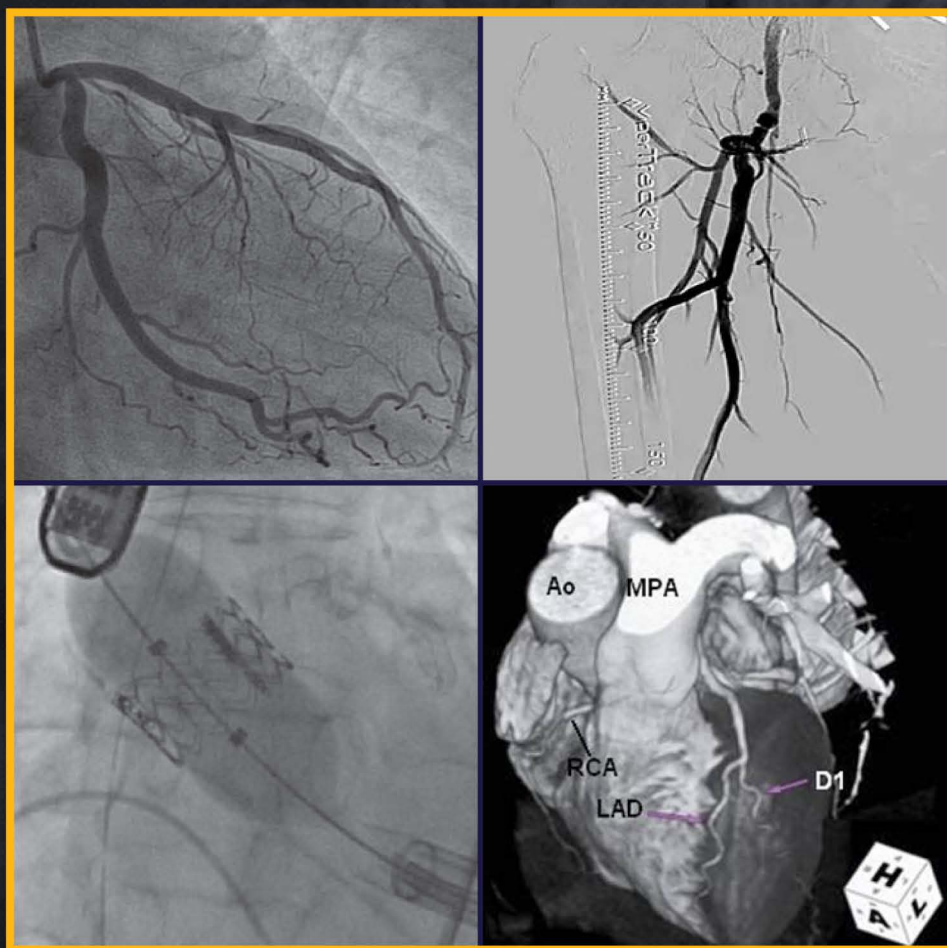


SECOND EDITION

Cardiovascular Catheterization and Intervention

A Textbook of Coronary, Peripheral,
and Structural Heart Disease



Edited by

Debabrata Mukherjee • Eric R. Bates
Marco Roffi • Richard A. Lange • David J. Moliterno



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CRC Press

Taylor & Francis Group

Boca Raton London New York

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

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

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Printed on acid-free paper

International Standard Book Number-13: 978-1-4987-5019-6 (Pack – Hardback and eBook)

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Library of Congress Cataloging-in-Publication Data

Names: Mukherjee, Debabrata, editor. | Bates, Eric R., editor. | Roffi, Marco, editor. | Lange, Richard A., editor. | Moliterno, David J., editor.
Title: Cardiovascular catheterization and intervention / [edited by] Debabrata Mukherjee, Eric R. Bates, Marco Roffi, Richard Lange, David J. Moliterno.
Other titles: Cardiovascular catheterization and intervention (Mukherjee)
Description: Second edition. | Boca Raton, FL : CRC Press/Taylor & Francis Group, 2018. | Includes bibliographical references and index.
Identifiers: LCCN 2017006001 | ISBN 9781498750196 (pack-hardback and ebook : alk. paper) | ISBN 9781498750264 (ebook) | ISBN 9781498752169 (ebook) | ISBN 9781498752671 (ebook)
Subjects: | MESH: Cardiac Catheterization--methods | Cardiovascular Diseases--diagnosis | Cardiovascular Diseases--therapy | Catheterization, Peripheral--methods | Coronary Angiography--methods
Classification: LCC RC683.5.C25 | NLM WG 141.5.C2 | DDC 616.1/20754--dc23
LC record available at <https://lccn.loc.gov/2017006001>

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

Dedication

To all the cardiology fellows who enrich my academic experience every day, to my parents who continue to inspire me, to wonderful Suchandra for her love, friendship, and support, and to my beloved nephew, Rohin Hegde.

Debabrata Mukherjee

I would like to thank my wife, Nancy, and children, Andrew, Lyndsay, Alexis, and Evan, for all their love and support during the writing of this book.

Eric R. Bates

To my spouse, Muriel, and our children, Emma, Thomas, Giulia, and Edouard, with love and gratitude.

Marco Roffi

The truly important matters of the heart have been imparted to me by my parents, my lovely wife, Bobette, and our three sons—David, Jonathan, and Brian. My dedication is to them, as my love and admiration for them is ineffable.

Richard A. Lange

To my loving wife, Judith, and our sons, Nathaniel and Benjamin, of whom I am forever proud.

David J. Moliterno



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Preface

The field of interventional cardiovascular medicine continues to rapidly evolve in both the diagnostic and therapeutic arenas. Over the past decade, substantial advances have been made on many fronts, including the development and utilization of techniques and devices for intravascular and intracardiac imaging, percutaneous hemodynamic support, newer drug-eluting stents, drug-coated balloons, and percutaneous valve repair and replacement. The evolution of newer drugs and devices challenges the cardiologist to stay abreast of cutting-edge pharmacological and mechanical strategies for optimal patient care. The second edition of *Cardiovascular Catheterization and Intervention: A Textbook of Coronary, Peripheral, and Structural Heart Disease* aims to provide clinicians with comprehensive guidance on the preprocedural, procedural, and postprocedural aspects of coronary, peripheral, and structural heart disease interventions. The text features evidence-based discussions on patient selection, vascular access, general principles of interventional cardiology, and postprocedure management of these patients; it also serves as a comprehensive, easily accessible reference for busy practitioners and cardiovascular trainees.

Of foremost importance, the topic areas covered are relevant to the daily practice of interventional cardiology. The book begins with several chapters dedicated to key concepts associated with cardiac catheterization and interventional cardiovascular medicine. The subsequent chapters focus on hemodynamic assessment and coronary angiography in general and in specific situations, such as those in pediatric patients and in adults with congenital heart disease. The bulk of the text addresses coronary and noncoronary interventions, including structural heart disease interventions. Finally, we have included dedicated chapters on credentialing and organizing prehospital and hospital systems

that focus on cardiovascular care. A large number of high-quality illustrations make this textbook particularly attractive to the practitioner.

Essential to the quality and appropriateness of the text is the expertise of the chapter authors. We are fortunate to have assembled a stellar roster of interventional cardiovascular experts to create this book. The contributing authors from leading medical centers around the world have collectively performed hundreds of thousands of procedures and have published thousands of peer-reviewed manuscripts. We are greatly indebted to them. The practice of interventional cardiovascular medicine is exciting, rewarding, and a privilege that each of us enjoys. Likewise, it has been our personal honor to work with these superb contributors, our colleagues in interventional cardiology, as well as the editorial team at CRC Press. It is our hope that you will enjoy this book and that it will be a valuable resource to you in providing the highest quality of care to your patients.

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PART 1

General Concepts



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Introduction to cardiac catheterization

RICHARD A. LANGE AND STEVEN R. BAILEY

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INTRODUCTION

Cardiac catheterization is one of the most frequently performed procedures in the United States. Over the past 25 years, the number of procedures has increased 3.5-fold because of expanded indications and improvements in techniques and equipment.¹ In 2005, an estimated 1,322,000 inpatient left heart diagnostic catheterizations and 1,271,000 inpatient percutaneous coronary interventional (PCI) procedures were performed in the United States.¹ According to the most recent American Hospital Association survey, 36% of the 4,836 hospitals in the United States have adult diagnostic catheterization laboratories. Of the 1,728 hospital-centered adult diagnostic laboratories, 78% are PCI capable.²

Historical perspective

THE EARLY YEARS OF CATHETERIZATION: ANIMAL AND CADAVERIC STUDIES (1711–1927)

The earliest known cardiac catheterization of an animal was performed in 1710 by Reverend Stephen Hales, an English physiologist and parson, who “bled a sheep to death and then led a gun barrel from the neck vessels into the still beating heart. Through this, he filled the hollow chambers with molten wax and then measured from the resultant cast the volume of the heartbeat and the minute-volume of the heart, which he calculated from the pulse beat.”^{3,4} In addition, Hales was the first to determine systemic arterial pressure, when, in 1727, he measured the rise in a column of blood in a long glass tube secured in an artery (Figure 1.1). Brass pipes placed in the carotid artery and jugular vein of a horse were connected to an 11-ft-high glass tube for pressure measurements, with the trachea of a goose used as a flexible connector. Hales astutely noted that the pressure was different in arteries and veins (blood

from the carotid artery rose to a height of more than 8 ft in the glass tube, whereas blood from the jugular vein rose less than 1 ft) and between contractions and relaxations of the heart.

In 1844, the term *cardiac catheterization* was coined by Claude Bernard, a French physiologist who inserted long glass thermometers into a horse’s right and left ventricles from its jugular vein and carotid artery, respectively. By demonstrating that blood temperature was higher in the right ventricle than in the left, he established that “chemical reactions” (i.e., metabolism) occurred in the body rather than the lungs. Subsequently, he used this technique to acquire blood samples from various arterial and venous sites for metabolic studies, and he performed intracardiac pressure recordings in dogs and sheep to study the regulation of systemic arterial pressure by the nervous system. He was the first to describe right and left heart catheterization via the femoral vein and artery.^{5,6} Although Bernard was not the first to perform catheterization, his careful application of scientific methods to the study of cardiac physiology demonstrated the potential importance of cardiac catheterization and initiated an era of cardiovascular physiologic investigation.

In 1861, Etienne Jules Marey, another French physiologist, in collaboration with Jean Baptiste Aguste Chauveau, a veterinarian, elucidated the nature of the apex beat by simultaneously recording its movement and the right atrial and right ventricular pressures of a conscious horse.⁷ Their observation that the apical impulse was caused by early forceful ventricular contraction remains a milestone as the first graphic recording of intracardiac events in a conscious animal (Figure 1.2).⁸ Gaining access to the left ventricle via the carotid artery, they studied left ventricular pressure waveforms and characterized various phases of the cardiac cycle, and they were the first to obtain simultaneous recordings of left ventricular and aortic pressures. In addition,



Figure 1.1 First documented cardiac catheterization performed by Hales in 1711. (Courtesy of the Bettmann Archives.)

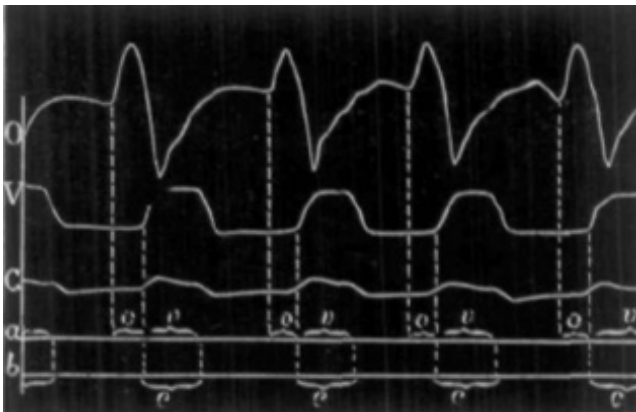


Figure 1.2 First published records of pressure pulses in a cardiac chamber obtained by catheterization of the right atrium (O) and ventricle (V) via the jugular vein in an unanesthetized horse. The third tracing (C) is from an intrathoracic balloon catheter placed to detect the cardiac impulse. (From Chaveau, A., and Marey, É. J., *Circulation Research*, 22, 96, 1968. With permission.)

Marey and Chaveau invented the double-lumen catheter, with which they simultaneously measured pressures in contiguous cardiac chambers in horses and dogs. Decades later, André Cournand (see following text) utilized this catheter design to perform similar studies in humans.

In 1870, Adolph Fick (Figure 1.3), a German physicist and physiologist, proposed a direct method of measuring cardiac output. In a commentary to his local medical society that resulted in a publication less than one page long (the Fick principle, 1870), Fick proposed that the cardiac output could be measured by dividing the oxygen uptake by the corresponding arteriovenous oxygen content difference.⁹ Interestingly, in 1873 Fick published the results of right and left heart catheterizations that he performed in animals, but he did not utilize or validate his method.¹⁰ Only two decades later did physiologists begin to apply the Fick principle in animals. Although Grehan and Quinquand published a brief report describing use of the technique in dogs in 1886, it was not until 1898, when Zuntz and Hageman made a detailed study of cardiac output in the horse at rest and during exercise, that the Fick method was established as reliable and reproducible.¹¹ Application of the Fick principle in humans was hindered by the difficulty of obtaining samples of mixed venous blood. Invasive catheterization was thought to be too dangerous to be applied to human subjects because of excessive blood loss and the risk of infection. Furthermore, radiography was not yet available, so attempts to obtain samples of mixed venous blood were made by such avant-garde interventions as direct transthoracic needle puncture of the right ventricle.¹²

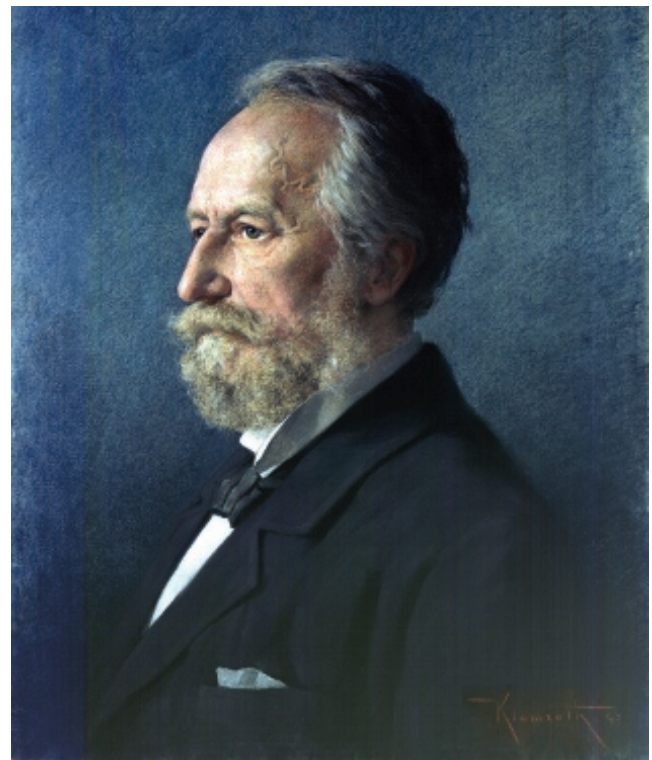


Figure 1.3 Adolph Fick (1829–1901), a mathematician, physicist, and physiologist. His major research interest was in the physiology of muscular contraction. He described the calculation of cardiac output as an outgrowth of his mathematical approach to physiologic events.