

INTERNATIONAL EDITION

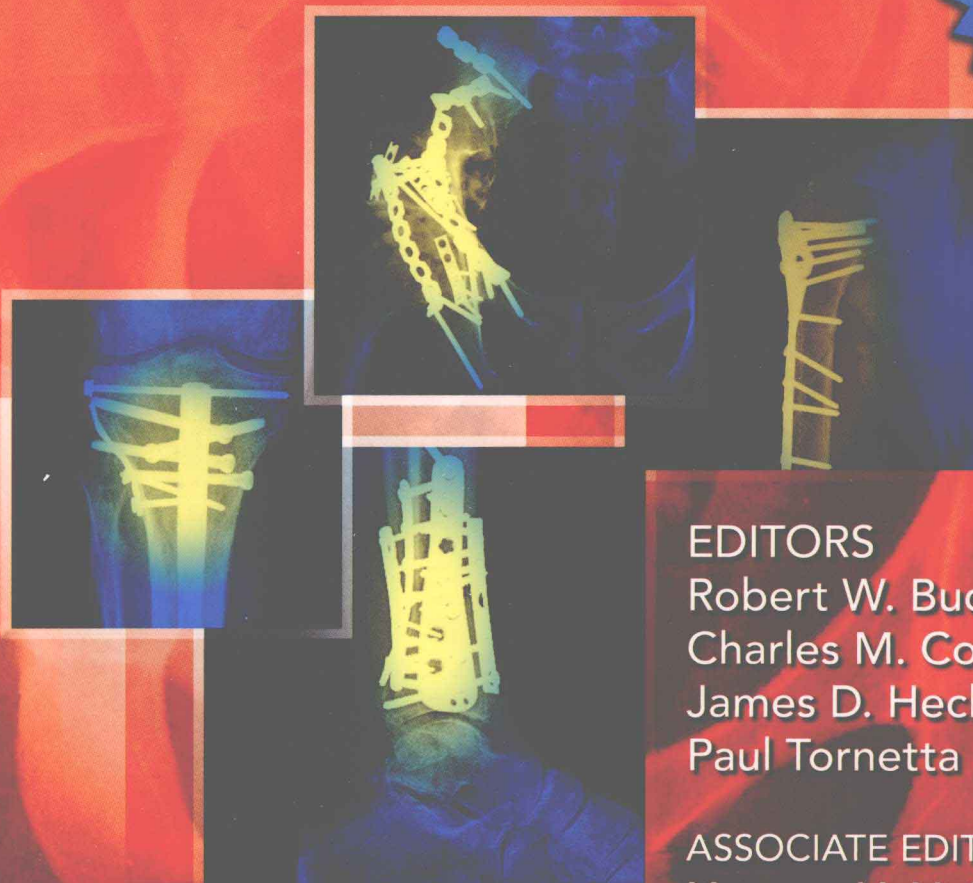
Not authorised for sale in North America and the Caribbean

VOLUME TWO

ROCKWOOD AND GREEN'S  
FRACTURES  
IN ADULTS

SEVENTH EDITION

Includes  
online access  
to the fully  
searchable text,  
image bank,  
and videos!



EDITORS

Robert W. Bucholz  
Charles M. Court-Brown  
James D. Heckman  
Paul Tornetta III

ASSOCIATE EDITORS

Margaret M. McQueen  
William M. Ricci



Wolters Kluwer | Lippincott Williams & Wilkins  
Health



# ROCKWOOD AND GREEN'S FRACTURES IN ADULTS

## VOLUME 2

### SEVENTH EDITION

#### EDITORS

**Robert W. Bucholz, MD**

Professor

Department of Orthopaedic Surgery

The University of Texas Southwestern Medical Center

Dallas, Texas

**James D. Heckman, MD**

Editor-in-Chief

The Journal of Bone and Joint Surgery

Needham, Massachusetts

Clinical Professor of Orthopaedic Surgery

Harvard Medical School

Visiting Orthopaedic Surgeon

Department of Orthopaedic Surgery

Massachusetts General Hospital

Boston, Massachusetts

#### ASSOCIATE EDITORS

**Margaret M. McQueen, MD, FRCS Ed  
(Orth)**

Consultant Orthopaedic Trauma Surgeon

Royal Infirmary of Edinburgh

Edinburgh, United Kingdom

**William M. Ricci, MD**

Associate Professor

Chief, Orthopaedic Trauma Service

Department of Orthopaedic Surgery

Washington University School of Medicine

St. Louis, Missouri

**Charles M. Court-Brown, MD, FRCS Ed  
(Orth)**

Professor of Orthopaedic Trauma

Royal Infirmary of Edinburgh

Edinburgh, United Kingdom

**Paul Tornetta, III, MD**

Professor and Vice Chairman

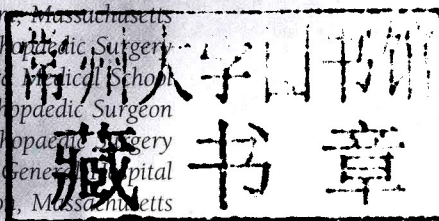
Department of Orthopaedic Surgery

Boston University Medical Center

Director of Orthopaedic Trauma

Boston University Medical Center

Boston, Massachusetts



Wolters Kluwer | Lippincott Williams & Wilkins

Health

Philadelphia • Baltimore • New York • London  
Buenos Aires • Hong Kong • Sydney • Tokyo

Acquisitions Editor: Robert Hurley  
Product Manager: Dave Murphy  
Senior Manufacturing Manager: Benjamin Rivera  
Marketing Manager: Lisa Lawrence  
Design Coordinator: Doug Smock  
Production Service: Absolute Service/Maryland Composition

© 2010 by LIPPINCOTT WILLIAMS & WILKINS, a WOLTERS KLUWER business  
530 Walnut Street  
Philadelphia, PA 19106 USA  
LWW.com

All rights reserved. This book is protected by copyright. No part of this book may be reproduced in any form by any means, including photocopying, or utilized by any information storage and retrieval system without written permission from the copyright owner, except for brief quotations embodied in critical articles and reviews. Materials appearing in this book prepared by individuals as part of their official duties as U.S. government employees are not covered by the above-mentioned copyright.

*Printed in China*

Not authorised for Sale in North America or the Caribbean  
CIP data available upon request

ISBN-13: 9781609130169  
ISBN-10: 1609130162

Care has been taken to confirm the accuracy of the information presented and to describe generally accepted practices. However, the authors, editors, and publisher are not responsible for errors or omissions or for any consequences from application of the information in this book and make no warranty, expressed or implied, with respect to the currency, completeness, or accuracy of the contents of the publication. Application of the information in a particular situation remains the professional responsibility of the practitioner.

The authors, editors, and publisher have exerted every effort to ensure that drug selection and dosage set forth in this text are in accordance with current recommendations and practice at the time of publication. However, in view of ongoing research, changes in government regulations, and the constant flow of information relating to drug therapy and drug reactions, the reader is urged to check the package insert for each drug for any change in indications and dosage and for added warnings and precautions. This is particularly important when the recommended agent is a new or infrequently employed drug.

Some drugs and medical devices presented in the publication have Food and Drug Administration (FDA) clearance for limited use in restricted research settings. It is the responsibility of the health care provider to ascertain the FDA status of each drug or device planned for use in their clinical practice.

To purchase additional copies of this book, call our customer service department at (800) 638-3030 or fax orders to (301) 223-2320. International customers should call (301) 223-2300.

Visit Lippincott Williams & Wilkins on the Internet: at LWW.com. Lippincott Williams & Wilkins customer service representatives are available from 8:30 am to 6 pm, EST.

10 9 8 7 6 5 4 3 2 1

We dedicate this Seventh Edition of *Rockwood and Green's Fractures in Adults* to Charles A. Rockwood, Jr, MD, and David P. Green, MD, who served as our inspiration and mentors for carrying on the revision and update of this textbook.

To Marybeth for her unwavering support over the years.

RWB

To Susan for her encouragement and understanding.

JDH

To my family for their help and support.

CCB

To my mother, Phyllis, who found the best in people, had compassion for all, and whose insight, guidance, and love have always made me believe that anything is possible.

PT3



# CONTRIBUTING AUTHORS

**Stuart A. Aitken, MRCS, Ed** Registrar in Orthopaedic and Traumatology, Royal Infirmary of Edinburgh, Edinburgh, United Kingdom

**George S. Athwal, MD FRCS** Assistant Professor of Orthopaedic Surgery, University of Western Ontario, Consultant, Hands and Upper Limbs Centre, St. Joseph's Health Care, London, Ontario, Canada

**Roger M. Atkins, MA DM, FRCS** Professor of Orthopaedic Surgery, British Royal Infirmary, Bristol, England

**T. William Axelrad, MD, PhD** Chief Resident of Orthopaedics, Boston University, Boston, Massachusetts

**David P. Barei, MD** Associate Professor of Orthopaedics and Sports Medicine, University of Washington, Attending Surgeon, Department of Orthopaedics and Sports Medicine, Harborview Medical Center, Seattle, Washington

**Asheesh Bedi, MD** Assistant Professor of Sports Medicine and Shoulder Surgery, University of Michigan and University of Michigan Hospitals, Ann Arbor, Michigan

**Mohit Bhandari, MD, MSc, FRCS** Associate Professor and Canada Research Chair, Division of Orthopaedic Surgery, McMaster University, Consultant Surgeon, Hamilton Health Sciences-General Hospital, Hamilton, Ontario, Canada

**Brett R. Bolhofner, MD** Assistant Clinical Professor of Orthopaedic Surgery, University of South Florida, Director of Orthopaedic Trauma Service, Bayfront Medical Center, St. Petersburg, Florida

**Christopher M. Bono, MD** Assistant Professor of Orthopaedic Surgery, Harvard Medical School, Chief of Orthopaedic Spine Service, Department of Orthopaedic Surgery, Brigham and Women's Hospital, Boston, Massachusetts

**Michael J. Bosse, MD** Department of Orthopaedic Surgery, Carolinas Medical Center, Charlotte, North Carolina

**Mark R. Brinker, MD** Clinical Professor of Orthopaedic Surgery, Baylor College of Medicine, Director of Acute and Reconstructive Trauma, Center for Problem Fractures and Limb Restoration, Texas Orthopaedic Hospital, Houston, Texas

**Joseph A. Buckwalter, MS, MD** Arthur Steindler Chair and Head of Orthopaedic Surgery, Department of Orthopaedics and Rehabilitation, University of Iowa, Iowa City, Iowa

**Lisa K. Cannada, MD** Associate Professor of Orthopaedics, Saint Louis University, Orthopaedic Traumatologist, Saint Louis University Hospital, St. Louis, Missouri

**Edward Carreras, MD** Boston University School of Medicine, Boston, Massachusetts

**Shew-Ping Chow, FRCS, FHKAM** Chair Professor, Department of Orthopaedics and Traumatology, The University of Hong Kong, Honorary Consultant, Department of Orthopaedics and Traumatology, Queen Mary Hospital, Hong Kong

**Michael P. Clare, MD** Director of Fellowship Education, Foot & Ankle Fellowship, Florida Orthopaedic Institute, Tampa, Florida

**Cory A. Collinge, MD** Director of Orthopaedic Trauma, Harris Methodist Fort Worth Hospital, Fort Worth, Texas

**Roy I. Davidovitch, MD** Assistant Professor of Orthopaedic Surgery, New York University Hospital for Joint Diseases, Chief of Orthopaedic Trauma Service, Jamaica Hospital Medical Center, Jamaica, New York

**Douglas R. Dirschl, MD** Professor and Chairman, Department of Orthopaedics, North Carolina School of Medicine, Chief, Department of Orthopaedics, University of North Carolina Hospitals, Chapel Hill, North Carolina

**Paul J. Dougherty, MD** Residency Program Director, Department of Orthopaedic Surgery, University of Michigan, Residency Program Director, Department of Orthopaedic Surgery, University of Michigan Hospital, Ann Arbor, Michigan

**Robert P. Dunbar, Jr., MD** Assistant Professor of Orthopaedics and Sports Medicine, Harborview Medical Center, University of Washington, Seattle, Washington

**Anil K. Dutta, MD** Department of Orthopaedics, University of Texas Health Science Center, San Antonio, Texas

**John S. Early, MD** Clinical Professor of Orthopaedic Surgery, University of Texas Southwestern Medical Center, Attending, Department of Orthopaedics, Texas Health Dallas, Dallas, Texas

**Kenneth A. Egol, MD** Professor and Vice Chairman of Orthopaedic Surgery, Chief of Division of Trauma Service, New York University Hospital for Joint Diseases, New York, New York

**Thomas A. Einhorn, MD** Professor and Chairman of Orthopaedic Surgery, Boston University School of Medicine, Chief of Orthopaedic Surgery, Boston Medical Center, Boston, Massachusetts

**William J. J. Ertl, MD** Assistant Professor, Department of Orthopaedics and Rehabilitation, University of Oklahoma College of Medicine, Oklahoma City, Oklahoma

**Gregory C. Fanelli, MD** Geisinger Health System Sports Medicine and Orthopaedic Surgery, Danville, Pennsylvania

**Daren Forward, MA, FRCS, DM** Trauma Fellow, R Adams Cowley Shock Trauma Center, University of Maryland School of Medicine, Baltimore, Consultant Orthopaedic Trauma Surgeon, Nottingham University Hospital, Nottingham, United Kingdom

**Christian Gaebler, MD, PhD** Sports Trauma Surgeon, Private Practice, Vienna, Austria

**Leesa M. Galatz, MD** Associate Professor of Shoulder and Elbow Service, Department of Orthopaedic Surgery, Washington University, Barnes-Jewish Hospital, St. Louis, Missouri

**Michael J. Gardner, MD** Assistant Professor of Orthopaedic Surgery, Washington University School of Medicine, Attending Surgeon, Department of Orthopaedic Trauma Service, Barnes-Jewish Hospital, St. Louis, Missouri

**Peter V. Giannoudis, MD, FRCS, EEC (Orth)** Professor of Trauma and Orthopaedic Surgery, University of Leeds, St. James University Hospital, Leeds, United Kingdom

**Larry Gulotta, MD** Sports Medicine/Shoulder Service Fellow, Department of Orthopaedic Surgery, Hospital for Special Surgery, New York, New York

**George J. Haidukewych, MD** Professor of Orthopaedic Surgery, University of Central Florida, Co-Director of Orthopaedic Trauma, Chief of Complex Adult Reconstruction, Orlando Health, Orlando, Florida

**Mark H. Henry, MD** Hand and Wrist Center of Houston, Houston, Texas

**Ronald F. Hollis, Jr., MD** Department of Orthopaedic Surgery, Washington University School of Medicine, St. Louis, Missouri

**Per Olof Josefsson, MD, PhD** Associate Professor of Clinical Sciences, Lund University, Senior Consultant and Head of Traumatology, Department of Orthopaedic Surgery, Malmö University Hospital, Malmö, Sweden

**Leo Joskowicz, PhD** Professor and Director, Computer Aided Surgery and Medical Image Processing Laboratory, School of Engineering and Computer Science, The Hebrew University of Jerusalem, Jerusalem, Israel

**Michael S.H. Kain, MD** Department of Orthopaedic Surgery, Boston University, Orthopaedic Surgeon, Lahey Clinic, Burlington, Massachusetts

**Sanjeev Kakar, MD, MRCS, MBA** Hand and Upper Extremity Fellow, Mayo Clinic, Rochester, Minnesota

**Kerry M. Kallas, MD** Musculoskeletal Radiologist, Center of Diagnostic Imaging, Sartell, Minnesota

**Magnus K. Karlsson, MD, PhD** Professor, Clinical and Molecular Osteoporosis Research Unit, Department of Clinical Sciences, Lund University, Senior Consultant and Professor, Department of Orthopaedic Surgery, Malmö University Hospital, Malmö, Sweden

**Madhav A. Karunakar, MD** Orthopaedic Traumatologist, Department of Orthopaedic Surgery, Carolinas Medical Center, Charlotte, North Carolina

**John Keating, FRCS, Ed (Orth)** Consultant Orthopaedic Surgeon, Royal Infirmary of Edinburgh, Edinburgh, United Kingdom

**Kevin J. Kulwicksi, MD** Shoulder and Elbow Surgery Fellow, Department of Orthopaedic Surgery, New York University Hospital for Joint Diseases, Staff Orthopaedic Surgeon, Columbia-Saint Mary's Hospital, Ozaukee Campus, Mequon, Wisconsin

**Young W. Kwon, MD, PhD** Assistant Professor of Orthopaedic Surgery, New York University School of Medicine, Shoulder and Elbow Service, Department of Orthopaedic Surgery, Hospital for Joint Disease, New York University, New York, New York



**Joseph Lane, MD** Attending Orthopaedic Surgeon, Hospital for Special Surgery, Professor of Orthopaedic Surgery, Weill Cornell Medical College, New York, New York

**Joshua Langford, MD** Instructor of Orthopaedic Surgery, University of Central Florida College of Medicine, Attending Orthopaedic Traumatologist, Orlando Health Orthopaedic Residency Program, Orlando Regional Medical Center, Orlando, Florida

**Sune Larsson, MD** Professor of Orthopaedics, Uppsala University, Director of Research, Uppsala University Hospital, Uppsala, Sweden

**Frankie Leung, FRCS, FHKAM** Clinical Associate Professor of Orthopaedics and Traumatology, The University of Hong Kong, Chief of Division of Orthopaedic Trauma, Department of Orthopaedics and Traumatology, Queen Mary Hospital, Hong Kong

**Meir Liebergall, MD** Professor of Orthopaedic Surgery, Hebrew University, Chairman, Department of Orthopaedic Surgery, The Hadassah-Hebrew University Medical Center, Jerusalem, Israel

**Ellen J. MacKenzie, PhD** Center for Injury Research and Health Policy, Johns Hopkins University Bloomberg School of Hygiene and Public Health, Baltimore, Maryland

**Samir Mardini, MD** Associate Professor of Surgery, Department of Plastic Surgery, Mayo Clinic, Rochester, Minnesota

**J. L. Marsh, MD** **Carroll B. Larson** Professor of Orthopaedics and Rehabilitation, University of Iowa Hospitals and Clinics, Iowa City, Iowa

**Michael D. McKee, MD, FRCS(C)** Professor, Upper Extremity Reconstructive Service, Division of Orthopaedics, Department of Surgery, St. Michael's Hospital and the University of Toronto, Toronto, Canada

**Sohail K. Mirza, MD, MPH** Professor of Orthopaedics, Dartmouth Medical School, Attending Surgeon and Vice Chair of Orthopaedics, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire

**Berton R. Moed, MD** Professor and Chairman, Department of Orthopaedic Surgery, Saint Louis University School of Medicine, Chief of Orthopaedic Surgery, Saint Louis University Hospital, St. Louis, Missouri

**Eric S. Moghadamian, MD** Assistant Professor, Department of Orthopaedic Surgery, University of Kentucky, Lexington, Kentucky

**Steven L. Moran, MD** Associate Professor of Orthopaedics and Division of Plastic Surgery, Mayo Clinic, Rochester, Minnesota

**Rami Mosheiff, MD** Associate Professor of Orthopaedic Surgery, Hebrew University, Head of Orthopaedic Trauma Center, The Hadassah-Hebrew University Medical Center, Jerusalem, Israel

**Soheil Najibi, MD, PhD** Senior Staff Orthopaedic Surgeon, Henry Ford Hospital, Detroit, Michigan

**Sean E. Nork, MD** Associate Professor of Orthopaedic Surgery, Harborview Medical Center at the University of Washington, Seattle, Washington

**Daniel P. O'Connor, PhD** Assistant Professor, Laboratory of Integrated Physiology, University of Houston, Joe W. King Orthopaedic Institute, Texas University Hospital, Houston, Texas

**Robert V. O'Toole III, MD** Associate Professor, R Adams Cowley Shock Trauma Center, University of Maryland School of Medicine, Baltimore

**Christina V. Oleson, MD** Assistant Professor of Orthopaedics, Section of Physical Medicine and Rehabilitation, Dartmouth Medical School and Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire

**Hans Christoph Pape, MD** W Pauwels Professor and Chairman, Department of Orthopaedics and Trauma, University of Aachen Medical Centre, Aachen, Germany

**Brad A. Petrisor, MSc, MD, FRCSC** Assistant Professor, McMaster University, Consultant Orthopaedic Surgeon, Hamilton Health-Sciences General Hospital, Hamilton, Ontario, Canada

**Anil S. Ranawat, MD** Assistant Attending Orthopaedic Surgeon Hospital for Special Surgery, Instructor in Orthopaedic Surgery, Weill Cornell Medical College, New York, New York

**Nalini Rao, MD** Clinical Professor of Medicine and Orthopaedic Surgery, University of Pittsburgh School of Medicine, Chief, Division of Infectious Disease, UPMC Shadyside Hospital Pittsburgh, Pennsylvania

**James J. Reid, MD** Private practice Los Angeles, California

**Mark C. Reilly, MD** Associate Professor, Co-Chief of Orthopaedic Trauma Service, Department of Orthopaedics, New Jersey Medical School, Newark, New Jersey

**David Ring, MD, PhD** Associate Professor of Orthopaedic Surgery, Harvard Medical School, Director of Research, Orthopaedic Hand and Upper Extremity Service, Massachusetts General Hospital, Boston, Massachusetts

**C. Michael Robinson, BMed Sci, FRCS, Ed (Orth)** Honorary Senior Lecturer, Department of Orthopaedic and Trauma Surgery, University of Edinburgh, Consultant Orthopaedic Trauma Surgeon, Orthopaedic Trauma Unit, Royal Infirmary of Edinburgh, Edinburgh, United Kingdom

**Charles A. Rockwood, Jr., MD** Professor and Chairman Emeritus of Orthopaedics, University of Texas Health Science Center, San Antonio, Texas

**David S. Ruch, MD** Professor, Director of Orthopaedic Hand Surgery, Duke University Medical Center, Durham, North Carolina

**Thomas P. Rüedi, MD, FACS** Professor Dr med, FACS Founding Member of the AO Foundation, Davos, Switzerland

**Thomas A. Russell, MD** Professor, Campbell Clinic Department of Orthopaedics, University of Tennessee, Staff Surgeon, Department of Orthopaedic Surgery, Elvis Presley Trauma Center, Memphis, Tennessee

**Claude Sagi, MD** Associate Clinical Professor of Orthopaedic Surgery, University of South Florida, Fellowship Director, Department of Orthopaedic Trauma Service, Tampa General Hospital, Tampa, Florida

**Christopher J. Salgado, MD** Assistant Professor of Surgery, Division of Plastic Surgery Cooper University Hospital, Camden, New Jersey

**David W. Sanders, MD, MSc, FRCS** Associate Professor of Orthopaedic Surgery, University of Western Ontario, Orthopaedic Surgeon, Victoria Hospital, London, Ontario, Canada

**Roy W. Sanders, MD** Clinical Professor of Orthopaedic Surgery, University of South Florida, Chief of Orthopaedic Surgery, Tampa General Hospital, Tampa, Florida

**Emil Schemitsch, MD, FRCS (C)** Professor of Surgery, University of Toronto, Head of Division of Orthopaedic Surgery, St. Michael's Hospital, Toronto, Ontario, Canada

**Robert C. Schenk, Jr., MD** Professor and Chair of Department of Orthopaedics, University of New Mexico School of Medicine, University of New Mexico Lobos Team Physician, Department of Sports Medicine, University of New Mexico Hospitals, Albuquerque, New Mexico

**Andrew H. Schmidt, MD** Professor of Orthopaedic Surgery, University of Minnesota, Faculty, Department of Orthopaedic Surgery, Hennepin County Medical Center, Minneapolis, Minnesota

**Michael A. Schütz, MD, PhD, FRACS, FAOrthA** Chair of Trauma, Faculty of Built Environment and Engineering, Queensland University of Technology, Director of Trauma and Orthopaedics, Princess Alexandra Hospital, Brisbane, Queensland, Australia

**Alexander Y. Shin, MD** Professor of Orthopaedic Surgery, Mayo Clinic, Consultant, Department of Orthopaedic Surgery, Mayo Clinic, Rochester, Minnesota

**Nathan E. Simmons, MD** Associate Professor of Neurosurgery, Dartmouth Medical School and Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire

**Wade Smith, MD** Director of Orthopaedic Trauma, Department of Orthopaedic Surgery, Geisinger Medical Center, Danville, Pennsylvania

**James P. Stannard, MD** Professor and Chairman, J. Vernon Luck Distinguished Professor, Department of Orthopaedic Surgery, University of Missouri, Columbia, Missouri

**David C. Teague, MD** Professor and Don H. O'Donoghue Chair, Department of Orthopaedic Surgery and Rehabilitation, University of Oklahoma Health Science Center, Chief of Department of Orthopaedics, OU Medical Center, Oklahoma City, Oklahoma

**Allan F. Tencer, PhD** Professor of Orthopaedics and Sports Medicine, University of Washington, Professor, Orthopaedic Sciences Laboratory, Harborview Medical Center, Seattle, Washington

**Alexander R. Vaccaro, MD, PhD** Vice-Chairman of Orthopaedics, The Rothman Institute, Professor and Co-Director, Delaware Valley Regional Spine Cord Injury Center, Co-Chief of Spine Surgery and Spine Fellowship Program, Department of Orthopaedics and Neurosurgery, Thomas Jefferson Hospital, Philadelphia, Pennsylvania

**Arthur van Noort, MD, PhD** Department of Orthopaedic Surgery, Spaarne Hospital, Hoofddorp, The Netherlands

**J. Tracy Watson, MD** Professor of Orthopaedic Surgery, St. Louis University School of Medicine, Chief of Division of Orthopaedic Traumatology, Saint Louis University Hospital, St. Louis, Missouri

**Adam Watts, BSc, MBBS, FRCS (Tr and Ortho)** Royal Infirmary of Edinburgh, Edinburgh, United Kingdom

**Kristy L. Weber, MD** Professor of Orthopaedic Surgery and Oncology, Johns Hopkins University, Chief of Division of Orthopaedic Surgery, Johns Hopkins University, Baltimore, Maryland

**Peter G. Whang, MD** Assistant Professor of Orthopaedics and Rehabilitation, Yale University School of Medicine, Attending Physician, Department of Orthopaedics and Rehabilitation, Yale-New Haven Hospital, New Haven, Connecticut

**Tim White, MD, FRCS (Tr and Orth)** Honorary Senior Lecturer, Department of Orthopaedic and Trauma Surgery, University of Edinburgh, Consultant Orthopaedic Trauma Surgeon, Orthopaedic Trauma Unit, Royal Infirmary of Edinburgh, Edinburgh, United Kingdom



**Gerald R. Williams, Jr., MD** Professor of Orthopaedic Surgery, Chief of Shoulder and Elbow Service, The Rothman Institute, Jefferson Medical College, Philadelphia, Pennsylvania

**Michael A. Wirth, MD** Professor and Charles A. Rockwood, Jr., MD Chair of Orthopaedics, University of Texas Health Science Center at San Antonio, Staff, Department of Orthopaedics, University Hospital, San Antonio, Texas

**Donald A. Wiss, MD** Director of Orthopaedic Trauma at Cedars-Sinai Medical Center, Los Angeles, California

**Bruce H. Ziran, MD** Director of Orthopaedic Trauma, Orthopaedic Surgery Residency Program, Atlanta Medical Center, Atlanta, Georgia

**Joseph D. Zuckerman, MD** Walter A.L. Thompson Professor of Orthopaedic Surgery, Department of Orthopaedic Surgery, New York University School of Medicine, Chairman; Surgeon-in-Chief, Department of Orthopaedic Surgery, New York University Hospital for Joint Diseases, New York, New York

# PREFACE

The 7th edition of *Rockwood and Green's Fractures in Adults* continues with the changes that were instituted in the 6th edition. In this edition there are four more chapters and 53 new authors drawn from three continents and ten different countries. Eleven new chapters focus on topics that have not been covered in separate chapters in previous editions of *Rockwood and Green*. To allow us to cope with the advances and changes in Orthopaedic Trauma, Paul Tornetta has become an Editor, and Margaret McQueen from Edinburgh and Bill Ricci from St Louis have been appointed Associate Editors. All three are accomplished orthopaedic trauma surgeons and their complementary interests and areas of expertise have greatly assisted the production of the 7th edition. In addition, many of the new authors represent the next generation of orthopaedic trauma surgeons who will be determining the direction of trauma management over the next two or three decades.

Orthopaedic trauma continues to be an expanding discipline, with change occurring more quickly than is often realized. When Drs. Rockwood and Green published the 1st edition in 1975, there were virtually no orthopaedic trauma specialists in most countries, fractures were usually treated nonoperatively, and mortality following severe trauma was considerable. In one generation the changes in orthopaedic surgery, as in the rest of medicine, have been formidable. We have worked to incorporate these changes in this edition. The continuing importance of wartime and severe civilian injuries is reflected in new chapters on gunshot and wartime injuries, the principles of mangled extremity management, bone and soft tissue reconstruction, and amputation. There is expanded coverage in this edition of the inevitable complications that all orthopaedic surgeons have to deal with, and we have included new chapters that discuss systemic complications, complex regional pain syndrome, infec-

tion, nonunion, and malunion. We have also separated distal tibial fractures into pilon and ankle fractures.

The other area of orthopaedic trauma that is expanding quickly, particularly in the developed countries, is the treatment of osteoporotic (or fragility) fractures. These fractures are assuming a greater medical and political importance, and orthopaedic implants are now being designed specifically to treat elderly patients. It is likely that this trend will continue over the next few decades; many of the chapters in this edition reflect this change in emphasis.

The changes in the 7th edition are highlighted by the altered presentation of the book. Many of the operative pictures and diagrams are now in color, as are all the tables. This edition is strengthened by the inclusion online of 20 new videos of surgical procedures done by Drs. Tornetta, Ricci, and Schmidt. Twelve additional videos will be created in the next year. The user will be able to download clips from these videos for lectures and presentations. We have also made available videos of many surgical approaches useful for trauma procedures. Two features that we have not changed are the Pearls and Pitfalls and the Authors' Preferred Treatment, these features having been present in the last edition. It is perhaps a paradox that we ask our authors to emphasize Level 1 evidence in the form of randomized double blind studies but we promote the authors' preferred methods, which is Level V evidence! However, we continue to believe that it is the function of *Rockwood and Green* to feature the world's leading orthopaedic trauma surgeons and to listen to what they say.

Robert W. Bucholz  
James D. Heckman  
Charles M. Court-Brown  
Paul Tornetta, III



# CONTENTS

Dedication .....	v
Contributing Authors .....	xi
Preface .....	xvii

## VOLUME 1

### SECTION I: GENERAL PRINCIPLES BASICS

1 Biomechanics of Fractures and Fracture Fixation .....	3
<i>Allan F. Tencer</i>	
2 Classification of Fractures .....	39
<i>Douglas R. Dirschl and Lisa K. Cannada</i>	
3 The Epidemiology of Fractures .....	53
<i>Charles M. Court-Brown, Stuart A. Aitken, Daren Forward, and Robert V. O'Toole III</i>	
4 Bone and Joint Healing .....	85
<i>Joseph A. Buckwalter, Thomas A. Einhorn, Lawrence J. Marsh, Larry Gulotta, Anil Ranawat, and Joseph Lane</i>	
5 Biological and Biophysical Technologies for the Enhancement of Fracture Repair .....	104
<i>T. William Axelrad, Sanjeev Kakar, and Thomas A. Einhorn</i>	

### PRINCIPLES OF TREATMENT

6 Principles of Nonoperative Fracture Treatment .....	124
<i>Charles M. Court-Brown</i>	
7 Principles of Internal Fixation .....	162
<i>Michael Schütz and Thomas P. Rüedi</i>	
8 Principles of External Fixation .....	191
<i>J. Tracy Watson</i>	

9 Management of the Multiply Injured Patient .....	244
<i>Peter V. Giannoudis and Hans Christoph Pape</i>	
10 Initial Management of Open Fractures .....	283
<i>Robert P. Dunbar, Jr. and Michael J. Gardner</i>	
11 Gunshot and Wartime Injuries .....	303
<i>Paul J. Dougherty and Soheil Najibi</i>	
12 Principles of Mangled Extremity Management .....	333
<i>Eric S. Moghadamian, Michael J. Bosse, and Ellen J. MacKenzie</i>	
13 Amputations .....	350
<i>William J. J. Ertl</i>	
14 Bone and Soft Tissue Reconstruction .....	362
<i>Christopher J. Salgado, Alexander Y. Shin, Samir Mardini, and Steven L. Moran</i>	
15 Outcome Studies in Trauma .....	409
<i>Mohit Bhandari</i>	
16 Imaging Considerations in Orthopaedic Trauma .....	431
<i>Andrew H. Schmidt and Kerry M. Kallas</i>	
17 Computer-Aided Orthopaedic Surgery in Skeletal Trauma .....	464
<i>Meir Liebergall, Rami Mosheiff, and Leo Joskowicz</i>	

### FRACTURE TYPES

18 Principles of Osteoporosis and Fragility Fractures .....	492
<i>Magnus K. Karlsson and Per Olof Josefsson</i>	

- 19 **Stress Fractures** ..... 518  
*David C. Teague*
- 20 **Pathologic Fractures** ..... 531  
*Kristy L. Weber*
- 21 **Periprosthetic Fractures** ..... 554  
*William M. Ricci and George J. Haidukewych*

## **COMPLICATIONS**

- 22 **Systemic Complications** ..... 590  
*Tim White and Adam Watts*
- 23 **Principles of Complex Regional Pain Syndrome** ..... 602  
*Roger M. Atkins*
- 24 **Orthopaedic Infections and Osteomyelitis** ..... 615  
*Bruce H. Ziran, Wade Smith, and Nalini Rao*
- 25 **Principles of Nonunion Treatment** ..... 641  
*Brett R. Bolhofner and William M. Ricci*
- 26 **Principles of Malunions** ..... 664  
*Mark R. Brinker and Daniel P. O'Connor*
- 27 **Acute Compartment Syndrome** ..... 689  
*Margaret M. McQueen*

## **SECTION II: UPPER EXTREMITY**

- 28 **Hand Fractures and Dislocations** ..... 709  
*Mark H. Henry*
- 29 **Carpus Fractures and Dislocations** ..... 781  
*Christian Gaebler and Margaret M. McQueen*
- 30 **Distal Radius and Ulna Fractures** ..... 829  
*David S. Ruch and Margaret M. McQueen*
- 31 **Radial and Ulnar Shaft Fractures** ..... 881  
*Shew-Ping Chow and Frankie Leung*
- 32 **Elbow Fractures and Dislocations** ..... 905  
*David Ring*
- 33 **Distal Humerus Fractures** ..... 945  
*George S. Athwal*
- 34 **Humeral Shaft Fractures** ..... 999  
*Michael D. McKee and Sune Larsson*
- 35 **Proximal Humerus Fractures** ..... 1039  
*C. Michael Robinson*
- 36 **Clavicle Fractures** ..... 1106  
*Michael D. McKee*
- 37 **Scapular Fractures** ..... 1144  
*Arthur van Noort*

- 38 **Glenohumeral Joint Subluxations, Dislocations, and Instability** ..... 1165  
*Young W. Kwon, Kevin J. Kulwicksi, and Joseph D. Zuckerman*
- 39 **Acromioclavicular Joint Injuries** ..... 1210  
*Leesa M. Galatz, Ronald F. Hollis Jr., and Gerald R. Williams Jr.*
- 40 **Sternoclavicular Joint Injuries** ..... 1243  
*Anil K. Dutta, Michael A. Wirth, and Charles A. Rockwood Jr.*

## **VOLUME 2 SECTION III: SPINE**

- 41 **Principles of Spine Trauma Care** ..... 1279  
*Christina V. Oleson, Nathan E. Simmons, and Sohail K. Mirza*
- 42 **Cervical Spine Fractures and Dislocations** ..... 1312  
*Christopher M. Bono and Edward Carreras*
- 43 **Thoracolumbar Spine Fractures and Dislocations** ..... 1377  
*Peter G. Whang and Alexander R. Vaccaro*

## **SECTION IV: LOWER EXTREMITY**

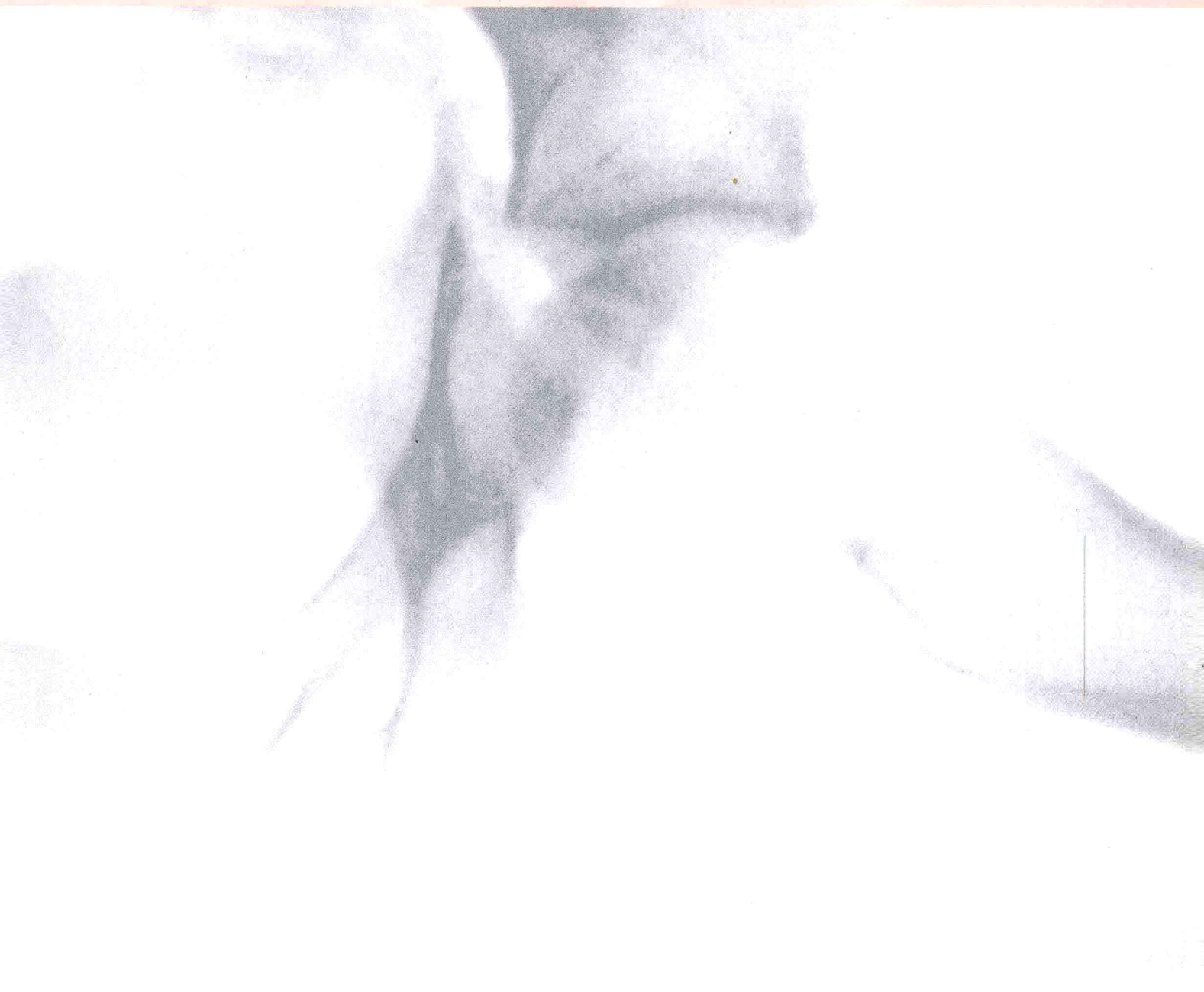
- 44 **Pelvic Ring Fractures** ..... 1415  
*Claude Sagi*
- 45 **Acetabulum Fractures** ..... 1463  
*Berton R. Moed and Mark C. Reilly*
- 46 **Hip Dislocations and Fractures of the Femoral Head** ..... 1524  
*Michael S. H. Kain and Paul Tornetta III*
- 47 **Femoral Neck Fractures** ..... 1561  
*John Keating*
- 48 **Intertrochanteric Fractures** ..... 1597  
*Thomas A. Russell*
- 49 **Subtrochanteric Fractures** ..... 1641  
*George J. Haidukewych and Joshua Langford*
- 50 **Femoral Shaft Fractures** ..... 1655  
*Sean E. Nork*
- 51 **Distal Femur Fractures** ..... 1719  
*Cory A. Collinge and Donald A. Wiss*
- 52 **Patella Fractures and Extensor Mechanism Injuries** ..... 1752  
*Asheesh Bedi and Madhav A. Karunakar*
- 53 **Tibial Plateau Fractures** ..... 1780  
*J. L. Marsh*



<b>54 Knee Dislocations and Fracture-Dislocations</b> .....	<b>1832</b>	<b>58 Talus Fractures</b> .....	<b>2022</b>
<i>James P. Stannard, Robert C. Schenck, Jr, and Gregory C. Fanelli</i>		<i>David W. Sanders</i>	
<b>55 Tibia and Fibula Fractures</b> .....	<b>1867</b>	<b>59 Calcaneus Fractures</b> .....	<b>2064</b>
<i>Brad A. Petrisor, Mohit Bhandari, and Emil Schemitsch</i>		<i>Roy W. Sanders and Michael P. Clare</i>	
<b>56 Pilon Fractures</b> .....	<b>1928</b>	<b>60 Fractures and Dislocations of the Midfoot and Forefoot</b> .....	<b>2110</b>
<i>David P. Barei</i>		<i>James J. Reid and John S. Early</i>	
<b>57 Ankle Fractures</b> .....	<b>1975</b>	<i>Index</i> .....	<i>I-1</i>
<i>Roy I. Davidovitch and Kenneth A. Egol</i>			

SECTION  
**THREE**

**SPINE**







# PRINCIPLES OF SPINE TRAUMA CARE

*Christina V. Oleson, Nathan E. Simmons, and Sohail K. Mirza*

## INTRODUCTION 1279

### MECHANISMS OF VERTEBRAL COLUMN INJURY 1280

SPINAL CORD INJURY MECHANISMS 1280

MECHANICS OF CERVICAL SPINE INJURY

FRACTURE 1283

MECHANICS OF THORACIC, LUMBAR, AND SACRAL

FRACTURE 1284

### ASSOCIATED INJURIES 1284

VERTEBRAL COLUMN INJURY 1284

CERVICAL SPINE FRACTURES 1285

THORACIC AND LUMBAR FRACTURES 1285

SPINAL CORD INJURY 1285

### INITIAL ASSESSMENT AND CARE 1286

FIELD CARE 1286

PHARMACOLOGIC INTERVENTION 1287

EMERGENCY ROOM CARE 1287

### IMAGING AND DIAGNOSTIC STUDIES 1294

DIAGNOSTIC IMAGING 1294

MAGNETIC RESONANCE IMAGING 1298

SEQUENCE OF IMAGING STUDIES 1298

UNRESPONSIVE PATIENTS 1299

PATIENT CARE UNTIL THE SPINE IS CLEARED 1299

MISSED INJURIES 1299

### CURRENT TREATMENT OPTIONS 1299

TREATMENT PRIORITIES 1299

PROVISIONAL STABILIZATION 1300

CLOSED REDUCTION 1300

DEFINITIVE TREATMENT 1300

### COMPLICATIONS 1303

### OUTCOMES OF SPINE INJURY 1303

PAIN AND FUNCTION 1303

NEUROLOGIC RECOVERY 1303

### SPECIAL CONSIDERATIONS 1305

CHILDREN 1305

ELDERLY 1305

GUNSHOT INJURIES 1305

### CONTROVERSIES 1305

PROBLEMS WITH STABILITY ASSESSMENT IN AND  
INSTABILITY OF VERTEBRAL COLUMN SPINAL  
INJURIES 1305

ADMINISTRATION OF STEROIDS IN ACUTE SPINAL CORD  
INJURY 1306

LIMITATIONS OF INFERENCES FROM BIOMECHANICAL  
STUDIES 1307

### FUTURE DIRECTIONS 1307

## INTRODUCTION

An undiagnosed or suboptimally managed spine injury can result in a neurologic deficit and permanently impair a patient's function and quality of life, and in some cases may lead to death. Additionally, the legal context of working in emergency rooms makes the difficult work of evaluating trauma patients for a potential spine injury even more stressful for training and prac-

ticing physicians. Making this work a little less stressful is the goal of this chapter.

Archeological records from over 45,000 years ago are noted to forewarn that paralysis is incurable<sup>137</sup> and this remains true today, but that does not that nothing can be done for patients who sustain severe neurologic deficits. Patients with spinal cord injury today regain mobility, improve their quality of life, and achieve prolonged survival.<sup>19</sup> Research at the cellular and ge-



netic level continues to improve our understanding of the fundamental processes,<sup>222</sup> and clinical research methods to study spinal cord injury in real patient populations have improved, renewing optimism for novel spinal cord injury treatments.<sup>278</sup> This chapter focuses on general principles of spinal injury care. Subsequent chapters in this section discuss specific injury patterns in greater detail.

## MECHANISMS OF VERTEBRAL COLUMN INJURY

### Spinal Cord Injury Mechanisms

#### Terminology of Spinal Cord Injury

The meaning of terms commonly used to describe spinal cord injury depends on the context of the discussion.<sup>184</sup> Although precise definitions for many of these terms are lacking, broad interpretations are nevertheless useful for conveying a general meaning when discussing related processes.

Neural tissue injuries are divided into two broad etiology-based categories: primary injury refers to physical tissue disruption caused by mechanical forces, and secondary injury refers to additional neural tissue damage resulting from the biologic response initiated by the physical tissue disruption. The extent of structural damage to neural tissue is indicated by other descriptive terms. Concussion refers to physiologic disruption without anatomic injury. Contusion refers to physical neural tissue disruption leading to hemorrhage and swelling (the most common type of spinal cord injury). Or laceration, which describes loss of structural continuity of the neural tissue (rare in blunt trauma). The clinical response to injury is typically described in temporal terms: acute refers to the first few hours after injury; subacute typically refers to several hours to days following injury, and chronic refers to intervals of weeks to months after the injury. The functional consequences of spinal cord injury are usually described by terms that refer to the severity and pattern of neurologic dysfunction. Complete spinal cord injury, incomplete injury, or transient spinal cord dysfunction describe different grades of severity of neurologic injury. Names for different types of spinal cord injury syndromes, such as anterior cord syndromes, central cord syndrome, and Brown-Séquard syndrome, refer to patterns of neurologic dysfunction observed during clinical evaluation.<sup>295</sup>

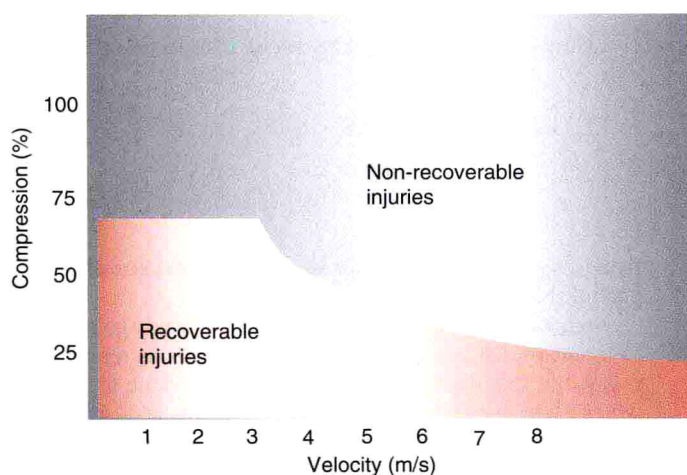
### Mechanics of Neural Injury

Structural failure of the spinal column displaces bone and ligament structures into the neural space, the spinal canal, and neural frame. These displaced and disrupted structures apply forces on the neural tissue that result in either functional or anatomic disruption.<sup>25</sup> Most spinal cord injuries are crushing injuries resulting in acute neural tissue contusion from applied physical forces. Laceration or transection of the spinal cord is rare, even in markedly displaced fracture dislocations.<sup>151</sup>

Experimental models of spinal cord injury have identified several characteristics of the injury force that determine the extent of neural tissue damage. These include the rate of force application, the degree of neural tissue compression, and the duration of neural tissue compression.<sup>150</sup> The severity of neural tissue disruption is proportional to the energy absorbed from the injury mechanism.<sup>10</sup> For direct impact on neural tissue, contact velocity and maximum cord compression are better predictors of injury severity than either force or acceleration.

The viscoelastic properties of soft tissues provide the principal resistance to deformation in the early stages of impact during compression injuries.<sup>25,290</sup> Spinal cord tolerance for compression decreases as the velocity of compression increases (Fig. 41-1).<sup>150</sup> Minimum compression of the cord at high-contact velocity may produce severe anatomic injury and limited functional recovery.<sup>150</sup> At about 50% cord compression, functional recovery is minimal regardless of the contact velocity.<sup>150</sup> Although this threshold effect denotes an upper limit of compression in the acute injury model, it is not apparent in extremely slow onset of cord compression seen in chronic degenerative conditions, such as cervical spondylotic myelopathy. Cord compression that develops over years of progressive arthritic changes can be quite severe and yet manifest minimal clinical symptoms.

The spinal cord can withstand considerable axial displacement without sustaining structural or neurologic deficit. Contrary to the relationship between nerve roots and neural foramina during physiologic movement, the spinal cord does not slide up and down in the spinal canal during spinal flexion and extension. Rather, the cord appears to deform like an accordion.<sup>228</sup> Physiologic movements can stretch the cord an average of 10%, and maximum change can be as much as 18% of the longitudinal length of the spinal cord.<sup>228</sup> Maximum stretching occurs between C2 and T1. Cord deformations may be more severe



**FIGURE 41-1** Effect of rate and severity of cord compression on potential for neurologic recovery. The threshold varies inversely with the magnitude of compression and the velocity of compression of the spinal cord.