Contemporary Cardiology

Series Editor:

Peter P. Toth
Ciccarone Center for the Prevention of Cardiovascular Disease
Johns Hopkins University School of Medicine
Baltimore, Maryland
USA

For more than a decade, cardiologists have relied on the Contemporary Cardiology series to provide them with forefront medical references on all aspects of cardiology. Each title is carefully crafted by world-renown cardiologists who comprehensively cover the most important topics in this rapidly advancing field. With more than 75 titles in print covering everything from diabetes and cardiovascular disease to the management of acute coronary syndromes, the Contemporary Cardiology series has become the leading reference source for the practice of cardiac care.

More information about this series at http://www.springer.com/series/7677

Arman T. Askari • Adrian W. Messerli
Editors

Cardiovascular Hemodynamics

An Introductory Guide

Second Edition

Humana Press

Editors
Arman T. Askari
Premier Health Advocates
Beachwood, OH
USA

Adrian W. Messerli
Gill Heart and Vascular Institute
University of Kentucky HealthCare
Lexington, KY
USA

ISSN 2196-8969 ISSN 2196-8977 (electronic)
Contemporary Cardiology
ISBN 978-3-030-19130-6 ISBN 978-3-030-19131-3 (eBook)
https://doi.org/10.1007/978-3-030-19131-3

This Humana imprint is published by the registered company Springer Nature Switzerland AG.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

To our families for their unwavering support.

Preface to the Second Edition

For any cardiovascular care provider, an understanding of physiology is absolutely essential for delivering patient care. Whether sitting in the echocardiography reading room, performing procedures in the catheterization laboratory, or rounding in the coronary care unit, such an understanding is equally vital. While the underpinnings of cardiovascular physiology from a systems perspective have changed little in recent time, there have been substantial advances in the ability to apply these concepts to newer technologies.

Our primary goal for this second edition of *Cardiovascular Hemodynamics: An Introductory Guide* is not only to expound on the fundamental education of cardiovascular physiology but also to focus additionally on the clinical application of these hemodynamic principles. In order to achieve this, we have updated all of the first edition chapters and have added a new section, "Effects of Selected Interventions on Cardiovascular Hemodynamics."

Born out of the huge economic burden of heart failure is an increased pressure on the healthcare system to decrease the often-avoidable readmissions for those patients with heart failure. We believe that a solid knowledge of heart failure physiology will arm those charged with the care of these patients with the tools necessary to decrease these costly readmissions. In addition, we have added another chapter, "Objective Evaluation of Hemodynamics in the Outpatient," that aims to familiarize the reader with the recent advancements (medical and technological) that have proven helpful with regard to optimizing patient care.

Of course, an emphasis on the basic tenets of cardiovascular physiology remains our central focus, and we use numerous figures, hemodynamic tracings, tables, board style review questions, and hemodynamic "pearls" in order guide our readers. We believe this manual will be of immense value and interest to every student and practitioner of cardiovascular medicine who wishes to fully learn the hemodynamic foundation of cardiovascular medicine.

Beachwood, OH, USA — Arman T. Askari, MD
Lexington, KY, USA — Adrian W. Messerli, MD

Acknowledgment

We would like to acknowledge the authors, who, in many cases, were also mentors.

Contents

Contributors

Ahmed Abdel-Latif VA Medical Center, Lexington, KY, USA

Saha Cardiovascular Research Center, University of Kentucky, Lexington, KY, USA

Olcay Aksoy David Geffen School of Medicine, UCLA Medical Center, Los Angeles, CA, USA

Paul Anaya Gill Heart Institute, University of Kentucky, Lexington, KY, USA

Jordan D. Awerbach Division of Cardiovascular Medicine, Duke University Health System, Durham, NC, USA

Chirag Bavishi Department of Cardiology, Lifespan Cardiovascular Institute, Rhode Island Hospital, Warren Alpert Medical School of Brown University, Providence, RI, USA

David C. Booth The Gill Heart and Vascular Institute, University of Kentucky Medical Center, Lexington, KY, USA

Michael P. Brunner Spectrum Health Medical Group, Grand Rapids, MI, USA

Justin M. Dunn Interventional Cardiology, Summa Health, Akron, OH, USA

Stephen G. Ellis Cleveland Clinic, Cleveland, OH, USA

Michael D. Faulx Cleveland Clinic, Cleveland, OH, USA

Sachin S. Goel Prairie Heart Institute, St John's Hospital, Springfield, IL, USA

Andrew D. M. Grant Libin Cardiovascular Institute, Calgary, AB, Canada

Brian P. Griffin Cardiovascular Imaging, Cleveland Clinic, Cleveland, OH, USA

Richard A. Grimm Cleveland Clinic, Cleveland, OH, USA

Ehud Grossman The Chaim Sheba Medical Center, The Sackler Faculty of Medicine, Tel-Aviv University, Tel Aviv, Israel

Mazen A. Hanna Cleveland Clinic, Cleveland, OH, USA

Michael A. Hanna Cleveland Clinic, Cleveland, OH, USA

James E. Harvey York Hospital, WellSpan Health System, York, PA, USA

Frederick Heupler Cleveland Clinic, Cleveland, OH, USA

Daniel H. Katz Beth Israel Deaconess Medical Center, Boston, MA, USA

Allan Klein The Miller Family Heart and Vascular Institute, Cleveland Clinic, Cleveland, OH, USA

Richard A. Krasuski Division of Cardiovascular Medicine, Duke University Health System, Durham, NC, USA

Amar Krishnaswamy Interventional Cardiology, Cleveland Clinic, Cleveland, OH, USA

Tracy E. Macaulay Gill Heart Institute, University of Kentucky, Lexington, KY, USA

Franz H. Messerli Department of Cardiology, University of Bern, Bern, Switzerland

Alexandra-Maria Neagoe Department of Cardiology, University Hospital Bern, Bern, Switzerland

Gbolahan Ogunbayo Gill Heart Institute and Division of Cardiovascular Medicine, University of Kentucky, Lexington, KY, USA

VA Medical Center, Lexington, KY, USA

Alper Ozkan Acibadem University, Istanbul, Turkey

Navin Rajagopalan Heart Failure/Cardiac Transplant Program, The Gill Heart and Vascular Institute, Lexington, KY, USA

Roberto Ramirez Department of Cardiology, Mount Sinai St. Luke's Hospital, New York, NY, USA

Emrush Rexhaj Department of Cardiology, University Hospital Bern, Bern, Switzerland

Department for Biomedical Research, University of Bern, Bern, Switzerland

Leonardo Rodriguez Cleveland Clinic, Cleveland, OH, USA

Marwa A. Sabe Beth Israel Deaconess Medical Center, Boston, MA, USA

Harvard Medical School, Boston, MA, USA

Begum Sezer UCLA Medical Center, Los Angeles, CA, USA

William J. Stewart Department of Cardiovascular Medicine, Cleveland Clinic, Cleveland, OH, USA

Jose Mariano T. Tan Spectrum Health Medical Group, Grand Rapids, MI, USA

Jordan S. Thomas Advanced Heart Failure/Transplant Cardiology, Ohio State University, Columbus, OH, USA

E. Murat Tuzcu Heart and Vascular Institute, Cleveland Clinic, Cleveland, OH, USA

Amanda R. Vest Division of Cardiology, Tufts Medical Center, Boston, MA, USA

Chun Pong Wong Department of Cardiology, Khoo Teck Puat Hospital, National Healthcare Group, Singapore, Singapore

Omeed Zardkoohi Northwestern Medicine, Chicago, IL, USA

Khaled M. Ziada Gill Heart and Vascular Institute, University of Kentucky, Lexington, KY, USA

Andrew O. Zurick III St. Thomas Heart, Nashville, TN, USA

List of Figures

List of Tables