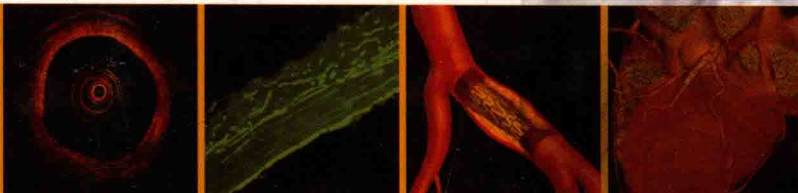


ERIC J. TOPOL
PAUL S. TEIRSTEIN

Textbook of Interventional Cardiology

TH



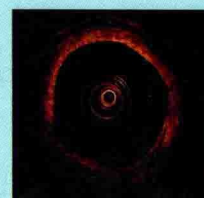
EDITION

Textbook of Interventional Cardiology

sixth edition

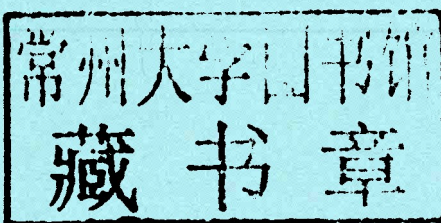
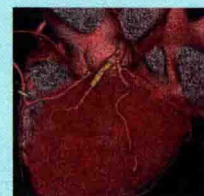
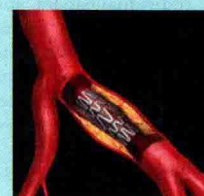
ERIC J. TOPOL, MD

Director, Scripps Translational Science Institute
Chief Academic Officer, Scripps Health
Sr. Consultant, Division of Cardiology, Scripps Clinic
Professor of Genomics, The Scripps Research Institute
La Jolla, California



PAUL S. TEIRSTEIN, MD

Chief of Cardiology
Director, Interventional Cardiology
Scripps Clinic
Director, Scripps Prebys Cardiovascular Institute
Scripps Health
La Jolla, California



ELSEVIER
SAUNDERS

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions.

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

With respect to any drug or pharmaceutical products identified, readers are advised to check the most current information provided (i) on procedures featured or (ii) by the manufacturer of each product to be administered, to verify the recommended dose or formula, the method and duration of administration, and contraindications. It is the responsibility of practitioners, relying on their own experience and knowledge of their patients, to make diagnoses, to determine dosages and the best treatment for each individual patient, and to take all appropriate safety precautions.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

ISBN: 978-1-4377-2358-8

Acquisitions Editor: Dolores Meloni
Developmental Editor: Taylor Ball
Editorial Assistant: Brad McIlwain
Publishing Services Manager: Catherine Jackson
Project Manager: Sara Alsup
Design Direction: Ellen Zanolle
Illustrations manager: Karen Giacomucci
Marketing Manager: Helena Mutak

Printed in Canada

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

Working together to grow
libraries in developing countries

www.elsevier.com | www.bookaid.org | www.sabre.org

ELSEVIER

BOOK AID
International

Sabre Foundation

Textbook of Interventional Cardiology

This book is dedicated to Alvin S. Teirstein, MD (1927–2011). Forever a student, in his final year he introduced himself as PGY 58. He was a clinician, a teacher, a father, and a giant.

And to our wives, Susan and Jacki, who have given us loving support throughout our careers.

Takashi Akasaka, MD, PhD

Professor, Department of Cardiovascular Medicine
Wakayama Medical University
Wakayama, Japan

Ibrahim Akin, MD

Universitätsklinikum Hamburg-Eppendorf
Abteilung Kardiologie
Hamburg, Germany

Jorge R. Alegria, MD

Assistant Professor
Co-Medical Director of Adult Congenital Heart Disease Clinic
Department of Medicine
Saha Cardiovascular Research Center
University of Kentucky
Lexington, Kentucky

Alexandra Almonacid, MD

Brigham and Women's Hospital
Boston, Massachusetts

Carlos L. Alviar, MD

Post Doctoral Residency Fellow
Department of Medicine
St. Luke's-Roosevelt Hospital Center
Columbia University College of Physicians and Surgeons
New York, New York

Dominick J. Angiolillo, MD, PhD

Associate Professor of Medicine
Director of Cardiovascular Research
University of Florida College of Medicine Jacksonville
Jacksonville, Florida

Gary M. Ansel, MD

MidOhio Cardiology and Vascular Consultants
Columbus, Ohio

Saif Anwaruddin, MD

Assistant Professor of Medicine
Penn Heart and Vascular Center
University of Pennsylvania
Philadelphia, Pennsylvania

David T. Balzer, MD

Professor, Pediatrics
Division of Pediatric Cardiology
Washington University School of Medicine at St. Louis
Director, Cardiac Catheterization Laboratory
St. Louis Children's Hospital
St. Louis, Missouri

Amr T. Bannan, MD

Director, Cardiac Catheterization Laboratories
Hospital of the University of Pennsylvania
Philadelphia, Pennsylvania

Gregory W. Barsness, MD

Assistant Professor of Medicine
Departments of Cardiovascular Diseases and Radiology
Mayo Clinic
Rochester, Minnesota

Robert H. Beekman III, MD

Professor of Pediatric Cardiology
Cincinnati Children's Hospital Medical Center
Cincinnati, Ohio

Farzin Beygui, MD, PhD

Pitié-Salpêtrière University Hospital
Institut de Cardiologie
Paris, France

John A. Bittl, MD

Ocala Heart Institute
Munroe Regional Medical Center
Ocala, Florida (JAB)

Philipp Bonhoeffer, MD

Professor and Chief of Cardiology
Director of the Cardiac Catheterisation Laboratory
Great Ormond Street Hospital for Children, NHS Trust
London, United Kingdom

Michael Braendle, MD, MS

Associate Professor of Endocrinology
Zurich School of Medicine
Zurich, Switzerland
Division Chief, Division of Endocrinology and Diabetes
Department of Internal Medicine
Kantonsspital St. Gallen
St. Gallen, Switzerland

J. Matthew Brennan, MD

Assistant Professor of Medicine
Division of Cardiology
Duke University School of Medicine
Durham, North Carolina

Ralph Brindis, MD, MPH

Clinical Professor of Medicine
University of California, San Francisco
San Francisco, California
Regional Senior Advisor for Cardiovascular Diseases
Kaiser Permanente
Oakland, California

Eric Brochet, MD

Cardiology Department
Hopital Bichat
Paris, France

David Burke, MD

Clinical Assistant Professor of Medicine
Michigan State University/Kalamazoo Center for Medical Studies
Clinical Cardiologist
Heart Center for Excellence
Kalamazoo, Michigan

Heinz Joachim Büttner, MD

Chief of Interventional Cardiology, Herz-Zentrum Bad Krozingen
Universitäres Herz- und Kreislaufzentrum Freiburg—Bad Krozingen
Germany

Robert Byrne, MB

Interventional Cardiologist
Deutsches Herzzentrum and 1. Medizinische Klinik rechts der Isar
Technische Universität
Munich, Germany

Christopher P. Cannon, MD

Associate Professor of Medicine
Harvard Medical School
Associate Physician, Cardiovascular Division,
Brigham and Women's Hospital
Boston, Massachusetts

Ivan P. Casserly, MB, BCh

Assistant Professor of Medicine, University of Colorado
University of Colorado—Denver
Anschutz Medical Campus
Denver, Colorado

Matthews Chacko, MD

Assistant Professor of Medicine
The Johns Hopkins University
Director, Peripheral Vascular Interventions
Faculty, Interventional Cardiology, CCU & the Thayer Firm
The Johns Hopkins Hospital
Baltimore, Maryland

Derek P. Chew, MBBS, MPH

Professor of Cardiology
Department of Cardiovascular Medicine
Flinders University
Regional Director of Cardiology
Department of Cardiovascular Medicine
Southern Adelaide Health Service
Adelaide, South Australia
Australia

Leslie Cho, MD

Director, Cleveland Clinic's Women's Cardiovascular Center
Section Head, Preventive Cardiology and Rehabilitation
Robert and Suzanne Tomsich Department of Cardiovascular
Medicine
Cleveland Clinic
Cleveland, Ohio

Louise Coats, PhD

Director of Cardiology
Freeman Hospital
Newcastle upon Tyne, United Kingdom

Antonio Colombo, MD

EMO-GVM Centro Cuore Columbus and San Raffaele Scientific
Institute
Milan, Italy

Marco A. Costa, MD, PhD

University Hospitals Harrington-McLaughlin Heart & Vascular
Institute
Case Western Reserve University School of Medicine
Cleveland, Ohio

Alain Cribier, MD

Professor of Cardiology
Rouen University
Chief of Cardiology
Hospital Charles Nicolle
Rouen, France

Kevin J. Croce, MD, PhD

Instructor in Medicine
Harvard Medical School
Associate Physician
Cardiovascular Division
Brigham and Women's Hospital
Boston, Massachusetts

Fernando Cura, MD, PhD

Sub-Director of Interventional Cardiology and Endovascular
Therapies
Instituto Cardiovascular de Buenos Aires
Buenos Aires, Argentina

Gregory J. Dehmer, MD

Professor of Medicine
Texas A&M Health Science Center College of Medicine
Director, Cardiology Division
Scott & White Healthcare
Temple, Texas

Robert S. Dieter, MD

Department of Cardiology
Edward Hines, Jr. VA Hospital
Hines, Illinois

John S. Douglas, Jr., MD

Professor of Medicine
Director, Interventional Cardiology
Emory University School of Medicine
Director, Cardiac Catheterization Laboratories
Emory University Hospital
Atlanta, Georgia

Helene Eltchaninoff, MD

Professor of Cardiology
Rouen University
Chief, Cardiac Catheterization Laboratory
Hospital Charles Nicolle
Rouen, France

Marvin H. Eng, MD

Assistant Professor of Medicine
University of Texas Health Sciences Center San Antonio
San Antonio, Texas

Peter J. Fitzgerald, MD, PhD

Director, Center for Cardiovascular Technology
Director, Cardiovascular Core Analysis Laboratory (CCAL)
Stanford University Medical School
Stanford, California

Valentin Fuster, MD

Professor of Medicine
Department of Cardiology
Mount Sinai School of Medicine
Director, Zena and Michael A. Wiener Cardiovascular Institute
New York, New York

Mario J. Garcia, MD

Professor, Department of Medicine (Cardiology)
Professor, Department of Radiology
The Pauline Levitt Endowed Chair in Medicine
Chief, Division of Cardiology, Department of Medicine
Co-Director of the Montefiore-Einstein Heart Center
Montefiore Medical Center
Bronx, New York

Scot Garg, MB ChB, MRCP

Department of Interventional Cardiology
Erasmus Medical Center
Rotterdam, Netherlands

Jeffrey Goldstein, MD

Assistant Professor of Medicine
Southern Illinois School of Medicine
Cardiologist
Prairie Heart Institute
Springfield, Illinois

Nilesh J. Goswami, MD

Director, Coronary Care Unit and Chest Pain Center
Prairie Heart Institute
Springfield, Illinois

William A. Gray, MD

Assistant Professor of Clinical Medicine
Columbia University College of Physicians and Surgeons
Director, Endovascular Services
Columbia University Medical Center / New York-Presbyterian
Hospital
New York, New York

Giulio Guagliumi, MD

Cardiovascular Department
Ospedali Riuniti di Bergamo
Bergamo, Italy

Hidehiko Hara, MD

Minneapolis Heart Institute Foundation
Minneapolis, Minnesota

Rani Hasan, MD

Fellow, Department of Cardiology
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Timothy D. Henry, MD

Director of Research
Minneapolis Heart Institute Foundation
Professor of Medicine—University of Minnesota
Minneapolis, Minnesota

Howard C. Herrmann, MD

Professor of Medicine
University of Pennsylvania School of Medicine
Director, Interventional Cardiology Program and Cardiac
Catheterization Laboratories
Hospital of the University of Pennsylvania
Philadelphia, Pennsylvania

Dominique Himbert, MD

Cardiology Department
Hopital Bichat
Paris, France

Russel Hirsch, MD

Assistant Professor
University of Cincinnati College of Medicine
Director, Cardiac Catheterization Laboratory
Cincinnati Children's Hospital
Cincinnati, Ohio

David R. Holmes, Jr., MD

Scripps Professor of Medicine
Mayo Clinic College of Medicine
Consultant
Mayo Clinic
Rochester, Minnesota

Yasuhiro Honda, MD

Clinical Associate Professor of Medicine
Division of Cardiovascular Medicine
Stanford University School of Medicine
Co-Director, Cardiovascular Core Analysis Laboratory
Center for Cardiovascular Technology
Stanford University Medical Center
Stanford, California

Hüseyin Ince, MD

Universitätsklinikum Hamburg-Eppendorf
Hamburg, Germany

Bernard lung, MD

Professor of Cardiology
University of Paris VII
Hospital Doctor
Service de Cardiologie
Hopital Bichat
Paris, France

Hani Jneid, MD

Assistant Professor of Medicine
Baylor College of Medicine
Houston, Texas

Samuel L. Johnston, MD

Cardiologist/Cardiac Electrophysiologist
Cascade Heart, PS
Southwest Washington Medical Center
Vancouver, Washington

James G. Jollis, MD

Professor of Medicine and Radiology
Departments of Medicine
Division of Cardiology
Duke University School of Medicine
Durham, North Carolina

David Kandzari, MD

Director, Interventional Cardiology and
Interventional Cardiology Research
Piedmont Heart Institute
Atlanta, Georgia

Samir R. Kapadia, MD

Professor of Medicine
Director, Sones Cardiac Catheterization Laboratories
Director, Interventional Cardiology Fellowship
Department of Cardiovascular Medicine
Cleveland Clinic
Cleveland, Ohio

Adnan Kastrati, MD

Professor of Cardiology
Deutsches Herzzentrum and 1. Medizinische Klinik rechts der Isar
Technische Universität
Munich, Germany

Dean J. Kereiakes, MD

Medical Director
The Christ Hospital Heart and Vascular Center and The Lindner
Research Center
Professor of Clinical Medicine
Ohio State University
Cincinnati, Ohio

Morton J. Kern, MD

Professor of Medicine
Departments of Medicine and Cardiology
Associate Chief, Cardiology
University of California Irvine
Orange, California

Ahmed A. Khattab, MD

Associate Professor of Cardiology
University Hospital Bern
Bern, Switzerland

Young-Hak Kim, MD, PhD

Heart Institute, Asan Medical Center
University of Ulsan College of Medicine
Seoul, Korea

Ajay J. Kirtane, MD, SM

Chief Academic Officer
Director, Interventional Cardiology Fellowship Program
Columbia University Medical Center
New York—Presbyterian Hospital
New York, New York

Raghu Kolluri, MD

Director of Vascular Medicine
Prairie Heart Institute
Springfield, Illinois

Amar Krishnaswamy, MD

Fellow, Interventional Cardiology
Cleveland Clinic
Cleveland, Ohio

Takashi Kubo, MD, PhD

Assistant Professor, Department of Cardiovascular Medicine
Wakayama Medical University
Wakayama, Japan

Roger Laham, MD

Angiogenesis Research Center
Department of Medicine
Harvard Medical School
Beth Israel Deaconess Medical Center
Boston, Massachusetts

John Lasala, MD, PhD

Associate Professor, Medicine
Director, Interventional Cardiology
Medical Director, Cardiac Catheterization Lab
Washington University School of Medicine
St. Louis, Missouri

Michael J. Lim, MD

Interim Director and Associate Professor of Medicine
Cardiology Division
Saint Louis University
St. Louis, Missouri

Thomas R. Lloyd, MD

Professor, Pediatric Cardiology
Department of Pediatrics and Communicable Diseases
University of Michigan Health System
Ann Arbor, Michigan

Daniel Mark, MD, MPH

Professor of Medicine
Duke University Medical Center
Director, Outcomes Research
Duke Clinical Research Institute
Durham, North Carolina

Bernhard Meier, MD

Professor of Cardiology
Faculty of Medicine
University of Bern
Director of Cardiology
University Hospital
Bern, Switzerland

Gilles Montalescot, MD, PhD

Professor of Cardiology
Pitié-Salpêtrière University Hospital
Institut de Cardiologie
Paris, France

Pedro R. Moreno, MD

Professor of Cardiology
Department of Medicine
The Mount Sinai Medical Center
New York, New York

Jeffrey W. Moses, MD

Professor of Medicine
Columbia University Medical Center
Director, Center for Interventional Vascular Therapy
New York Presbyterian Hospital
New York, New York

Arashk Motiei, MD

Assistant Professor of Medicine
Department of Cardiovascular Disease
Mayo Clinic
Rochester, Minnesota

Debabrata Mukherjee, MD

Chief, Cardiovascular Medicine
Professor of Internal Medicine
Vice Chairman, Department of Internal Medicine
Texas Tech University
El Paso, Texas

Srihari S. Naidu, MD

Assistant Professor of Medicine
SUNY—Stony Brook School of Medicine
Director, Cardiac Catheterization Laboratories
Winthrop University Hospital
Mineola, New York

Brahmajee K. Nallamothu, MD, MPH

Associate Professor of Cardiovascular Medicine
Department of Internal Medicine
University of Michigan Medical School
Ann Arbor, Michigan

Craig R. Narins, MD

Associate Professor of Medicine and Surgery
Divisions of Cardiology and Vascular Surgery
University of Rochester Medical Center
Rochester, New York

Gjin Ndrepepa, MD

Associate Professor of Cardiology
Deutsches Herzzentrum
Technische Universität
Munich, Germany

Franz-Josef Neumann, MD, PhD

Honorary Professor of Cardiology
Albert Ludwigs-Universität, Freiburg
Medical Director and Chairman
Herz-Zentrum Bad Krozingen
Bad Krozingen, Germany

Christoph A. Nienaber, MD

Professor of Internal Medicine and Cardiology
University of Rostock School of Medicine
Head, Division of Cardiology and Vascular Medicine
University Hospital Rostock
Rostock, Germany

Masakiyo Nobuyoshi, MD

Division of Cardiology
Kokura Memorial Hospital
Kokura, Japan

Igor Palacios, MD

Director of Interventional Cardiology
Division of Cardiology
Massachusetts General Hospital
Harvard Medical School
Boston, Massachusetts

Seung-Jung Park, MD, PhD

Heart Institute, Asan Medical Center
University of Ulsan College of Medicine
Seoul, Korea

Uptal D. Patel, MD

Assistant Professor of Medicine and Pediatrics
Department of Pediatrics
Duke University School of Medicine
Durham, North Carolina

Marc S. Penn, MD, PhD

Director of Research
Summa Cardiovascular Institute
Summa Health System
Akron, Ohio
Professor of Medicine and Integrative Medical Sciences
Northeast Ohio Medical University
Rootstown, Ohio

Jeffrey Popma, MD

Associate Professor of Medicine
Harvard Medical School
Director, Interventional Cardiology Clinical Services
Department of Medicine (Cardiovascular Division)
Beth Israel Deaconess Medical Center
Boston, Massachusetts

Matthew J. Price, MD

Director, Cardiac Catheterization Laboratory
Scripps Clinic
Assistant Professor, Scripps Translational Science Institute
La Jolla, California

Vivek Rajagopal, MD

Staff Cardiologist
Piedmont Heart Institute
Atlanta, Georgia

Kausik K. Ray, MBChB, MRCP, MD, MPhil

Professor of Cardiovascular Disease Prevention
Department of Clinical Services
St. George's University of London
Consultant Cardiologist
Department of Cardiology
St. George's Hospital NHS Trust
London, United Kingdom

G. Russell Reiss, MD

Fellow, Interventional Cardiology, Center for Interventional
Vascular Therapy
Attending Surgeon, Department of Cardiothoracic Surgery
New York-Presbyterian Hospital
Columbia University
New York, New York

Krishna Rocha-Singh, MD

Medical Director, Prairie Vascular Institute
Prairie Cardiovascular Consultants
Medical Director, Prairie Education and Research Cooperative
Springfield, Illinois

Marco Roffi, MD

Director, Interventional Cardiology Unit
Division of Cardiology, University Hospital
Geneva, Switzerland

R. Kevin Rogers, MD, MSc

Vascular Medicine and Interventional Fellow
Massachusetts General Hospital
Boston, Massachusetts

Javier Sanz, MD

Assistant Professor Medicine/Cardiology
Cardiac MR/CT Program
Cardiovascular Institute
Mount Sinai School of Medicine
New York, NY

Bruno Scheller, MD

Department of Cardiology
Division of Internal Medicine III
University of Saarland
Homburg/Saar, Germany

Albert Schömig, MD

Professor of Medicine
Deutsches Herzzentrum and I. Medizinische Klinik rechts der Isar
Technische Universität
Munich, Germany

Robert S. Schwartz, MD

Minneapolis Heart Institute and Foundation
Minneapolis, Minnesota

Patrick Serruys, MD, PhD

Professor and Head, Department of Interventional Cardiology
Erasmus University
Director, Clinical Research Program of the Catheterization
Laboratory
Rotterdam, Netherlands

Shinichi Shirai, MD

Division of Cardiology
Kokura Memorial Hospital
Kokura, Japan

Mehdi H. Shishehbor, DO, MPH

Staff, Interventional Cardiology & Vascular Medicine
Associate Director, Interventional Cardiology Fellowship
Department of Cardiovascular Medicine
Cleveland Clinic
Cleveland, Ohio

Mitchell J. Silver, DO

MidOhio Cardiology and Vascular Consultants
Columbus, Ohio

Daniel I. Simon, MD

University Hospitals Harrington-McLaughlin Heart & Vascular
Institute
Case Western Reserve University School of Medicine
Cleveland, Ohio

Vasile Sirbu, MD

Director, Cardiovascular Department
Ospedali Riuniti di Bergamo
Bergamo, Italy

Goran Stankovic, MD

Clinic for Cardiology, Department for Diagnostic and
Catheterization Laboratories
Clinical Center of Serbia
Medical School of Belgrade
Belgrade, Serbia

Curtiss Stinis, MD

Director of Peripheral Interventions
Division of Cardiology
Scripps Clinic and Research Foundation
La Jolla, California

Gregg W. Stone, MD

Director of Cardiovascular Research and Education
Columbia University Medical Center
New York—Presbyterian Hospital
New York, New York

Gus Theodos, MD

Department of Cardiovascular Medicine
Cleveland Clinic
Cleveland, Ohio

On Topaz, MD

Professor of Medicine and Pathology
Chief, Division of Cardiology
Charles George Veterans Affairs Medical Center
Asheville, North Carolina

Christophe Tron, MD

Cardiology Department
Hopital Bichat
Paris, France

Alec Vahanian, MD

Professor of Cardiology
University of Paris VII
Head, Cardiology Department
Hopital Bichat
Paris, France

Robert A. Van Tassel, MD

Minneapolis Heart Institute and Foundation
Minneapolis, Minnesota

Christopher J. White, MD

Chairman, Department of Cardiovascular Diseases
The John Ochsner Heart & Vascular Institute
Ochsner Clinic Foundation
New Orleans, Louisiana

Matthew R. Williams, MD

Surgical Director, Cardiovascular Transcatheter Therapies
Assistant Professor, Department of Cardiothoracic Surgery
Interventional Cardiologist, Center for Interventional Vascular
Therapy
New York-Presbyterian Hospital
Columbia University
New York, New York

Paul Yock, MD

The Martha Meier Weiland Professor, School of Medicine
Professor of Bioengineering and, by courtesy, of Mechanical
Engineering and at the GSB
Stanford University
Stanford, California

Hiroyoshi Yokoi, MD

Department of Cardiology
Kokura Memorial Hospital
Fukuoka, Japan

Alan Zajarias, MD

Assistant Professor of Medicine
Cardiovascular Division
Washington University School of Medicine
St. Louis, Missouri

Khaled Ziada, MD

Associate Professor of Medicine
Director, Cardiac Catheterization Laboratories
Director, Cardiovascular Interventional Fellowship
Gill Heart Institute, University of Kentucky
Lexington, Kentucky

Andrew A. Ziskind, MD

Senior Executive, Accenture
Chicago, Illinois

Matthew Zussman, MD

Fellow, Pediatric Cardiology
Cincinnati Children's Hospital
Cincinnati, Ohio

The 6th Edition of the *Textbook of Interventional Cardiology* has been more extensively revamped than any other previous edition, starting with the addition of a co-editor which we refer to as T + T and what will hopefully be viewed as T² with respect to the product transcending the sum of the editors input and perspective. We have tried to fully capture the excitement in the field of interventional cardiology, highlighting such breakthroughs as transcatheter aortic valve implantation (TAVI). In this procedure, the sense at the moment the stent valve is deployed is a combination of exhilaration and anxiety, reminiscent of the early pioneering days of balloon angioplasty, and new device development. Over the years, coronary intervention became increasingly predictable and, in many ways, routine, with the progressive maturation of stents and leaps forward in our adjunct pharmacologic therapies. In some ways, the field of interventional cardiology lost a bit of its pioneering spark that had so characterized this discipline from its inception in the 1980s. In those heady times, performing balloon angioplasty in the coronary artery was unpredictable. The predictability provided by stents was replaced with the unpredictability of stent thrombosis. Interventional cardiologists, and scientists, had to not only rise to the challenge for each individual patient, but also discover the vital innovations that would perpetuate the prominence and importance of the specialty.

Today, the challenges continue, but they have morphed considerably. The profile of patients who undergo coronary intervention has dramatically increased in complexity including patients with advanced age, those with left main stem lesions, chronic occlusions, and what would formerly have been considered prohibitive complexity. Whatever happened to patients with Type A lesions? How can we break the maximal SYNTAX score barrier for PCI? At the same time, the crisis in health care economics has placed an undue burden on interventional cardiologists with respect to time, constraints in equipment selection, and fulfilling the responsibility of 24/7 coverage for such emergencies as acute myocardial infarction. There is also the incremental pressure from scorecarding initiatives and challenges to the appropriateness of

procedures. But, hopefully, all of these challenges are outweighed by the immense gratification of helping a symptomatic patient with limitations in the quality of life get back to his or her baseline.

This book is intended to serve as a resource for the interventional cardiology community, which not only includes practicing cardiologists, but also the team involved in procedures, referring physicians, and those training or who have aspiration to train in this awe inspiring field. We have changed authors of several chapters to provide a sense of newness and a fresh perspective, and have added several chapters that reflect how the field has changed such as left mainstem disease, thrombus containing lesions, transradial intervention, complications of procedures, the role of cardiac surgeons, and optical coherence tomography. In every chapter, we have sought the authors who are widely regarded as the true expert(s) in the field. Going forward, we fully recognize that there needs to be increased cooperativity with cardiac surgeons—the rising popularity of hybrid and collaborative valve procedures that capitalize on the best parts of percutaneous and surgical approaches is clearly indicative of that collaboration.

We want to express our genuine and deep appreciation to all 130 authors from all over the world who have graciously contributed to this new edition. The old line “it takes a village” needs to be replaced by “it takes a world” to comprehensively and authentically present the ever-burgeoning field of interventional cardiology. We thank Taylor Ball and Natasha Andjelkovic both at Elsevier, for their first rate, professional support of this endeavor. And we are especially grateful to the interventional community of readers of this book who have supported it as the primary reference textbook source for over 25 years. That represents a large sense of responsibility for us to maintain and we hope to have lived up to that, and perhaps exceeded expectations with the 6th edition.

Paul S. Teirstein and Eric J. Topol
La Jolla, California, 2011

SECTION

1 Patient Selection

- 1 Individualized Assessment for Percutaneous or Surgical Revascularization 3
SCOT GARG | PATRICK W. SERRUYS
- 2 Evidence-Based Interventional Practice 16
FRANZ-JOSEF NEUMANN | HEINZ JOACHIM BÜTTNER
- 3 Diabetes 30
MARCO ROFFI | MICHAEL BRAENDLE
- 4 Prior Evaluation: Functional Testing, Multidetector CT 50
MARIO J. GARCIA
- 5 Contrast-Induced Acute Kidney Injury and the Role of Chronic Kidney Disease in PCI 66
J. MATTHEW BRENNAN | BRAHMAJEE K. NALLAMOTHU | UPTAL D. PATEL
- 6 Preoperative Coronary Intervention 75
CRAIG R. NARINS
- 7 Gender and Ethnicity Issues in Percutaneous Coronary Interventions 85
LESLIE CHO

SECTION

2 Pharmacologic Intervention

- 8 Platelet Inhibitor Agents 97
MATTHEW J. PRICE | DOMINICK J. ANGIOLILLO
- 9 Anticoagulation in Percutaneous Coronary Intervention 113
DEREK P. CHEW
- 10 Lipid Lowering in Coronary Artery Disease 126
KAUSIK K. RAY | CHRISTOPHER P. CANNON
- 11 Thrombolytic Intervention 142
MATTHEWS CHACKO | RANI HASAN
- 12 Other Adjunctive Drugs for Coronary Intervention: β -Blockers, Calcium Channel Blockers, and Angiotensin-Converting Enzyme Inhibitors 159
VIVEK RAJAGOPAL

SECTION

3 Coronary Intervention

- 13 Bare Metal and Drug-Eluting Coronary Stents 171
GREGG W. STONE | AJAY J. KIRTANE
- 14 Drug-Coated Balloons 197
BRUNO SCHELLER | WILLIAM A. GRAY
- 15 History of Coronary Balloon Angioplasty and Current Indications 203
JORGE R. ALEGRÍA | DAVID R. HOLMES JR.
- 16 Elective Intervention for Stable Angina or Silent Ischemia 209
GREGORY W. BARSNESS | DAVID E. KANDZARI

- 17 Intervention for Non-ST-Segment Elevation Acute Coronary Syndromes 223
CURTISS T. STINIS
- 18 Percutaneous Coronary Intervention in Acute ST Segment Elevation Myocardial Infarction 237
ALBERT SCHÖMIG | GJIN NDREPEPA | ROBERT A. BYRNE | ADNAN KASTRATI
- 19 Interventions in Cardiogenic Shock 263
AMR BANNAN | HOWARD C. HERRMANN
- 20 Bifurcations and Branch Vessel Stenting 270
ANTONIO COLOMBO | GORAN STANKOVIC
- 21 Small Vessel and Diffuse Disease 288
MASAKIYO NOBUYOSHI | HIROYOSHI YOKOI | SHINICHI SHIRAI
- 22 Percutaneous Coronary Intervention for Unprotected Left Main Coronary Artery Stenosis 294
SEUNG-JUNG PARK | YOUNG-HAK KIM
- 23 Complex and Multi-vessel Percutaneous Coronary Intervention 303
ARASHK MOTIEI | DAVID R. HOLMES, JR.
- 24 Chronic Total Occlusion 312
AHMED A. KHATTAB | BERNHARD MEIER
- 25 Bypass Graft Intervention 323
JOHN S. DOUGLAS, JR.
- 26 The Thrombus-Containing Lesion 336
ON TOPAZ
- 27 Complications of Percutaneous Coronary Intervention 357
MARVIN H. ENG | JEFFERY W. MOSES | PAUL S. TEIRSTEIN
- 28 Periprocedural Myocardial Infarction and Embolism Protection Devices 372
KHALED ZIADA | DEBABRATA MUKHERJEE
- 29 Access Management and Closure Devices 388
FERNANDO CURA
- 30 Transradial Percutaneous Coronary Intervention for Major Reduction of Bleeding Complications 399
FARZIN BEYGUI | GILLES MONTALESCOT
- 31 The Role of the Cardiac Surgeon 412
G. RUSSELL REISS | MATTHEW R. WILLIAMS
- 32 Restenosis 421
KEVIN J. CROCE | MARCO A. COSTA | DANIEL I. SIMON
- 33 Bioabsorbable stents 432
DEBABRATA MUKHERJEE
- 34 Role of Adjunct Devices: Cutting Balloon, Laser, Ultrasound, and Atherectomy 442
JOHN A. BITTL
- 35 Support Devices for High-Risk Percutaneous Coronary Interventions 455
SRIHARI S. NAIDU | HOWARD C. HERRMANN

- 36** Regional Centers of Excellence for the Care of Patients with Acute Ischemic Heart Disease 467
DEAN J. KEREIAKES | TIMOTHY D. HENRY




SECTION

4 Peripheral Vascular Interventions

- 37** Lower Extremity Interventions 481
DEBABRATA MUKHERJEE
- 38** Upper Extremities and Aortic Arch 496
SAMUEL L. JOHNSTON | ROBERT S. DIETER
- 39** Carotid and Cerebrovascular Intervention 513
R. KEVIN ROGERS | IVAN P. CASSERLY
- 40** Chronic Mesenteric Ischemia: Diagnosis and Intervention 534
CHRISTOPHER J. WHITE
- 41** Renal Artery Stenosis 538
KRISHNA ROCHA-SINGH | NILESH J. GOSWANI | RAGHU KOLLURI | JEFFREY GOLDSTEIN
- 42** Aortic Vascular Interventions (Thoracic and Abdominal) 548
CHRISTOPH A. NIENABER | IBRAHIM AKIN | HÜSEYİN INCE
- 43** Venous Interventions 563
MITCHELL J. SILVER | GARY M. ANSEL
- 44** Stroke Centers and Interventional Cardiology 576
CHRISTOPHER J. WHITE

SECTION

5 Intracardiac Intervention

- 45** Imaging for Intracardiac Interventions 585
MEHDI H. SHISHEHBOR | SAMIR R. KAPADIA
- 46** Percutaneous Closure of Patent Foramen Ovale and Atrial Septal Defect  603
ALAN ZAJARIAS | DAVID T. BALZER | JOHN LASALA
- 47** Left Atrial Appendage Closure and Stroke: Local Device Therapy for Cardioembolic Stroke Protection 623
ROBERT S. SCHWARTZ | ROBERT A. VAN TASSEL | HIDEHIKO HARA | DAVID R. HOLMES, JR.
- 48** Mitral Valvuloplasty  635
ALEC VAHANIAN | DOMINIQUE HIMBERT | ERIC BROCHET | BERNARD IJUNG
- 49** Percutaneous Mitral Valve Repair 647
AMAR KRISHNASWAMY | SAMIR R. KAPADIA
- 50** Trans-catheter Aortic Valve Interventions: From Balloon Aortic Valvuloplasty to Trans-catheter Aortic Valve Implantation  661
ALAIN CRIBIER | ALAN ZAJARIAS | HELENE ELTCHANINOFF | CHRISTOPHE TRON | ROGER LAHAM | JEFFREY POPMA

- 51** Pulmonary and Tricuspid Valve Interventions 684
LOUISE COATS | PHILIPP BONHOEFFER

- 52** Hypertrophic Cardiomyopathy 694
GUS THEODOS | SAMIR R. KAPADIA

- 53** Percutaneous Balloon Pericardiotomy for Patients with Pericardial Effusion and Tamponade 707
HANI JNEID | ANDREW A. ZISKIND | IGOR PALACIOS

- 54** Transcatheter Therapies for Congenital Heart Disease 718
ROBERT H. BEEKMAN III | RUSSEL HIRSCH | MATTHEW ZUSSMAN | THOMAS R. LLOYD

- 55** Stem Cell Therapy for Ischemic Heart Disease 745
MARC S. PENN | SAIF ANWARUDDIN

SECTION

6 Evaluation of Interventional Techniques

- 56** Qualitative and Quantitative Coronary Angiography 757
JEFFREY POPMA | ALEXANDRA ALMONACID | DAVID BURKE
- 57** Intracoronary Pressure and Flow Measurement 776
MORTON J. KERN | MICHAEL J. LIM
- 58** Intravascular Ultrasound 793
YASUHIRO HONDA | PETER J. FITZGERALD | PAUL YOCK
- 59** High-Risk Vulnerable Plaques: Definition, Diagnosis, and Treatment 809
PEDRO R. MORENO | CARLOS L. ALVIAR | JAVIER SANZ | VALENTIN FUSTER
- 60** Optical Coherence Tomography 842
GIULIO GUAGLIUMI | TAKASHI AKASAKA | VASILE SIRBU | TAKASHI KUBO

SECTION

7 Outcome Effectiveness of Interventional Cardiology

- 61** Medical Economics in Interventional Cardiology 861
DANIEL MARK
- 62** Quality of Care in Interventional Cardiology 877
GREGORY J. DEHMER | RALPH G. BRINDIS
- 63** Volume and Outcome 894
JAMES G. JOLLIS

Index 899

VIDEO TABLE OF CONTENTS

27 Complications of Percutaneous Coronary Intervention

MARVIN H. ENG | JEFFERY W. MOSES | PAUL S. TEIRSTEIN

- Video 27-1** Coronary Dissection
- Video 27-2** Coronary Perforations
- Video 27-3** Treatment of a Coronary Perforation Using the Two Guide Technique to Deploy a Polytetrafluoroethylene (PTFE)-Covered Stent
- Video 27-4** Snaring of an Embolized Coronary Stent at the Right Coronary Ostium
- Video 27-5** Air Embolism

29 Access Management and Closure Devices

FERNANDO CURA

- Video 29-1** Femoral Artery Landmarks
- Video 29-2** AngioSeal

30 Transradial Percutaneous Coronary Intervention for Major Reduction of Bleeding Complications

FARZIN BEYGUI | GILLES MONTALESCOT

- Video 30-1** Abnormal Plethysmo-oxymetric Test
- Video 30-2** Right Radial Puncture & Sheath Insertion
- Video 30-3** Retrieving Catheter with Guidewire in Place
- Video 30-4A** Brachial Loop
- Video 30-4B** Brachial Loop Unlooped
- Video 30-5** High Brachial Curve Uncurved
- Video 30-6** Subclavian Loop Unlooped
- Video 30-7** RRA Spasm
- Video 30-8A** RRA Spasm
- Video 30-8B** RRA Spasm after Intraradial Injection of GTN & Verapamil
- Video 30-9** Right Ulnar Approach in a Patient with Right Radial Occlusion and Collateral Circulation

46 Percutaneous Closure of Patent Foramen Ovale and Atrial Septal Defect

ALAN ZAJARIAS | DAVID T. BALZER | JOHN LASALA

- Video 46-1** Atrial Septal Development
- Video 46-2** Atrial Septal Defect and Patent Foramen Ovale
- Video 46-3** Thrombus in Transit Across a Patent Foramen Ovale

Video 46-4 Atrial Septal Aneurysm and Eustachian Valve

Video 46-5 Lipomatous Hypertrophy of the Atrial Septum

Video 46-6 Bubble Study Using TTE

Video 46-7 Bubble Study Using TEE

Video 46-8 Bubble Study Using ICE

Video 46-9 Deployment of PFO Device to the Left Atrial Disk

Video 46-10 Deployment of PFO Device to the Right Atrial Disk

Video 46-11 Release of the PFO Device

Video 46-12 Atrial Septal Defect with Negative Echo Contrast

Video 46-13 Balloon Assisted Technique for Deployment of ASD Occluder #1

Video 46-14 Balloon Assisted Technique for Deployment of ASD Occluder #2

Video 46-15 Balloon Assisted Technique for Deployment of ASD Occluder #3

Video 46-16 Balloon Assisted Technique for Deployment of ASD Occluder #4

48 Mitral Valvuloplasty

ALEC VAHANIAN | DOMINIQUE HIMBERT | ERIC BROCHET | BERNARD IUNG

Video 48-1 Inoue Balloon Technique (Fluoroscopy)

Video 48-2 Inflation of the Inoue Balloon During Percutaneous Mitral Commissurotomy

Video 48-3 Transseptal Puncture

Video 48-4 3D Transthoracic View after Percutaneous Mitral Commissurotomy

Video 48-5 Transesophageal View after Percutaneous Mitral Commissurotomy

Video 48-6 Transesophageal View before Percutaneous Mitral Commissurotomy

50 Trans-catheter Aortic Valve Interventions: From Balloon Aortic Valvuloplasty to Trans-catheter Aortic Valve Implantation

MARVIN H. ENG | PAUL S. TEIRSTEIN

Video 50-1 Routine Transfemoral Edwards-Sapien Aortic Valve Deployment

Video 50-2 Routine Transapical Edwards Sapien Aortic Valve Implantation

SECTION

1

Patient Selection

