Intraoperative Echocardiography

PRACTICAL ECHOCARDIOGRAPHY SERIES

سرشناسه : آکسورن، دونالد سی.، ویراستار
.Oxorn, Donald C
عنوان و نام پدیدآور : Intraoperative echocardiography / [edited by] Donald C. Oxorn
مشخصات نشر : تهران: دیباج، ۱۳۹۱= ۲۰۱۳م.
مشخصات ظاهری : ۳۰۷ ص.: مصور(رنگی)، جدول، نمودار.
وضعیت فهرست : فیپا
نویسی
یادداشت : انگلیسی.
آوانویسی عنوان : اینترا اپرایتیو ..
موضوع : اکوکاردیوگرافی
موضوع : مراقبت‌های حین عمل
رده بندی کنگره : RC۶۸۳/۵/آ۷الف۹ ۱۳۹۱
رده بندی دیویی : ۶۱۶/۱۲۰۷۵۴
شماره کتابشناسی : ۳۰۸۵۰۳۳

نام کتاب : Intraoperative echocardiography
مؤلف : Donald C. Oxorn
ناشر : دیباج
نوبت چاپ : اول
سال چاپ : ۱۳۹۱
تیراژ : ۱۰۰۰
قیمت : ۱,۴۰۰,۰۰۰ ریال

مرکز پخش: انتشارات کتاب امیر- تهران خیابان انقلاب- روبروی درب اصلی دانشگاه تهران- مقابل کتابفروشی فروزنده طبقه اول-واحد ۴۲۶-تلفن:۶۶۴۸۱۷۳۳-۶۶۴۱۲۵۹۰-۶۶۹۶۰۲۲۵-۰۹۱۲۶۳۵۱۲۳۰

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INTRAOPERATIVE ECHOCARDIOGRAPHY ISBN: 978-1-4377-2698-5

Library of Congress Cataloging-in-Publication Data
Intraoperative echocardiography / edited by Donald C. Oxorn.—1st ed.
p. ; cm.—(Practical echocardiography series)
Includes bibliographical references and index.
ISBN 978-1-4377-2698-5 (hardcover : alk. paper)
I. Oxorn, Donald C. II. Series: Practical echocardiography series.
[DNLM: 1. Echocardiography—methods. 2. Intraoperative Care—methods. 3. Cardiovascular Diseases—ultrasonography. 4. Image Processing, Computer-Assisted. WG 141.5.E2]
LC classification not assigned
616.1'2075—dc23 2011033842

Senior Acquisitions Editor: Dolores Meloni
Editorial Assistant: Brad McIlwain
Publishing Services Manager: Pat Joiner-Myers
Senior Project Manager: Joy Moore
Designer: Steven Stave

Printed in China

Last digit is the print number: 9 8 7 6 5 4 3 2 1

Contributors

Atilio Barbeito, MD
Assistant Professor of Anesthesiology, Duke University Medical Center; Staff Anesthesiologist and Intensivist, and Investigator, Patient Safety Center of Inquiry, Veterans Affairs Medical Center, Durham, North Carolina
Right-Sided Valvular Disease

Arthur A. Bert, MD
Clinical Professor of Surgery (Anesthesiology), Warren Alpert School of Medicine at Brown University, Brown University, Providence, Rhode Island; Associate Chief, Department of Anesthesiology, Rhode Island Hospital, Providence, Rhode Island; Director of Experimental Cardiac Surgery, Imaging and Anesthesia, Cardiac Surgery Research Laboratories, Children's Mercy Hospital, Kansas City, Missou
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Albert T. Cheung, MD
Professor, Anesthesiology and Critical Care, University of Pennsylvania, hilade hia, Pennsylvania
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James Drew, MBChB(UC , FRC ANZCA
Simulation Instructo Facult of Medical and Health Sciences, A ck d niversity; Specialist Anaesth tist, uckla City Hospital, Auckland, N alan
Intraoperative choca phy for Heart and Lung T splan ion

Mark Edw rds, BChB, FANZCA, Dipr Echo
Anaesthet d Clinical Director, Department of Cardiothoracic and ORL Anaesthesia, Auckland City Hospital, Auckland, New Zealand
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Kathryn E. Glas, MD, FASE, MBA
Associate Professor, Anesthesiology, Emory University School of Medicine, A Georgia
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Marjan Jariani, MD, FRCPC
Assistant Professor, Depa ent Anesthesia, University of To onto St Anesthesiologist, Toronto eneral H pital, oronto, Ontario, Canada
Aortic Valve a Aortic

Deni e Jo MD
Asso ate rofessor, Department of Anesthesio University of Washington; Attending Anes siolo st, Seattle Children's Hospital and Uni ersity of Washington Medical Center, attle, Washington
Congenital Heart Disease

Ca ol Kraft, BS, RDCS
Cardiac Sonographer Specialist, University of Washington Medical Center, Seattle, Washington
Introduction to Intraoperative Echocardiography

A. Stephane Lambert, MD, FRCP(C)
Assistant Professor of Anesthesiology, University of Ottawa; Attending Anesthesiologist, University of Ottawa Heart Institute, Ottawa, Ontario, Canada
Mitral Valve Diseases

Jonathan B. Mark, MD
Professor of Anesthesiology, Duke University Medical Center; Chief, Anesthesiology Service, and Principal Investigator, Patient Safety Center of Inquiry, Veterans Affairs Medical Center, Durham, North Carolina
Right-Sided Valvular Disease

Andrew D. Maslow, MD
Clinical Associate Professor in Anesthesiology, Warren Alpert School of Medicine, Brown University; Director of Cardiac Anesthesiology, Department of Anesthesiology, Rhode Island Hospital, Providence, Rhode Island
Echocardiographic Evaluation of Prosthetic Valves

Massimiliano Meineri, MD
Assistant Professor, University of Toronto; Staff Anesthesiologist, University Health Network, Toronto General Hospital, Toronto, Ontario, Canada
Masses and Devices

Patricia Murphy, MD, FRCPC
Associate Professor, University of Toronto; Staff Anesthesiologist, University Health Network, Toronto General Hospital, Toronto, Ontario, Canada
Masses and Devices

Alina Nicoara, MD
Assistant Professor, Duke University; Attending Physician, Duke University Medical Center, Durham, North Carolina
Ventricular Function

Donald C. Oxorn, MD
Professor of Anesthesiology, Division of Cardio-Thoracic Anesthesia, and Adjunct Professor of Medicine (Cardiology), University of Washington Medical Center, Seattle, Washington
Introduction to Intraoperative Echocardiography

Wendy L. Pabich, MD
Staff Anesthesiologist, Physicians Anesthesia Service, Swedish Medical Center, Seattle, Washington
Ventricular Function

Rebecca A. Schroeder, MD
Assistant Associate Professor of Anesthesiology, Duke University Medical Center; Staff Anesthesiologist, and Investigator, Patient Safety Center of Inquiry, Veterans Affairs Medical Center, Durham, North Carolina
Right-Sided Valvular Disease

Stanton K. Shernan, MD, FAHA, FASE
Associate Professor, Harvard Medical School; Director of Cardiac Anesthesia, Department of Anesthesiology, Perioperative and Pain Medicine, Brigham and Women's Hospital, Boston, Massachusetts
Epiaortic Ultrasonography and Epicardial Echocardiography

Madhav Swaminathan, MD
Associate Professor, Duke University; Attending, Duke University Hospital, Durham, North Carolina
Ventricular Function

Annette Vegas, MD, CM, FRCPC, FASE
Associate Professor, University of Toronto; Staff Anesthesiologist, Toronto General Hospital, Toronto, Ontario, Canada
Aortic Valve and Aortic Root

Peter von Hoffmeyer, MD
Assistant Professor, University of Washington; Assistant Professor, Department of Anesthesiology and Pain Medicine, University of Washington Medical Center, Seattle, Washington
Pericardial Disease

Stuart J. Weiss, MD, PhD
Department of Anesthesiology and Critical Care, University of Pennsylvania, Philadelphia, Pennsylvania
Diseases of the Aorta

Foreword

Echocardiography is a core component of every aspect of clinical cardiology and now plays an essential role in daily decision making. Both echocardiographers and clinicians face unique challenges in interpretation of imaging and Doppler data and in integration of these data with other clinical information. However, with the absorption of echocardiography into daily patient care, there are some voids in our collective knowledge base. First, clinicians caring for patients need to understand the value, strengths, and limitations of echocardiography relevant to their specific scope of practice. Second, echocardiographers need a more in-depth understanding of the clinical context of the imaging study. Finally, there often are unique aspects of data acquisition and analysis in different clinical situations, all of which are essential for accurate echocardiographic diagnosis. The books in the Practical Echocardiography Series are aimed at filling these knowledge gaps, with each book focusing on a specific clinical situation in which echocardiographic data are key for optimal patient care.

In addition to *Intraoperative Echocardiography*, edited by Donald C. Oxorn, MD, other books in the series are *Echocardiography in Congenital Heart Disease*, edited by Mark Lewin, MD, and Karen Stout, MD; *Echocardiography in Heart Failure*, edited by Martin St. John Sutton, MBBS, FRCP, FASE, and Susan E. Wiegers, MD, FASE; and *Advanced Approaches in Echocardiography*, edited by Linda Gillam, MD, and myself. Information is presented as concise bulleted text accompanied by numerous illustrations and tables, providing a practical approach to data acquisition and analysis, including technical details, pitfalls, and clinical interpretation, supplemented by web-based video case examples. Each volume in this series expands on the basic principles presented in the *Textbook of Clinical Echocardiography, Fourth Edition*, and can be used as a supplement to that text or can be used by physicians interested in a focused introduction to echocardiography in their area of clinical practice.

With advances in cardiac surgery and interventional cardiology, echocardiographic monitoring and guidance of therapeutic procedures has become an essential element in the procedure itself. These echocardiographic studies often are appropriately performed and interpreted by the anesthesiologist in conjunction with real-time review by the cardiac surgeon or interventional cardiologist. Other cardiologists and cardiac sonographers also often are asked to assist with imaging during these procedures. The optimal use of echocardiographic data in this setting requires specialized knowledge, as summarized in this book on intraoperative echocardiography.

The editor of this volume, Donald C. Oxorn, MD, is a Professor of Anesthesiology at the University of Washington Medical Center, where he is a key part of the echocardiography team in the operating room and interventional cardiology laboratory. He also is an Adjunct Professor of Medicine in recognition of his substantial clinical and teaching contributions in the Division of Cardiology. In this book, *Intraoperative Echocardiography*, Dr. Oxorn has built upon his extensive clinical experience and skills as an educator, along with the expertise of the chapter authors, to produce a truly practical guide to this area of clinical competence. This book introduced me to several new concepts in procedural imaging, as well as filling in many details about the use of echocardiography in the operating room. I hope you learn as much as I did.

Catherine M. Otto, MD

Preface

As the complexity of cardiac surgery and invasive cardiology has increased, so has the reliance on skilled interpretation of periprocedural echocardiography. As well as having a detailed knowledge of the pathophysiology of each disease process, the operative techniques available, and the validity of imaging information, the echocardiographer must be expert at knowing what information is critical, and the most expeditious way of obtaining it.

Intraoperative Echocardiography is one of four volumes contained within the Practical Echocardiography Series. Whereas most other textbooks of intraoperative echocardiography present an extensive review based on a detailed search of the literature, the focus in the current volume is practical aspects of image acquisition and interpretation in the operating room. The book is organized into 12 chapters covering all aspects of intraoperative echocardiography, including the aortic, mitral, tricuspid, pulmonic, and prosthetic heart valves; the pericardium; the aorta; and the right and left ventricles; as well as cardiac masses. In addition, chapters are dedicated to specialized procedures such as heart and lung transplantation, the surgical treatment of congenital heart disease, the complimentary technology of epicardial and epiaortic ultrasound, and intracardiac and intravascular devices, which are seen with increasing frequency both in the operating room and interventional suites.

The goal of this book is to provide content as concise text in a visually rich volume complimented by online video and case presentations. In each chapter, background information is followed by a step-by-step approach to patient examination. Information is conveyed in bulleted points, with each set of major principles followed by a list of key points. Potential pitfalls are identified and approaches to avoiding errors are provided. Data measurements and calculations are explained with specific examples. Numerous illustrations with detailed figure legends demonstrate each major point and guide the reader through the teaching points.

This atlas will be of interest to all health care providers involved in the acquisition and interpretation of perioperative echocardiograms. In addition to cardiac anesthesiologists, this book will be useful to cardiologists and cardiology fellows interested in expanding their knowledge of cardiac surgery and the important aspects of intraoperative imaging, cardiac sonographers who wish to participate as part of the intraoperative team, cardiac surgeons seeking to understand echocardiography, and individuals wishing to become more familiar with what actually transpires in the operating room.

This atlas is not a substitute for formal training in TEE performance and interpretation; instead it is designed to serve as an adjunct in furthering the skill required in the obtaining of relevant information critical for successful intraoperative interventions.

Donald C. Oxorn, MD

Acknowledgments

I wish to acknowledge the contributions and encouragement of my colleagues in Cardiothoracic Anesthesiology: T. Andrew Bowdle, Krishna Natrajan, Jorg Dziersk, Peter von Homeyer, Stefan Lombaard, Kei Togashi, Srdjan Jelacic, Erin Failor, and Sally Barlow; in Cardiothoracic Surgery: Edward Verrier, Gabriel Aldea, and Nahush Mokadam; and Starr Kaplan for her artwork. My appreciation extends to Natasha Andjelkovic at Elsevier and the production team who supported this project and helped make it a reality.

I would also like to acknowledge the guidance and encouragement provided by Catherine R. Otto in the preparation of this volume.

Finally, I wish to thank my wife Susan Murdoch and my children, Jonathan Oxorn, Sean Murdoch-Oxorn, and Alexandra Murdoch-Oxorn; their understanding and cheerful disposition was ever present and much appreciated.

I would like to thank two individuals from the University of Toronto: my friend and mentor Gerald Edwards, and Wm Joyner, my first and foremost teacher of echocardiography.

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Glossary

2C two-chamber
2D two-dimensional
3D three-dimensional
4C four-chamber
5C five-chamber
A late diastolic ventricular filling velocity with atrial contraction
A′ diastolic tissue Doppler velocity with atrial contraction
Ab abscess
AC atrial contraction
ACC American College of Cardiology
AHA American Heart Association
AI aortic insufficiency
AIDS acquired immunodeficiency syndrome
AL anterior leaflet
ALCAPA anomalous origin of the left coronary artery from the pulmonary artery
AML anterior mitral leaflet
AMVL anterior mitral valve leaflet
AO or Ao aorta
AoA effective orifice area-to-aortic area
APCs aortopulmonary collateral arteries
APV absent pulmonary valve
AR aortic regurgitation
AS aortic stenosis
ASD atrial septal defect
ASE American Society of Echocardiography
ASO arterial switch operation
AV aortic valve
AVA aortic valve area
AVC atrioventricular canal
AVR aortic valve replacement
AVR aortic valve repair
AVV atrioventricular valve
AVVR atrioventricular valve repair
BAV bicuspid aortic valve
BiVAD biventricular assist device
BLT bilateral lung transplant
BSA body surface area
BT Blalock-Taussig (shunt)
BVF biventricular flow
CABG coronary artery bypass graft
CAD coronary artery disease
CAVC common atrioventricular canal
CF color flow
CHD congenital heart disease
CHF congestive heart failure
CI cardiac index
cm centimeter(s)
cm/s centimeters per second
CO cardiac output
CPB cardiopulmonary bypass
CS coronary sinus
CSA cross-sectional area
CT computed tomography
CT connective tissue
CTGA congenitally corrected transposition of the great arteries
CVA cerebrovascular accident
CVC central venous catheter
CVD cardiovascular disease
CVP central venous pressure
CW continuous wave
Cx circumflex coronary artery
dB decibel(s)
DCRV double-chamber right ventricle
DGC depth gain compensation
DILV double-inlet left ventricle
DKS Damus-Kaye-Stansel
DORV double-outlet right ventricle
dP/dt rate of change in pressure over time
DT deceleration time
D-TGA D-transposition of the great arteries
dT/dt rate of increase in temperature
DVI Doppler velocity index
E early diastolic peak velocity
E′ early diastolic tissue Doppler velocity
EAU epiaortic ultrasonography
ECE epicardial echocardiography
ECG electrocardiogram
ECMO extracorporeal membrane oxygenation
EDD end-diastolic dimension
EF ejection fraction
EOA effective orifice area
ERO effective regurgitant orifice
EROA effective regurgitant orifice area
ESC European Society of Cardiology
ESD end-systolic dimension
ET ejection time

FAC fractional area of change
FL false lumen
FO fossa ovalis
FS fractional shortening
HACEK (group) haemophilus, aggregatibacter, cardiobacterium hominis, eikenella corrodens, kingella
HFNEF heart failure with a normal ejection fraction
HLHS hypertrophic left heart syndrome
HOCM hypertrophic cardiomyopathy
HPRF high pulse repetition frequency
HR heart rate
hr hour(s)
HV hepatic vein
HVF hepatic venous flow
Hz Hertz (cycles per second)
IABP intra-aortic balloon pump
IAS interatrial septum
IE infective endocarditis
iEOA indexed effective orifice area
IV innominate vein
IVC inferior vena cava
IVR isovolumic relaxation
IVRT isovolumic relaxation time
IVS interventricular septum
LA left atrium/left atrial
LAA left atrial appendage
LAD left anterior descending artery
LAE left atrial enlargement
LAP left atrial pressure
LAX long axis
LCA left coronary artery
LCC left coronary cusp
LCX left circumflex artery
LLPV left lower pulmonary vein
LMCA left main coronary artery
LPA left pulmonary artery
LPV left pulmonary vein
LSPV left superior pulm[illegible] vein
LSVC left superior vena [illegible]va
LTGA left transposition o[illegible]he grea[illegible]teries
LUPV left upper p[illegible]nary vein
LV left ventricle/left ven[illegible]ular
LVAD left v[illegible]icular assist d[illegible]vice
LVAd left v[illegible]tric[illegible] a[illegible]a in end-diastole
LVAs left ven[illegible]icular [illegible] in end-systole
LVDd [illegible] ven[illegible]icular end-diastolic dimension
LVDs [illegible] v[illegible]tr[illegible]ular end-systolic dimension
LVE left [illegible]entric[illegible]ar enlargement
LVE[illegible]P le[illegible] ventricular end-diastolic pressure
LVEDV [illegible] ventricular end-diastolic volume
LVEF left ventricular ejection fraction
LVESV left ventricular end-systolic volume
LVH left ventricular hypertrophy
LVOT left ventricular outflow tract
LVOTO left ventricular outflow tract obstruction
LVP left ventricular pressure
M-mode motion display (depth versus time)
MAPCAs multiple aortopulmonary collateral arteries
ME midesophageal
MG mean valve gradient
min minute(s)
mL milliliter(s)
mPA or MPA main pulmonary artery
MR mitral regurgitation
MRI magnetic resonance imaging
MS mitral stenosis
MV mitral valve
MVA mitral valve area
MVR mitral valve replacement
MVR mitral valve repair
n number of subjects
NCC noncoronary cu[illegible]
NVE native valve endoc[illegible]tis
NYHA New York Heart A[illegible]ciation
OR operating room
PA pulmonary art[illegible]y
PAC pulmonary [illegible]rtery [illegible]ter
PAIVS pulmona[illegible]y at[illegible]sia v[illegible]ntact ventricular septum
PAP pulm[illegible]y arte[illegible]ssure
PAPVD partia[illegible]nomalous pulmonary venous d[illegible]
PB[illegible]F pul[illegible]onary blood flow
PD[illegible]A [illegible]tent [illegible]ctus arteriosus
PD[illegible] posteri[illegible] descending artery
PE p[illegible]al effusion
PFO patent foramen ovale
P[illegible] [illegible]ressure half-time
PHTN pulmonary hypertension
PI pulmonic insufficiency
PISA proximal isovelocity surface area
PL posterior leaflet
PLs paravalvular leaks
PM papillary muscle
PPM patient-prosthesis mismatch
PR pressure recovery
PR pulmonic regurgitation
PRF pulse repetition frequency
PS pulmonic stenosis
PulmV pulmonic valve
PV pulmonary vein
PVC pulmonary vein confluence
PVD pulmonary vascular disease
PVE prosthetic valve endocarditis
PVF pulmonary venous flow
PVR pulmonary vascular resistance
PW pulsed wave
RA right atrium/right atrial
RAA right atrial appendage
RAE right atrial enlargement
RAP right atrial pressure
RCA right coronary artery
RCC right coronary cusp

RF rapid filling
RLPV right lower pulmonary vein
RMPV right middle pulmonary vein
ROA regurgitant orifice area
RPA right pulmonary artery
RPV right pulmonary vein
RUPV right upper pulmonary vein
RV right ventricle/right ventricular
RVAD right ventricular assist device
RVAd right ventricular area in end-diastole
RVAs right ventriclular area in end-systole
RVDCA right ventricle-dependent coronary artery
RVE right ventricular enlargement
RVEDP right ventricular end-diastolic pressure
RVEDV right ventricular end-diastolic volume
RVESV right ventricular end-systolic volume
RVEF right ventricular ejection fraction
RVH right ventricular hypertrophy
RVOT right ventricular outflow tract
RVOTO right ventricular outflow tract obstruction
RVP right ventricular pressure
RVSP right ventricular systolic pressure
RWMA regional wall motion abnormality
s second(s)
SAM systolic anterior motion
SAX short axis
SBP systolic blood pressure
SCA Society of Cardiovascular Anesthesiolog
SF slow filling
SL septal leaflet
SLT single lung transplant
SOB shortness of breath
SoV sinus(es) of Valsalva
SR sarcoplasmic reticulum
STJ sinotubular junction
SV single ventricle
SV stroke volume
SV ASD sinus venosus atrial septal defect
SVC superior vena cava
SVR systemic vascular resistance
TA transapical
TAA thoracic aortic aneurysm
TAFS tricuspid annulus fractional shortening
TAPSE tricuspid annular plane systolic excursion
TAPVD total anomalous pulmonary venous discharge
TEE transesophageal echocardiography
TEVAR thoracic endovascular aortic repair
TF transfemoral
TG transgastric
TGA transposition of the g arteries
TGC time gain compensation
TL true lumen
TMF transmitral inf w
TOF tetralogy of F lot
TR tricuspi regurgitati n
TS tricuspid nosis
TTE transthora echo graphy
TTF tran ricuspi low
TV tri dspid lve
TVR ricus d valve repair
UE u e esoph geal
a alia g velo ty
AD vent ar assist device
C vena contracta
OO a nchronous ventricular pacing
S ventricular septum
V ventricular septal defect
VTI velocity time integral
WMAs wall motion abnormalities