures, and tables than the previous one. It includes new topics while expanding on issues that were already covered in the first edition. The DVD, with its numerous 3D animations and systematic approach to various physiological and pathological situations, will also allow the reader to complement and elaborate on the book's content.

The numerous editors and authors of this new edition of *Transesophageal Echocardiography Multimedia Manual* have to be commended for their contribution to the teaching of TEE and sustained commitment toward improving perioperative care.

Pierre Drolet, MD, FRCPC
Chairman, Department of Anesthesiology,
Université de Montréal, Quebec, Canada

This page intentionally left blank

Preface to the second edition

Since its introduction two decades ago, perioperative transesophageal echocardiography (TEE) has become a valuable adjunct in the management of cardiac surgery patients. Over the past five years there has been a rapid expansion in the use of TEE, to encompass newer cardiac surgical techniques, more diverse surgical procedures, and in the intensive care unit. This Second Edition of the *Transesophageal Echocardiography Multimedia Manual* is now geared to present these new developments and challenges for the anesthesiologist, cardiologist, cardiac surgeon and those interested in perioperative TEE.

Every chapter in this edition has been updated and six new chapters have been added which emphasize the role of TEE in (1) new cardiac surgical techniques (minimally invasive, transcatheter valves), (2) non cardiac surgery (transplant, endovascular, electrophysiology procedures) and (3) complementary imaging techniques (transthoracic, epicardial, three-dimensional echocardiography). This transdisciplinary book remains unique in that it contains the experience of individuals trained in anesthesiology, cardiology, critical care, internal medicine, cardiac and vascular surgery, lung and hepatic transplantation, radiology, pathology, physics, and computer technology.

As in the first edition, detailed figures present complementary information that provides the context to assist the clinician practicing perioperative TEE. But if ''an image is worth a thousand words,'' what about a video? Transesophageal echocardiography is a dynamic process and most of our two-dimensional examples are presented in their original video format accompanied by sketches, three-dimensional orientation, Doppler information, hemodynamic, radiologic and anatomical correlation in a user-friendly companion DVD. The content of the DVD has expanded to include the key elements of several common surgical procedures and a multiple choice exam created by the cardiac anesthesiologists of St. Boniface General Hospital in Winnipeg under the supervision of G. Scott Mackenzie. This exam is inspired by the format of the National Board of Echocardiography. In addition, a web link to the Universities of Montreal, McGill and Toronto will offer continuing medical education (AMA certification) credits for those who use the TEE Multimedia Manual as an educational resource.

Such work would not have been possible without the collaboration of several individuals. First, we welcome Dr. Annette Vegas from the Toronto General Hospital who agreed to share her knowledge and passion for TEE and join the editorial team. Annette has significantly contributed to TEE education in Canada through the organization of an annual TEE Symposium in Toronto and by producing an outstanding pocket TEE manual. The editorial team includes Dr. Pierre Couture, who pioneered the development of perioperative TEE in Quebec and has been my most significant collaborator in TEE since 1993. I am also privileged to benefit from the expertise of Drs. Jean Buithieu and Jean-Claude Tardif, who contributed to the creation and revision of the second edition. My assistant, Denis Babin, supplied his enormous skill and talent in organizing, digitalizing, and his determination to make the dream a reality. I am grateful to my anesthesiologist colleagues and the surgical team of the Montreal Heart Institute who have always mutually shared their knowledge and informed me of interesting cases. Dr. Michel Pellerin, chief of cardiac surgery at the Montreal Heart Institute, remains a significant contributor by teaching us surgical anatomy and sharing his video material. Finally, Dr. Yoan Lamarche, a cardiac surgeon trained in TEE and in critical care medicine, provided us with a unique surgical perspective by stressing the key issues that the cardiac surgeon wants to resolve when a TEE exam is performed.

In addition to the authors of this TEE manual, there are several individuals in the operating room who have collaborated in the creation of this book. These individuals made suggestions for chapter content, figures, video clips, and DVD

creation which greatly facilitated our work. Their names are listed on the following page. Financial support for the DVD, which accompanies this book, was provided with the support of Robert Busilacchi, Danielle Pagé and Dr. Annie Dore, through an educational grant from the Montreal Heart Institute, and by the Montreal Heart Institute Foundation. Sponsorship from Philips has allowed us to insert their brilliantly educational transesophageal echocardiography three-dimensional normal exam in the DVD. Finally, educational grants from General Electric, Sonosite, the Foundation of the Association des Anesthésiologistes du Québec (AAQ), and Organon through the Department of Anesthesiology at the University of Montreal, were pivotal in supporting image preparation for the manual.

I sincerely hope that this TEE manual will help to improve your care in providing echocardiographic diagnosis and monitoring, and that it will be useful in your teaching of perioperative echocardiography.

André Y. Denault, M.D., Ph.D., ABIM-CCM, FRCPC, FASE

Acknowledgments

Luce Begin
Sylvain Bélisle
Jean-Sébastien Bilodeau
Robert Blain
Denis Bouchard
Michèle Brault
Monique Brouillard
Diane Campeau
Jennifer Cogan
Philippe Demers
Nathalie De Mey
Sarah Dery
Sylvain Durocher
Amélie Gariepy
Alain Girard
Yves Hébert
Gisèle Hemmings
Stuart Herd
Normand Hey
Christophe Heyllbroeck
Christian Jodoin
Suzanne Kaprélian
Jean Leclerc
Tack Ki Leung
Patrick Limoges
Ariane Marelli
Avrum Morrow
Antoinette Paolitto
Pierre Pagé
Guy Pelletier
Louis Perrault
Nancy Poirier
Terry Potts
Baqir Qizilbash
Anan Raghunathan
Catherine Roy
Philippe Sahab
Sophie St-Onge
Jean Taillefer
France Thériault
Pierrette Thivierge
Karine Toledano
Ann Wright
Les inhalothérapeutes du bloc opératoire de l'ICM
Fonds de la Recherche en Santé du Québec

Educational grant from: Foundation of the Association des Anesthésiologistes du Québec, Bourse Organon du département d'anesthésiologie de l'Université de Montréal, Danielle Pagé from the Montreal Heart Institute Foundation, Robert Busilacchi and Annie Dore from the Montreal Heart Institute Educational Services.

Industrial support (unrestricted grant) from: Suzan Clair from General Electric, Joseph Bestavros and Suzie Grisolia from Sonosite, Sylvain Brunet from Philips, Réal Côté from Fresenius.

This page intentionally left blank

Contents

Contributors

Robert Amyot, MD, FRCPC Associate Professor, Department of Medicine, Division of Cardiology, Hôpital du Sacré-Coeur de Montréal, Université de Montréal, Montreal, Canada

Marie Arsenault, MD, FRCPC Director of Echocardiography Laboratory, Institut Universitaire de Cardiologie et de Pneumologie de Québec, Université Laval, Quebec City, Canada

Christian Ayoub, MD, B.Pharm, FRCPC Clinical Assistant Professor, Department of Cardiac Anesthesiology, Montreal Heart Institute, Department of Anesthesiology, Maisonneuve-Rosemont Hospital, Université de Montréal, Montreal, Canada

Daniel Bainbridge, MD, FRCPC Director of Cardiac Anesthesiology, London Health Sciences Centre, Associate Professor, Department of Anesthesiology and Perioperative Medicine, University of Western Ontario, London, Canada

Miguel A. Barrero Garcia, MD Cardiologist, Centre hospitalier régional de Trois Rivières, Quebec, Clinical Lecturer, Université de Montréal, Montreal, Canada

Arsène-J. Basmadjian, MD, MSc, FACC, FRCPC Director of Echocardiography and Non-Invasive Cardiology, Montreal Heart Institute, Associate Professor, Department of Medicine, Division of Cardiology, Université de Montréal, Montreal, Canada

Yanick Beaulieu, MD, FRCPC Cardiologist – Echocardiographer / Intensivist, Director of the Bedside Ultrasound Curriculum, Hôpital du Sacré-Coeur de Montréal, Assistant Professor, Department of Medicine, Université de Montréal, Montreal, Canada

François A. Béïque, MD, FRCPC Director of Cardiac Anesthesia, Sir Mortimer B. Davis Jewish General Hospital, Associate Professor, Department of Anesthesiology, McGill University, Montreal, Canada

Denis Bouchard, MD, CM, MSc, FRCSC Program Director of Cardiac Surgery, Montreal Heart Institute, Associate Professor, Department of Surgery, Université de Montréal, Montreal, Canada

John Bowering, MD, FRCP Associate Professor, Department of Anesthesiology, Providence Health Care, University of British Columbia, Vancouver, Canada

Richard Bowry, MBBS, FRCA Medical Director of Cardiovascular Intensive Care, Department of Anesthesiology, St. Michael's Hospital, Assistant Professor, Department of Anesthesiology, University of Toronto, Toronto, Canada

Jean Buithieu, MD, FRCPC Director of Echocardiography and Non-Invasive Cardiology, McGill University Health Center, Assistant Professor, Department of Medicine, Division of Cardiology, McGill University, Montreal, Canada

Jean S. Bussières, MD, FRCPC, DABA Anesthesiologist, Anesthesiology Research Team Director, Department of Anesthesiology, Institut Universitaire de Cardiologie et de Pneumologie de Québec, Associate Clinical Professor, Université Laval, Quebec City, Canada

Michel Carrier, MD, FRCSC Professor of Surgery, Department of Cardiac Surgery, Montreal Heart Institute, Université de Montréal, Montreal, Canada

Raymond Cartier, MD, FRCSC Professor of Cardiac Surgery, Department of Cardiac Surgery, Montreal Heart Institute, Université de Montréal, Montreal, Canada

Jean Champagne, MD, FRCPC Associate Professor, Department of Medicine, Division of Cardiology and Electrophysiology, Institut Universitaire de Cardiologie et de Pneumologie de Québec, Université Laval, Quebec City, Canada

Carl Chartrand-Lefebvre, MD FRCPC Associate Professor, Department of Radiology, Centre Hospitalier de l'Université de Montréal (CHUM) and Montreal Heart Institute, Université de Montréal, Montreal, Canada

Pierre-Guy Chassot, MD Former Chief of Cardiovascular Anesthesia, University Hospital Lausanne, Privat-Docent, Faculty of Biology and Medicine, University of Lausanne, Lausanne, Switzerland

Robert Chen, MD, FRCPC Cardiac Anesthesia Fellowship Program Director, St. Michael's Hospital, Assistant Professor, Department of Anaesthesiology, University of Toronto, Toronto, Canada

Anson Cheung, MD, FRCSC Surgical Director of Cardiac Transplant, Clinical Associate Professor of Surgery, Division of Cardiothoracic Surgery, St. Paul's Hospital, University of British Columbia, Vancouver, Canada

Chris Christodoulou, MBChB Cum Laude, DA (UK), FRCPC Assistant Professor, University of Manitoba, Winnipeg, Canada

Guy Cloutier, P.Eng, PhD Director of the Laboratory of Biorheology and Medical Ultrasonics, Research Center of Université de Montréal Hospital Center (CRCHUM); Professor of Radiology and Biomedical Engineering, Université de Montréal, Montreal, Canada.

José W. Coddens, MD Staff Anesthesiologist, Responsible for the Section Cardiovascular and Thoracic Anesthesia, Responsible for the Section Perioperative Echocardiography, Department of Anesthesia and Intensive Care Medicine, Onze Lieve Vrouw Clinic, Aalst, Belgium

Annie V. Côté, MD, FRCPC Assistant-Professor, Department of Cardiac Anesthesiology, McGill University Health Center, Montreal, Canada

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

Jean-Marc Côté, MD, FRCPC Pediatric Cardiologist, Associate Professor, Department of Pediatrics, Centre Hospitalier Universitaire de Québec (CHUQ), Université Laval, Quebec City, Canada

Stéphane Coutu, MD, FRCPC Associate Professor, Department of Anesthesiology, Centre Hospitalier Universitaire de Sherbrooke (CHUS), Université de Sherbrooke, Sherbrooke, Canada

Pierre Couture, MD, FRCPC Cardiac Anesthesiology Department, Montreal Heart Institute, Associate Clinical Professor, Department of Cardiac Anesthesiology, Université de Montréal, Montreal, Canada

Robert James Cusimano, MD, BSc, MSc, FACS, FRCSC Peter Munk Cardiac Centre, Associate Professor, Department of Surgery, Division of Cardiac Surgery, University of Toronto, Toronto, Canada

Roland DeBrouwere, MD, FRCPC Assistant Professor, University of Manitoba, Winnipeg, Canada

André Y. Denault, MD, PhD, ABIM-CCM, FRCPC, FASE Associate Professor, Department of Cardiac Anesthesiology, Montreal Heart Institute, Division of Critical Care of the Department of Medicine, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montreal, Canada

Alain Deschamps, PhD, MD, FRCPC Director of Research of the Department of Anesthesiology, Montreal Heart Institute, Associate Professor, Department of Anesthesiology, Université de Montréal, Montreal Canada

Ariel Diaz, MD, MSc Cardiologist, Centre hospitalier régional de Trois Rivières, Quebec, Clinical Lecturer, Université de Montréal, Montreal, Canada

Maria Di Lorenzo, MD, FRCPC Cardiologist, Echocardiographist, Hôpital du Sacré-Coeur de Montréal, Assistant Professor, Department of Medicine, Division of Cardiology, Université de Montréal, Montreal, Canada

George Djaiani, MD, DEAA, FRCA, FRCPC Cardiac Anesthesia Fellowship Research Program Director, Associate Professor, Department of Anesthesia and Pain Management, Toronto General Hospital, University Health Network, University of Toronto, Toronto, Canada

Annie Dore, MD, FRCPC Director of Education, Montreal Heart Institute, Associate Professor, Department of Medicine, Université de Montréal, Montreal, Canada

Anique Ducharme, MD, MSc, FRCPC Director of the Heart Failure Clinic, Montreal Heart Institute, Associate Professor, Department of Medicine, Division of Cardiology, Université de Montréal, Montreal, Canada

Jean G. Dumesnil, CQ, MD, FRCPC, FACC Cardiologist, Institut Universitaire de Cardiologie et de Pneumologie de Québec /Québec Heart and Lung Institute, Professor of Medicine, Université Laval, Quebec City, Canada

Nicolas Dürrleman, MD Department of Cardiac, Thoracic and Vascular Surgery, Private Hospital Les Franciscaines, Nîmes, France

James P. Enns, BSc (Med), MD, FRCPC Assistant Professor, University of Manitoba, Winnipeg, Canada

Ashraf Fayad, MD, FRCPC, FASE, FACC Director of Echocardiography Fellowship for Non-Cardiac Surgery, Associate Professor, Department of Anesthesiology, University of Ottawa, Ottawa, Canada

Pasquale Ferraro, MD, FRCSC Associate Professor, Chief Division of Thoracic Surgery, Alfonso Minicozzi and Family Chair in Lung Transplantation, Surgical Director Lung Transplant Program, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montreal, Canada

Alain Gauvin, MSc, MCCPM, DABR, DABMP Lecturer, Department of Radiology, Université de Montréal, Montreal, Canada

Michel Germain, MD, FRCPC, BA.Sc, B.Eng Staff Anesthesiologist, Royal Victoria Hospital, McGill University Health Center, Assistant Professor, Department of Anesthesiology, McGill University, Montreal, Canada

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

Hilary P. Grocott, MD, FRCPC, FASE Professor of Anesthesia and Surgery, University of Manitoba, Winnipeg, Canada

Craig Guenther, MD, FRCPC Associate Clinical Professor, Anesthesiology and Pain Medicine, University of Alberta, Edmonton, Canada

François Haddad, MD, FRCPC Attending Cardiologist, Heart Failure and Transplant Program, Stanford University, Palo Alto, California, U.S.A.

Jane Heggie, MD, FRCP Assistant Professor of Anaesthesia, Director of Anaesthesia Fellowship Programs, Toronto General Hospital, University Health Network, University of Toronto, Toronto, Canada

George N. Honos, MD, FRCPC, FACC Head of Division of Cardiology, Medical Director of Cardiovascular Program, Centre Hospitalier de l'Université de Montréal (CHUM), Associate Professor of Medicine, Université de Montréal, Montreal, Canada

Mark Hynes, MD, FRCPC Department of Cardiac Anesthesiology, University of Ottawa Heart Institute, Assistant Professor, Department of Anesthesiology, University of Ottawa, Ottawa, Canada

Reda Ibrahim, MD, FRCPC Interventional Cardiology and Director of the Medical Care Unit, Montreal Heart Institute, Assistant Professor, Department of Medicine, Division of Cardiology, Université de Montréal, Montreal, Canada

Ivan Iglesias, MD, FRCPC, FASE Intraoperative Echocardiography Program Coordinator, Associate Professor, Department of Anaesthesia and Perioperative Medicine, London Health Sciences Centre, University of Western Ontario, London, Canada

Marjan Jariani, MD, FRCPC Assistant Professor, Department of Anesthesia, University of Toronto, Cardiovascular ICU and Transesophageal Echocardiography, Toronto General Hospital, University Health Network, Toronto, Canada

Philippe L.-L'Allier, MD, FRCPC Interventional Cardiologist and Director of the Coronary Care Unit, Department of Medicine, Division of Cardiology, Montreal Heart Institute, Associate Professor, Université de Montréal, Montreal, Canada

Yoan Lamarche, MD, MSc, FRCSC Cardiac surgeon and critical care physician, Department of Cardiac Surgery, Montreal Heart Institute and Hôpital du Sacré-Coeur de Montréal, Adjunct Clinical Professor, Université de Montréal, Montreal, Canada

Stéphane Lambert, MD, CM, FRCPC Assistant Professor, Division of Cardiac Anesthesiology, University of Ottawa Heart Institute, Ottawa, Canada

Réal Lebeau, MD Assistant Professor, Department of Medicine, Division of Cardiology, Hôpital du Sacré-Coeur de Montréal, Université de Montréal, Montreal, Canada

Jean-Sébastien Lebon, MD, FRCPC, B.Pharm Assistant Professor, Department of Cardiac Anesthesiology, Montreal Heart Institute, Université de Montréal, Montreal, Canada

Trevor W. R. Lee, MD, FRCPC, FASE, CPE Head, Department of Anesthesia and Perioperative Medicine, St. Boniface General Hospital, Assistant Professor, University of Manitoba, Winnipeg, Canada

G. Scott MacKenzie, MD, FRCPC Medical Director, Cardiac Anesthesia, WRHA/St. Boniface Cardiac Sciences Program, St. Boniface General Hospital, Winnipeg, Canada

Doug Maguire, MD, FRCPC Assistant Professor, University of Manitoba, Winnipeg, Canada

Warner M. Mampuya, MD, PhD, FRCPC Cardiology Fellow, Centre Hospitalier Universitaire de Sherbrooke, Université de Sherbrooke, Sherbrooke, Canada

François Marcotte, MD, FRCPC, FACC, FASE Cardiologist, Montreal Heart Institute, Associate Professor, Department of Medicine, Université de Montréal, Montreal, Canada

André Martineau, MD, FRCP Department of Anesthesiology, Institut Universitaire de Cardiologie et de Pneumologie de Québec, Laval Hospital, Université Laval, Quebec City, Canada

Luc Massicotte, MD Associate Professor, Department of Anesthesiology, Saint-Luc Hospital, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montreal, Canada

Patrick Mathieu, MD, MSc, FRCSC Director of the Laboratoire d'Études Moléculaires des Valvulopathies (LEMV), Research Center Institut Universitaire de Cardiologie et de Pneumologie de Québec, Associate Professor, Department of Surgery, Université Laval, Quebec City, Canada

Massimiliano Meineri, MD Assistant Professor of Anesthesia, University of Toronto, Staff Anesthesiologist, Toronto General Hospital, Toronto, Canada

Bradley I. Munt, MD, FRCPC, FACC Cardiologist, St. Paul's Hospital, Vancouver, Canada

John M. Murkin, MD, FRCPC Professor of Anesthesiology, Director of Cardiac Anesthesia Research, Department of Anesthesiology and Perioperative Medicine, London Health Sciences Center, University of Western Ontario, London, Canada

Viviane T. Q. Nguyen, MD, FRCPC Heart Failure and Transplant Program Director, Assistant Professor of Medicine, Division of Cardiology, McGill University Health Center, McGill University, Montreal, Canada

Georghios Nicolaou, MBBCh, FRCPC Director and Fellowship Coordinator of Thoracic and Vascular Anesthesia, Associate Professor and Chief of Anesthesia, Victoria Hospital, Department of Anesthesia and Perioperative Medicine, London Health Sciences Center, University of Western Ontario, London, Canada

Michel Pellerin, MD, FRCSC Head of Department of Surgery, Montreal Heart Institute, Michal & Renata Hornstein Chair in Cardiac Surgery, Professor of Surgery, Université de Montréal, Montreal, Canada

Michel-Antoine Perrault, MD, FRCPC Clinical Assistant Professor, Department of Anesthesiology, Centre Hospitalier Universitaire de Sherbrooke (CHUS), Sherbrooke, Canada

Philippe Pibarot, DVM, PhD, FACC, FAHA Chair of the Canada Research Chair in Valvular Heart Disease, Full Professor, Institut Universitaire de Cardiologie et de Pneumologie de Québec (IUCPQ), Université Laval, Quebec City, Canada

François Plante, MD, FRCPC Associate Clinical Professor, Department of Anesthesiology, Centre Hospitalier de l'Université de Montréal (CHUM), Université de Montréal, Montreal, Canada

Mackenzie Quantz, MD Division of Cardiac Surgery, London Health Sciences Centre, Associate Professor, University of Western Ontario, London, Canada

Chinniampalayam Rajamohan, MBBS, DA, MD, DNB, FCPS, FRCA, FRCPC Assistant Professor, University of Manitoba, Winnipeg, Canada

Anthony Ralph-Edwards, MD Division of Cardiovascular Surgery, Toronto General Hospital, University of Toronto, Toronto, Canada

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

André Saint-Pierre, MD, FRCPC Medical Director, Operating Suite, Institut Universitaire de Cardiologie et de Pneumologie de Québec, Clinical Professor, Department of Anesthesiology, Université Laval, Quebec City, Canada

Claude Sauvé, MD, FRCPC Director of Echocardiography Laboratory, Hôpital du Sacré-Coeur de Montréal, Associate Professor, Department of Medicine, Division of Cardiology, Université de Montréal, Montreal, Canada

John Scatliff, MD, FRCPC Assistant Professor, University of Manitoba, Winnipeg, Canada

Yan-Fen Shi, MD Cardiologist, Research Centre, Montreal Heart Institute, Research Associate, Department of Medicine, Division of Cardiology, Université de Montréal, Montreal, Canada

Peter Slinger, MD, FRCPC Staff Anesthesiologist, Toronto General Hospital, Professor of Anesthesia, University of Toronto, Toronto, Canada

Oren K. Steinmetz, MDCM, FRCSC Chief of Division of Vascular Surgery, Associate Professor, Department of Surgery, McGill University Health Centre and McGill University, Montreal, Canada

Johann Strumpher, MD Assistant Professor, University of Manitoba, Winnipeg, Canada

Jean-Claude Tardif, MD, FACC, FRCPC, FCAHS Director of the Research Center, Montreal Heart Institute, Professor, Department of Medicine, Université de Montréal, Montreal, Canada

Eric Therasse, MD, FRCPC Associate Professor, Department of Radiology, Centre Hospitalier de l'Université de Montréal (CHUM) and Montreal Heart Institute, Université de Montréal, Montreal, Canada

Ian R. Thomson, MD Professor, University of Manitoba, Winnipeg, Canada

Claude Tousignant, MD, FRCPC Assistant Professor, Department of Anesthesia and Critical Care, Director, Perioperative Echocardiography, St. Michael's Hospital, University of Toronto, Toronto, Canada

Franck Vandenbroucke-Menu, MD Assistant Professor, Department of Surgery, Université de Montréal, Hepatobiliary and Pancreatic Surgery and Liver Transplantation Service, Centre Hospitalier de l'Université de Montréal (CHUM), Centre de Recherche du CHUM (CRCHUM), Montreal, Canada

Michel J. Van Dyck, MD Staff Anesthesiologist, Cliniques universitaires Saint-Luc, Department of Acute Medicine, Division of Cardiac Anesthesiology, Université Catholique de Louvain (UCL), Brussels, Belgium

Hugo Vanermen, MD Head of the Department of Cardiovascular and Thoracic Surgery Unit, OLV Hospital, KUL University, Aalst, Belgium

Adriaan van Rensburg, MD Department of Anaesthesia, Toronto General Hospital, University of Toronto, Toronto, Canada

Annette Vegas, MD, FRCPC Staff Anesthesiologist, Director of Perioperative Transesophageal Echocardiography, Department of Anesthesiology, Toronto General Hospital, Associate Professor, University of Toronto, Toronto, Canada

Professor Antoine Vieillard-Baron, MD, PhD Chief of Intensive Care Unit, Hôpital Ambroise Paré, Boulogne, France, Assistance Publique des Hôpitaux de Paris, Faculté de Médecine Paris-Ile-de-France-Ouest, Université Versailles Saint-Quentin-en-Yvelines, France

Christine Watremez, MD Department of Anesthesiology, Cliniques Universitaires Saint-Luc, Brussels, Belgium

Terrence M. Yau, MD, MSc, FRCSC Angelo and Lorenza DeGasperis Chair in Cardiovascular Surgery Research, Director of Research, Division of Cardiovascular Surgery, Toronto General Hospital, Professor, Department of Surgery, University of Toronto, Toronto, Canada

R. Shawn Young, MD, FRCPC Medical Director, Anesthesia, Victoria General Hospital, Assistant Professor of Anesthesia, University of Manitoba, Winnipeg, Canada

Abbreviations

2D	two-dimensional
3D	three-dimensional
ε	strain
ε_L	Lagrangian strain
ε_N	natural or Eulerian strain
ρ	density
λ	wavelength
A	anterior
A-mode	amplitude mode
AA	apical anterior
AAA	abdominal aortic aneurysm
AC	accessory chamber
AC	atrial contraction
ACC	American College of Cardiology
ACGME	Accreditation Council for Graduate of Medical Education
ACT	activated clotting time
AF	atrial fibrillation
AHA	American Heart Association
AI	apical inferior
AIDS	acquired immunodeficiency syndrome
AL	antero-lateral
AL	apical lateral
AMA	American Medical Association
AML	anterior mitral leaflet
AMP	adenosine monophosphate
AMVL	anterior mitral valve leaflet
Ao	aorta
AoPV	aortic bioprosthetic valve
AoV	aortic valve
AP	antero-posterior
APE	acute pulmonary embolism
AR	aortic regurgitation
AR	atrial reversal
ARDS	acute respiratory distress syndrome
ARDS	adult respiratory distress syndrome
AS	anteroseptal
AS	aortic stenosis
AS	apical septal
ASA	American Society of Anesthesiologists
ASA	atrial septal aneurysm
ASC	ascending
ASD	atrial septal defect
ASE	American Society of Echocardiography
ASYNC	asynchronous
AT	acceleration time
AV	aortic valve
AV	atrioventricular
AVA	aortic valve area
AVC	aortic valve closure
AVJ	aorto-ventricular junction
AVO	aortic valve opening
AVR	aortic valve replacement

B-mode	brightness mode
BA	basal anterior
BAL	basal anterolateral
BAS	basal anteroseptal
BCA	brachiocephalic artery
BD	bile duct
BIL	basal inferior
BIS	basal inferoseptal
BP	blood pressure
BSA	body surface area
BTTAI	blunt traumatic thoracic aortic injury
BVR	balloon valvuloplasty registry
c	propagation speed
CABG	coronary artery bypass graft
CAD	coronary artery disease
CAP	congenital absence of the pericardium
CAS	Canadian Anesthesia Society
CFI	color flow imaging
CHF	congestive heart failure
CI	cardiac index
CJA	color jet area
CME	continuous medical education
CO	cardiac output
COPD	chronic obstructive pulmonary disease
CI	cardiac index
CP	constrictive pericarditis
CPB	cardiopulmonary bypass
CPS	cardiopulmonary surgery
CRT	cardiac resynchronization therapy
CS	coronary sinus
CSA	cross-sectional area
CSE	Canadian Society of Echocardiography
CRT	cardiac resynchronization therapy
CT	computed tomography
CT	celiac trunk
CTEPH	chronic thromboembolic pulmonary hypertension
CTF	celiac trunk flow
CVCAS	Cardiovascular Section of the Canadian Anesthesia Society
CVP	central venous pressure
CW	continuous wave
CXR	chest X-ray
d	depth
D	diastolic
D	diastasis
DA	dopamine
dB	decibel
dBP	diastolic blood pressure
DCM	dilated cardiomyopathy
DD	diastolic dysfunction
DESC	descending
DFT	diastolic filling time
DHCA	deep hypothermic cardiac arrest
dIVC	distensibility index of IVC
DT	deceleration time
DVI	dimensionless velocity index
E	peak early diastolic velocity of the mitral valve inflow
EAU	epiaortic ultrasonographic
EAU	epiaortic ultrasound
EC	endocardial cushion(s)
ECMO	extracorporeal membrane oxygenation
ED	end-diastolic
ED	end-diastole
EDA	end-diastolic area

EDP	end-diastolic pressure
EDV	end-diastolic volume
EE	epicardial echocardiography
EF	ejection fraction
EF	early filling
EI	eccentricity index
EKG	electrocardiogram
Eln	elastance
E_{max}	maximum time varying elastance
EMD	pseudo-electromechanical dissociation
EOA	effective orifice area
EP	ejection period
EPSS	E point septal separation
ERO	effective regurgitant orifice
EROA	effective regurgitant orifice area
ES	end-systole
ESA	end-systolic area
ESC	European Society of Cardiology
E'es	end-systolic elastance
ET	ejection time
$ETCO_2$	end-tidal CO_2
ETT	endotracheal tube
EXT SYNC	external synchronization
f	frequency
FAA	functional aortic annulus
FAC	fractional area change
FDA	Food and Drug Administration
FL	false lumen
FO	foramen oval
FO	fossa ovalis
FOCCUS	FOcused Critical Care Ultrasound Study
FOCUS	FOcused Cardiac Ultrasound Study
FP	foramen primum
Fr	frame rate
FS	fractional shortening
FVR	flow velocity ratio
GE	gastroesophaeal
GI	gastrointestinal
gm	gram
H	hour
HA	hepatic artery
HCM	hypertrophic cardiomyopathy
HCUs	hand-carried ultrasound devices
HOCM	hypertrophic obstructive cardiomyopathy
HPS	hepatopulmonary syndrome
HR	heart rate
HV	hepatic vein
HVF	hepatic venous flow
Hz	Hertz
I	inferior
I	intensity
IA	innominate artery
IAB	intra-aortic balloon
IABP	intra-aortic balloon pump
IAS	interatrial septal
ICA	internal carotid artery
ICE	intracardiac echocardiography
ICU	intensive care unit
IE	inner edge
IF	intimal flap
IH	intramural hematoma
IMR	ischemic mitral regurgitation

IOE	intraoperative echocardiography
IPPV	intermittent positive pressure ventilation
IRI	ischemia reperfusion injury
IS	inferoseptal
ISHLT	International Society of Heart and Lung Transplant
IVA	isovolumic acceleration
IVC	inferior vena cava
IVC	isovolumic contraction
IVCT	isovolumic contraction time
IVMD	interventricular mechanical delay
IVR	isovolumic relaxation
IVRT	isovolumic relaxation time
IVS	interventricular septum
IVST	interventricular septal thickness
IVUS	intravascular ultrasound
J/sec	Joule per second
k	compressibility or elasticity
L	left
L	length
L_0	unstressed length
LA	left atrial
LA	left atrium
LAA	left atrial appendage
LAD	left anterior descending
LAFB	left atrio-femoral bypass
LAP	left atrial pressure
LAX	long axis
LBBB	left bundle branch block
LBVC	left brachiocephalic vein
LCA	left coronary artery
LCC	left coronary cusp
LCCA	left common carotid artery
LCPC	left coronary prosthetic cusp
LCX	left circumflex
LDR	late diastolic reversal
LE	low esophageal
LE	leading edge
LGC	lateral gain control
LHV	left hepatic vein
LIJV	left internal jugular vein
LIMA	left internal mammary artery
LLPV	left lower pulmonary vein
LMCA	left main coronary artery
LPA	left pulmonary artery
LPV	left portal vein
LRA	left renal artery
LRV	left renal vein
LSCA	left subclavian artery
LSCV	left subclavian vein
LSVC	left superior vena cava
LUPV	left upper pulmonary vein
LV	left ventricle
LV	left ventricular
LVAD	left ventricular assist device
LVD	left ventricular diameter
LVEDA	left ventricular end-diastolic area
LVEDD	left ventricular end-diastolic dimension
LVEDP	left ventricular end-diastolic pressure
LVEDV	left ventricular end-diastolic volume
LVEF	left ventricular ejection fraction
LVES	left ventricular end systolic
LVESA	left ventricular end-systolic area