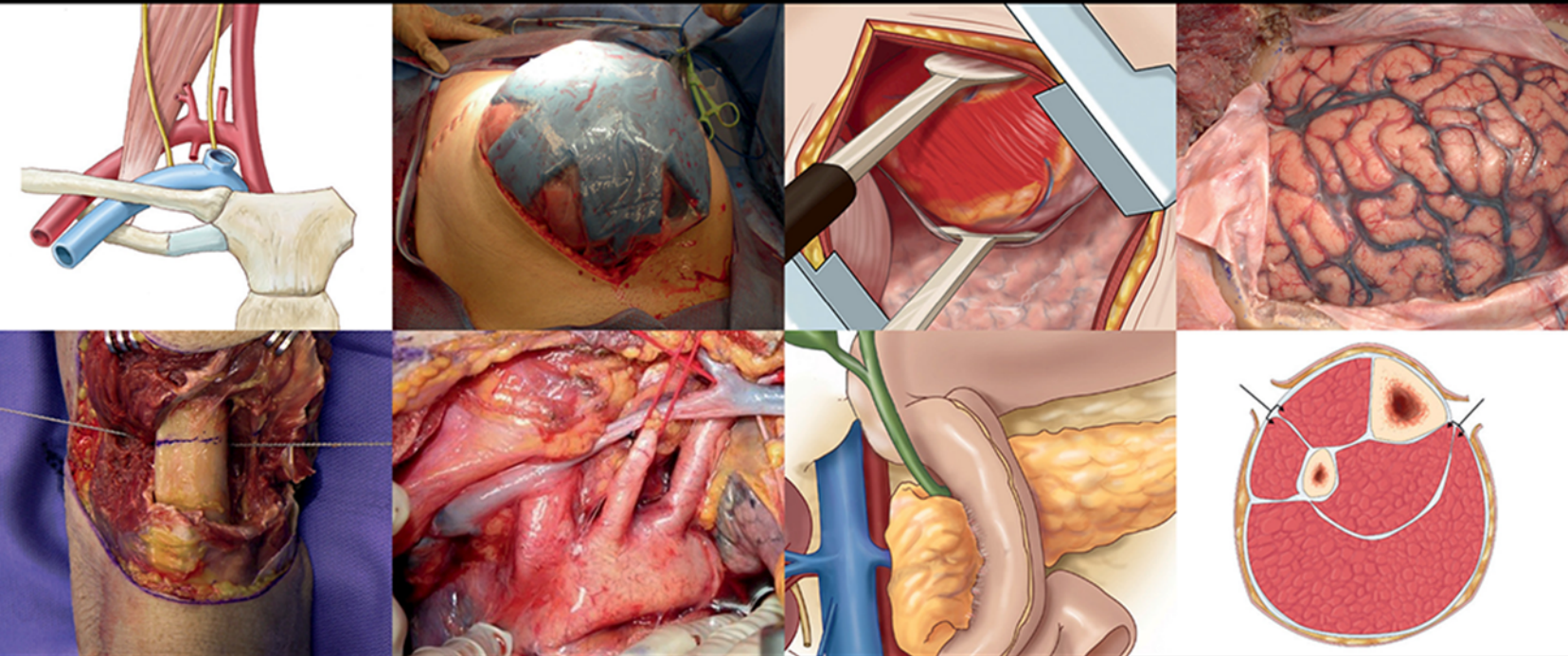


SECOND
EDITION

ATLAS OF SURGICAL TECHNIQUES IN TRAUMA



EDITED BY
Demetrios Demetriades
Kenji Inaba
George Velmahos

CAMBRIDGE

Medicine

Atlas of Surgical Techniques in Trauma

Second Edition

Atlas of Surgical Techniques in Trauma

Second Edition

Edited by

Demetrios Demetriades

University of Southern California

Kenji Inaba

University of Southern California

George C. Velmahos

Harvard University



CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre,
New Delhi – 110025, India

79 Anson Road, #06–04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.

It furthers the University’s mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org

Information on this title: www.cambridge.org/9781108477048

DOI: 10.1017/9781108698665

© Demetrios Demetriades, Kenji Inaba, and George C. Velmahos 2020

This publication is in copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of Cambridge University Press.

First published 2015

Second edition 2020

Printed in Singapore by Markono Print Media Pte Ltd

A catalogue record for this publication is available from the British Library.

Library of Congress Cataloging-in-Publication Data

Names: Demetriades, Demetrios, 1951– editor. | Inaba, Kenji, editor. | Velmahos, George C., editor.

Title: Atlas of surgical techniques in trauma / edited by Demetrios Demetriades, Kenji Inaba, George C. Velmahos.

Description: Second edition. | New York : Cambridge University Press, 2020. | Includes bibliographical references and index.

Identifiers: LCCN 2019010789 | ISBN 9781108477048 (hardback : alk. paper)

Subjects: | MESH: Wounds and Injuries–surgery | Atlas

Classification: LCC RD93.3 | NLM WO 517 | DDC 617.10022/3–dc23

LC record available at <https://lcn.loc.gov/2019010789>

ISBN 978-1-108-47704-8 Hardback

Cambridge University Press has no responsibility for the persistence or accuracy of URLs for external or third-party internet websites referred to in this publication and does not guarantee that any content on such websites is, or will remain, accurate or appropriate.

.....

Every effort has been made in preparing this book to provide accurate and up-to-date information that is in accord with accepted standards and practice at the time of publication. Although case histories are drawn from actual cases, every effort has been made to disguise the identities of the individuals involved. Nevertheless, the authors, editors, and publishers can make no warranties that the information contained herein is totally free from error, not least because clinical standards are constantly changing through research and regulation. The authors, editors, and publishers therefore disclaim all liability for direct or consequential damages resulting from the use of material contained in this book. Readers are strongly advised to pay careful attention to information provided by the manufacturer of any drugs or equipment that they plan to use.

To my parents, my wife Elizabeth, my daughters Alexis and Stefanie, and my son Nicholas.

D. Demetriades

To my parents, wife Susie, and son Koji.

K. Inaba

To the drivers of my inspiration: my parents, my wife, and children.

G. C. Velmahos

Contents

List of Contributors ix
Foreword xii
Preface xiii
Acknowledgments xiv

Section 1 The Trauma Operating Room

- 1 **Trauma Operating Room** 1
Brian Mecklenburg, Lisa L. Schlitzkus, and Kenji Inaba

Section 2 Resuscitative Procedures in the Emergency Room

- 2 **Cricothyroidotomy** 7
Morgan Schellenberg, Paul Wisniewski, and Travis M. Polk
- 3 **Thoracostomy Tube Insertion** 16
Demetrios Demetriades and Caroline Park
- 4 **Emergency Room Resuscitative Thoracotomy** 23
Demetrios Demetriades, James Bardes, and Scott Zakaluzny

Section 3 Head

- 5 **Intracranial Pressure Monitors** 33
Meghan Lewis and John Peter Gruen
- 6 **Evacuation of Acute Epidural and Subdural Hematomas** 38
Gabriel Zada and Kazuhide Matsushima

Section 4 Neck

- 7 **Neck Operations for Trauma: General Principles** 47
James Bardes, Emilie Joos, and Kenji Inaba
- 8 **Carotid Artery and Internal Jugular Vein Injuries** 51
Edward Kwon, Daniel Grabo, and George C. Velmahos
- 9 **Subclavian Vessels** 59
Demetrios Demetriades and Jennifer A. Smith

-
- 10 **Axillary Vessels** 70
Demetrios Demetriades and Emilie Joos
- 11 **Vertebral Artery Injuries** 74
Demetrios Demetriades, Morgan Schellenberg, and Nick A. Nash
- 12 **Trachea and Larynx** 82
Elizabeth R. Benjamin and Kenji Inaba
- 13 **Cervical Esophagus** 89
Elizabeth R. Benjamin and Kenji Inaba

Section 5 Chest

- 14 **General Principles of Chest Trauma Operations** 95
Demetrios Demetriades, Matthew J. Forestiere, and Rondi Gelbard
- 15 **Cardiac Injuries** 104
Demetrios Demetriades, Zachary D. Warriner, and Scott Zakaluzny
- 16 **Thoracic Vessels** 118
Demetrios Demetriades, Vincent Chong, and Stephen Varga
- 17 **Lungs** 130
Demetrios Demetriades and Jennifer A. Smith
- 18 **Thoracic Esophagus** 142
Anthony W. Kim and Caroline Park
- 19 **Diaphragm** 150
Lydia Lam and Caroline Park
- 20 **Surgical Fixation of Rib Fractures** 156
Travis M. Polk and Paul Wisniewski
- 21 **Video-Assisted Thoracoscopic Evacuation of Retained Hemothorax** 164
Aaron Strumwasser and Matthew J. Forestiere

Section 6 Abdomen

- 22 **General Principles of Abdominal Operations for Trauma** 171
Damon Clark, Zachary D. Warriner, and Lisa L. Schlitzkus
- 23 **Damage Control Surgery** 184
Mark J. Kaplan and Demetrios Demetriades
- 24 **Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)** 193
Elizabeth R. Benjamin and Kazuhide Matsushima
- 25 **Gastrointestinal Tract** 202
Morgan Schellenberg, Lisa L. Schlitzkus, and Kenji Inaba
- 26 **Duodenum** 211
Elizabeth R. Benjamin, Edward Kwon, and Demetrios Demetriades
- 27 **Liver and Biliary Tract Injuries** 220
Kenji Inaba, Zachary D. Warriner, and Kelly Vogt
- 28 **Splenic Injuries** 234
Demetrios Demetriades and Matthew D. Tadlock
- 29 **Pancreas** 244
Demetrios Demetriades, Emilie Joos, and George C. Velmahos
- 30 **Urological Trauma** 253
Leo R. Doumanian, Charles D. Best, Jessica A. Keeley, and Stephen Varga
- 31 **Abdominal Aorta and Splachnic Vessels** 268
Pedro G. Teixeira, Gregory A. Magee, and Vincent L. Rowe
- 32 **Iliac Vessel Injuries** 286
Demetrios Demetriades and Kelly Vogt
- 33 **Inferior Vena Cava** 291
Lydia Lam, Matthew D. Tadlock, and Demetrios Demetriades
- 34 **Cesarean Section** 311
Marcia Ciccone, Sigita Cahoon, and Laila I. Muderspach
- 35 **Emergency Hysterectomy** 321
Marcia Ciccone, Laila I. Muderspach, and Sigita Cahoon

Section 7 Pelvic Fractures and Bleeding

- 36 **Damage Control for Pelvic Fracture Bleeding** 335
Kazuhide Matsushima, Bryan Love, and Mathew D. Tadlock

Section 8 Upper Extremities

- 37 **Brachial Artery Injury** 343
Peep Talving and Elizabeth R. Benjamin
- 38 **Upper Extremity Fasciotomies** 354
Demetrios Demetriades
- 39 **Upper Extremity Amputations** 364
Peep Talving and Jackson Lee

Section 9 Lower Extremities

- 40 **Femoral Artery Injuries** 373
George C. Velmahos, Matthew J. Forestiere, and Rondi Gelbard
- 41 **Popliteal Vessels** 378
Demetrios Demetriades and Gregory A. Magee
- 42 **Harvesting of Saphenous Vein** 385
Aaron Strumwasser and Gregory A. Magee
- 43 **Lower Extremity Amputations** 390
Jackson Lee, Jessica A. Keeley, and Stephen Varga
- 44 **Lower Extremity Fasciotomies** 400
Elizabeth R. Benjamin and James Bardes

Section 10 Orthopedic Damage Control

- 45 **Orthopedic Damage Control** 413
Eric Pagenkopf, Daniel Grabo, and Peter M. Hammer

Section 11 Soft Tissues

- 46 **Skin Graft Technique** 427
Justin Gillenwater and Warren Garner
- 47 **Negative Pressure Therapy for Soft Tissue Wounds** 434
Elizabeth R. Benjamin and Demetrios Demetriades
- 48 **Escharotomy in Burns** 439
Justin Gillenwater and Warren Garner
- 49 **Temporary Vascular Shunts** 446
Morgan Schellenberg, Travis M. Polk, and Paul Wisniewski

Index 450

Contributors

James Bardes, MD

Trauma Fellow and Instructor in Surgery, University of Southern California; Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Elizabeth R. Benjamin, MD, PhD, FACS

Associate Professor of Clinical Surgery, Division of Trauma, Emergency Surgery, and Surgical Critical Care, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Charles D. Best, MD, FACS

Associate Professor of Urology and Surgery, University of Southern California; Chief of Surgery, Grays Harbor Community Hospital, Aberdeen, WA, USA

Sigita Cahoon, MD, MPH, FACOG

Assistant Professor of Clinical Obstetrics and Gynecology, University of Southern California; Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Vincent Chong, MD, MS

Trauma and Critical Care Fellow, Division of Trauma, Emergency Surgery, and Surgical Critical Care, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Marcia Ciccone, MD

Assistant Professor of Clinical Obstetrics and Gynecology, University of Southern California; Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Damon Clark, MD

Assistant Professor of Surgery, University of Southern California; Department of Trauma, Emergency Surgery, and Surgical Intensive Care, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Demetrios Demetriades, MD, PhD, FACS

Professor of Surgery, University of Southern California; Director of Trauma, Emergency Surgery, and Surgical Intensive Care Unit, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Leo R. Doumanian, MD

Associate Professor of Clinical Urology, Keck School of Medicine of USC, USC Institute of Urology, Los Angeles, CA, USA

Matthew J. Forestiere, MD

Trauma Fellow and Clinical Instructor in Surgery, Division of Trauma, Emergency Surgery, and Surgical Critical Care, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Warren Garner, MD, MS, FACS

Director LAC+USC Burn Center; Professor of Surgery, University of Southern California, Los Angeles, CA, USA

Rondi Gelbard, MD, FACS

Assistant Professor of Surgery, Emory University School of Medicine; Associate Medical Director, Surgical Intensive Care Unit; Associate Program Director, Surgical Critical Care Fellowship; Emory Department of Surgery at Grady Memorial Hospital, Atlanta, GA, USA

Justin Gillenwater, MD, MS

Assistant Professor, Plastic and Reconstructive Surgery, University of Southern California; Co-Director, LAC+USC Regional Burn Center, Los Angeles, CA, USA

Daniel Grabo, MD, FACS

Associate Professor of Surgery, West Virginia University, Morgantown, WV, USA

Peter Gruen, MD

Associate Professor of Neurosurgery, University of Southern California; Associate Medical Director, Critical Care, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Peter M. Hammer, MD, FACS

Assistant Professor of Surgery, Indiana University School of Medicine; Associate Trauma Medical Director, Indiana University Health Methodist Hospital, Indianapolis, IN, USA

Kenji Inaba, MD

Professor of Surgery, University of Southern California; Vice Chair and Residency Director, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Emilie Joos, MD, FRCSC, FACS

Clinical Assistant Professor, Trauma and Acute Care Surgery Fellowship Program Director, Department of Surgery, University of British Columbia, Vancouver, BC, Canada

Mark J. Kaplan, MD, FACS

Clinical Professor of Surgery, Kimmel School Medicine, Thomas Jefferson University; Associate Chairman Surgery, Einstein Medical Center Philadelphia; Chairman, Division of Trauma, Surgical Critical Care, and Acute Care Surgery, Einstein Medical Center, Philadelphia, PA, USA

Jessica A. Keeley, MD

Trauma Fellow, Division of Trauma, Emergency Surgery, and Surgical Critical Care, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Anthony W. Kim, MD, MS, FACS

Jeffrey P. Smith Endowed Chair in Surgery, Professor of Clinical Surgery, Chief, Division of Thoracic Surgery, Keck School of Medicine, The University of Southern California, Los Angeles, CA, USA

Edward Kwon, MD, FACS

Trauma Surgery and Surgical Critical Care, St. Francis Medical Center, Lynwood, CA, USA

Lydia Lam, MD, FACS

Assistant Professor of Clinical Surgery and Emergency Medicine, Associate Program Director, Surgical Critical Care Fellowship, LAC+USC Medical Center, Los Angeles, CA, USA

Jackson Lee, MD

Associate Professor of Clinical Orthopedics, Keck School of Medicine of University of Southern California; Service Chief, Orthopedics, LAC+USC Medical Center, Los Angeles, CA, USA

Meghan Lewis, MD, FACS

Assistant Professor of Surgery, University of Southern California; Associate Director, Surgical Intensive Care Unit, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Bryan Love, MD

Trauma Fellow and Clinical Instructor, Division of Trauma, Emergency Surgery, and Surgical Critical Care, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Gregory A. Magee, MD, MSc

Assistant Professor of Surgery, Division of Vascular Surgery and Endovascular Therapy, Keck Medical Center, University of Southern California, Los Angeles, CA, USA

Kazuhide Matsushima, MD, FACS

Assistant Professor of Clinical Surgery, University of Southern California; Division of Acute Care Surgery, LAC+USC Medical Center, Los Angeles, CA, USA

Brian Mecklenburg, MD

Anesthesiologist/Intensivist, Commander US Navy; Instructor, Navy Trauma Training Center, USA

Laila I. Muderspach, MD

Professor, Department of Obstetrics and Gynecology, Keck School of Medicine of University of Southern California, Los Angeles, CA, USA

Nick A. Nash, MD, FACS

Associate Professor of Surgery, Director of Surgical Critical Care, University of Louisville, Louisville, KY, USA

Eric Pagenkopf, MD

Captain (Retired), US Navy, USA

Caroline Park, MD

Trauma and Critical Care Fellow, Division of Trauma, Emergency Surgery, and Surgical Critical Care, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Travis M. Polk, MD, FACS

Assistant Professor of Clinical Surgery, Division of Trauma, Emergency Surgery and Surgical Critical Care, University of Southern California; Director, Navy Trauma Training Center, LAC+USC Medical Center; Commander, US Navy, Los Angeles, CA, USA

Vincent L. Rowe, MD, FACS

Professor of Surgery, Division of Vascular Surgery and Endovascular Therapy, Keck School of Medicine of University of Southern California, Los Angeles, CA, USA

Morgan Schellenberg, MD, MPH, FRCS

Assistant Professor of Surgery, University of Southern California; Division of Trauma and Surgical Critical Care, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Lisa L. Schlitzkus, MD, FACS

Assistant Professor of Surgery, University of Nebraska Medical Center; Trauma Medical Director, Nebraska Medicine, Omaha, NE, USA

Jennifer A. Smith, MD, FACS

Assistant Professor of Surgery, David Geffen School of Medicine at UCLA; Associate Chief of Trauma, Acute Care Surgery, and Surgical Critical Care, Harbor-UCLA Medical Center, Los Angeles, CA, USA

Aaron Strumwasser, MD, MSc, FACS

Assistant Professor of Clinical Surgery, Division of Trauma, Acute Care Surgery, and Surgical Critical Care, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Matthew D. Tadlock, MD, FACS

Assistant Professor of Surgery, Uniformed Services University of the Health Sciences; Head, Acute Care Surgery, Department of Surgery, Naval Medical Center San Diego, San Diego, CA, USA; Commander, Medical Corps, US Navy, USA

Peep Talving, MD, PhD, FACS

Professor of Surgery, University of Tartu; Director, Acute Care Surgery, North Estonia Medical Center, Tallinn, Estonia

Pedro G. Teixeira, MD, FACS, FSVS

Associate Professor of Surgery, Department of Surgery and Perioperative Care, Dell Medical School, University of Texas at Austin, Austin, TX, USA

Stephen Varga, MD, FACS

Assistant Professor of Surgery, University of Maryland; Director of Physician Education, R Adams Cowley Shock Trauma Center, University of Maryland Medical Center, Baltimore, MD, USA

George C. Velmahos, MD, PhD, MEd

John F. Burke Professor of Surgery, Harvard Medical School; Chief of Trauma, Emergency Surgery, and Surgical Critical Care, Massachusetts General Hospital, Boston, MA, USA

Kelly Vogt, MD, MSc, FRCS

Assistant Professor of Surgery, Western University; Associate Medical Director – Trauma Program, London Health Sciences Centre, London, ON, Canada

Zachary D. Warriner, MD

Trauma Fellow and Clinical Instructor in Surgery, Division of Trauma, Emergency Surgery, and Surgical Critical Care, Los Angeles County and University of Southern California Medical Center, Los Angeles, CA, USA

Paul Wisniewski, MD

Assistant Professor of Clinical Surgery, Division of Trauma, Emergency Surgery, and Surgical Critical Care, University of Southern California; Commander, US Navy, Los Angeles, CA, USA

Gabriel Zada, MD, MS, FAANS, FACS

Associate Professor of Neurosurgery, University of Southern California, Los Angeles, CA, USA

Foreword

Many books come and go; anatomy books have existed since the sixteenth century and have been the basis of expert surgical exploration during surgical disease management. A surgeon's knowledge of anatomy in trauma is based on the need to expose a wide variety of areas of the body that are often not learned through traditional dissection or elective surgery. The path of a bullet or the extreme energy transfer during blunt trauma can cause damage to structures that require exposures not normally encountered. The decision making in picking the right incision, understanding the anatomic relationships that can be exposed, and knowing the moves to get to a critical area of injury are often times what determines success or failure (even life or death), particularly when the patient is bleeding.

The current second edition of the book *Atlas of Surgical Techniques in Trauma* by Demetriades, Inaba, and Velmahos fills a void that has existed for several decades. The current atlas approaches trauma from the standpoint of the possible exposures and relevant anatomy that are needed when encountering a specific anatomic injury.

For each area, the surgical anatomy is reviewed in classic terms, but augmented with cadaveric vascular injections showing the anatomic structures with very clear photographs complementing traditional anatomic drawings. The relevant points of anatomy in the context of a clinical injury or during exposure are emphasized. The general principles of what can be done to manage an injury are included: the appropriate incision, a step-wise approach during exposure emphasizing anatomy, which structures might be injured, which structures

might be divided or ligated, and any specific goals of the operation.

A student using this book should be able to mentally rehearse and in fact visualize many of the structures that they may not have previously encountered. When accompanied by participation in cadaveric dissections, this should prepare the surgeon to encounter injuries which they may see infrequently. Dr. Demetriades and his co-authors have anticipated how important this challenge is to a trauma surgeon and have presented this knowledge in a wonderful text, which will serve many generations in the future.

The award-winning first version was translated into many languages, having a major impact around the world. I have no question that this version will be even more widely received. At a time when medical education is increasingly about efficiency, (with less time spent on classic subjects like anatomy) the need for understanding clinically relevant anatomy has never been greater.

This is truly a book that every surgeon who will ever encounter these kinds of clinical challenges should use. Own a copy and commit these wonderful photographs and principles to memory. You will find yourself well prepared when encountering these kinds of injuries. Your patients will benefit from this essential knowledge.

David B. Hoyt, MD, FACS
Executive Director, American College of Surgeons

Preface

The second edition of the *Atlas of Surgical Techniques in Trauma* provides a practical companion in the operating room to the surgeons who provide care to the injured. It is designed to be a rapid, highly visual summary of the critical anatomy, procedural sequencing, and pitfalls associated with these procedures. We believe that it will be a good companion for trainees as well as those in practice and in the military, as a rapid review of both common and uncommonly performed procedures.

The atlas is organized into chapters and sections according to anatomical areas. The text is written in a bulleted, reader-friendly format, and includes practical surgical anatomy, general principles, exposures, definitive management and technical tips, and pitfalls. It includes more than 900 high-quality photographs and illustrations, produced while performing

these procedures on fresh, perfused, and ventilated human cadavers at the USC Fresh Tissue Dissection Lab. The surgical techniques are shown step by step and with visual details that inform the reader accurately about the critical elements of each procedure.

Whereas these operations represent broadly applied standards of care, many specific details reflect the philosophy of the editors and the authors, all of whom bring their individual, extensive, real-world clinical experience to each chapter. It is, therefore, possible that different ways exist to access and control injured structures. However, the ways described here are tested and proven successful. As such, they belong to every surgeon's armamentarium, when one is called to save the life of an injured patient in need of an operation.