

BIBLIOTECA
A.A.O.T.

04 MAYO 1999

ROTHMAN - SIMEONE

THE SPINE

Fourth Edition

VOLUME II

Harry N. Herkowitz, M.D.

Chairman, Department of Orthopaedic Surgery,
William Beaumont Hospital;
Director, Section of Spine Surgery,
Department of Orthopaedic Surgery,
William Beaumont Hospital,
Royal Oak, Michigan

Steven R. Garfin, M.D.

Professor and Chair, Department of Orthopaedics,
University of California, San Diego;
Chief, Section of Spine Surgery,
UCSD Medical Center,
San Diego, California

Richard A. Balderston, M.D.

Professor, Orthopaedic Surgery, and Associate
Professor, Neurosurgery;
Vice-Chair, Department of Orthopaedics;
Chief, Spine and Scoliosis Service,
Allegheny University Hospitals,
Philadelphia, Pennsylvania

Frank J. Eismont, M.D.

Professor, Department of Orthopedics, and
Clinical Professor of Neurologic Surgery,
University of Miami School of Medicine;
Co-Director of Spinal Cord Injury Service,
Jackson Memorial Hospital,
Miami, Florida

Gordon R. Bell, M.D.

Vice Chairman, Department of Orthopaedic
Surgery;
Head, Section of Spinal Surgery;
Cleveland Clinic Foundation,
Cleveland, Ohio

Sam W. Wiesel, M.D.

Professor and Chairman, Department of
Orthopaedic Surgery,
Georgetown University School of Medicine and
Medical Center,
Washington, D.C.

1999

W.B. SAUNDERS COMPANY

A Division of Harcourt Brace & Company
Philadelphia London Toronto Montreal Sydney Tokyo

WE
225
MAY

Contents

Color plates follow pages 84 and 1464.

VOLUME I

Section 1 BASIC SCIENCE AND DIAGNOSIS 1

Chapter 1

Development of the Spine 3

Wesley W. Parke, Ph.D.

Chapter 2

Applied Anatomy of the Spine 29

Wesley W. Parke, Ph.D.

Chapter 3

Lumbar Musculature: Anatomy and Function 75

Tom G. Mayer, M.D.

Chapter 4

Anatomy of the Spinal Nerve Roots in the Lumbar and Lower Thoracic Spine 83

*Mark S. Cohen, M.D., Eric J. Wall, M.D.,
Kjell Olmarker, M.D., Ph.D., Björn L. Rydevik, M.D., Ph.D.,
and Steven R. Garfin, M.D.*

Chapter 5

Differential Diagnosis of Sciatica 89

Luis A. Mignucci, M.D., and Gordon R. Bell, M.D.

Chapter 6

Radiology of the Lumbar Spine 109

Gordon R. Bell, M.D., and Michael T. Modic, M.D.

Chapter 7

Electrodiagnosis 135

The Electrodiagnostic Examination 135
Asa J. Wilbourn, M.D.

Somatosensory and Motor
Evoked Potentials 150
Michael J. Aminoff, M.D., F.R.C.P.

Chapter 8

Pathophysiology of Spinal Nerve Roots as Related to Sciatica and Disc Herniation 159

Kjell Olmarker, M.D., Ph.D., and Björn L. Rydevik, M.D., Ph.D.

Chapter 9

Outcomes Research for Spinal Disorders 173

*Richard A. Deyo, M.D., M.P.H.,
and James N. Weinstein, D.O., M.S.*

Section 2

THE CHILD'S SPINE 185

Chapter 10

Back Pain in Children and Adolescents 187

*Anthony F. Guanciale, M.D., William H. Dillin, M.D.,
and Robert G. Watkins, M.D.*

Chapter 11

Congenital Anomalies of the Cervical Spine 221

Robert N. Hensinger, M.D.

Chapter 12

Congenital Anomalies of the Spinal Cord 267

Leslie N. Sutton, M.D., and Daniel M. Schwartz, Ph.D.

Myelomeningocele 267

Occult Spinal Dysraphism and
Tethered Cord 277

Chapter 13

Spinal Disorders Associated With Skeletal Dysplasias and Metabolic Diseases 303

Vernon Tolo, M.D.

Chapter 14

Discitis 317

Jeffery L. Stambough, M.D.

Chapter 15

Juvenile and Adolescent Scoliosis 325

Robert B. Winter, M.D., and John E. Lonstein, M.D.

Congenital Scoliosis 325

Idiopathic Scoliosis 339

Chapter 16

Neuromuscular Scoliosis 373

*Peter O. Newton, M.D., Dennis R. Wenger, M.D.,
and Scott J. Mubarak, M.D.*

Chapter 17**Juvenile Kyphosis** 405

Howard S. An, M.D., Steven C. Humphreys, M.D., and Richard Balderston, M.D.

Chapter 18**Thoracic and Lumbar Spinal Trauma
of the Immature Spine** 417

Ronney L. Ferguson, M.D.

Section 3**ARTHRITIS AND DISC DISEASE IN THE
ADULT** 427**Chapter 19****Arthritis of the Spine** 429

Robert E. Booth, Jr., M.D., J. Michael Simpson, M.D., and Harry N. Herkowitz, M.D.

Chapter 20**Cervical Disc Disease** 455

Clinical Syndromes and Differential
Diagnosis of Cervical Disc Disease 455
Richard S. Brower, M.D.

Cervical Spondylotic Radiculopathy:
Natural History and Pathophysiology 461
Jeffrey S. Fischgrund, M.D., and Harry N. Herkowitz, M.D.

Clinical Syndromes in
Cervical Myelopathy 465
John M. Small, M.D., William H. Dillin, M.D., and Robert G. Watkins, M.D.

Cervical Disc Disease:
Radiologic Evaluation 474
David P. Wesolowski M.D., and Ay-Ming Wang, M.D.

Nonoperative Treatment 492
Lawrence T. Kurz, M.D.

Chapter 21**Surgical Management of Cervical
Disc Disease** 497

Surgical Management of
Cervical Radiculopathy 497

Anterior Approach 497
Kanwaldeep S. Sidhu, M.D., and Harry N. Herkowitz, M.D.

Posterior Approach 511
William H. Dillin, M.D., and Frederick A. Simeone, M.D.

Surgical Management of
Cervical Myelopathy 515

Anterior Approach 515
Kanwaldeep S. Sidhu, M.D., and Harry N. Herkowitz, M.D.

Laminectomy 529

William H. Dillin, M.D., and Frederick A. Simeone, M.D.

**Role of Instrumentation in Cervical
Degenerative Disorders** 532

Howard S. An, M.D.

Complications of Cervical Spine Surgery 540

Richard D. Guyer, M.D., Rick B. Delamarter, M.D., Trey Fulp, D.O., and Samuel D. Small, D.O.

Cervical Laminoplasty 552

Kazuo Yonenobu, M.D.

Chapter 22**Ossification of the Posterior
Longitudinal Ligament** 565

Kazuhiko Satomi, M.D., Ph.D., and Kiyoshi Hirabayashi, M.D., Ph.D.

Chapter 23**Thoracic Disc Disease** 581

Bradford L. Currier, M.D., Andrew V. Slucky, M.D., Frank J. Eismont, M.D., and Barth A. Green, M.D.

Chapter 24**Thoracoscopy of the Spine** 597

John J. Regan, M.D., and Kenneth L. Jarolem, M.D.

Chapter 25**Lumbar Disc Disease** 613

Ronald J. Wisneski, M.D., Steven R. Garfin, M.D., Richard H. Rothman, M.D., Ph.D., and Gregory E. Lutz, M.D.

Chapter 26**Laparoscopic Spinal Fusion** 681

Thomas A. Zdeblick, M.D.

Chapter 27**Alternate Forms of Disc Excision** 691

Microdiscectomy 691
John A. McCulloch, M.D., F.R.C.S.C.

Chemonucleolysis 714
John A. McCulloch, M.D., F.R.C.S.C.

Minimally Invasive Spine Surgery 725
Jonathan L. Schaffer, M.D., and Parviz Kambin, M.D.

**Automated Percutaneous Lumbar
Discectomy (APLD)** 738

P. Langham Gleason, M.D., Joseph C. Maroon, M.D., and Matthew Quigley, M.D.

Chapter 28**Discogenic Back Pain** 749

Thomas A. Zdeblick, M.D.

Chapter 29**Sacroiliac Joint Dysfunction** 767

Vert Mooney, M.D.

Chapter 30**Spinal Stenosis** 779

Pathophysiology 779 <i>Steven R. Garfin, M.D., Björn L. Rydevik, M.D., Ph.D., Stephen J. Lipson, M.D., and Harry N. Herkowitz, M.D.</i>	Chapter 34 Biomechanical Considerations of Spinal Stability 1071 <i>Mark Bernhardt, M.D., Augustus A. White III, M.D., D. Med. Sci., and Manohar M. Panjabi, Ph.D., D. Tech.</i>
Clinical Evaluation and Differential Diagnosis 796 <i>Srdjan Mirkovic, M.D., George Cybulski, M.D., David M. Montgomery, M.D., Ay-Ming Wang, M.D., David P. Wesolowski, M.D., and Steven R. Garfin, M.D.</i>	Chapter 35 Spinal Orthoses for Traumatic and Degenerative Disease 1097 <i>Michael J. Botte, M.D., Steven R. Garfin, M.D., Kel Bergmann, C.P.O., Thomas P. Byrne, O.T.C., and Alexander R. Vaccaro, M.D.</i>
Conservative Management of Lumbar Spinal Stenosis 806A <i>Myron M. LaBan, M.D., and Ronald S. Taylor, M.D.</i>	Chapter 36 Spinal Cord Injury Rehabilitation 1125 <i>David F. Apple, Jr., M.D.</i>
Surgical Management of Lumbar Spinal Stenosis 806F Part I: Indications, Techniques, and Results of Decompressive Laminectomy 806F <i>Michael E. Russell, II, M.D., and Edward N. Hanley, M.D.</i>	Chapter 37 Experimental Spinal Cord Injury: Pathophysiology and Treatment 1143 <i>Alberto Martinez-Arizala, M.D., Barth A. Green, M.D., and Richard P. Bunge, M.D.</i>
Part II: Indications and Surgical Results of Arthrodesis Following Spinal Stenosis Decompression 806M <i>Harry N. Herkowitz, M.D., and Steven R. Garfin, M.D.</i>	Section 6 AFFLICTIONS OF THE VERTEBRA 1169
Section 4 DEFORMITY 807	Chapter 38 Tumors of the Spine 1171 <i>Robert F. McLain, M.D., and James N. Weinstein, D.O., M.S.</i>
Chapter 31 Adult Scoliosis 809 <i>Jean-Jacques Abitbol, M.D., Thomas J. Dowling, M.D., Robert J. Benz, M.D., and John P. Kostuik, M.D.</i>	Chapter 39 Infections of the Spine 1207 <i>Bradford L. Currier, M.D., and Frank J. Eismont, M.D.</i>
Chapter 32 Spondylolisthesis 835 <i>Glenn Amundson, M.D., Charles C. Edwards, M.D., and Steven R. Garfin, M.D.</i>	Chapter 40 Metabolic Bone Disorders of the Spine 1259 <i>Joseph M. Lane, M.D., and Joseph Bernstein, M.D.</i>
VOLUME II	Chapter 41 Rheumatoid Arthritis: Surgical Considerations 1281 <i>Charles R. Clark, M.D., and Arnold H. Menezes, M.D.</i>
Section 5 TRAUMA 887	Chapter 42 Ankylosing Spondylitis: Surgical Considerations 1303 <i>Edward H. Simmons, M.D., B.Sc.(Med), F.R.C.S.(C), M.S.(Tor), F.A.C.S.</i>
Chapter 33 Spine Trauma in Adults 889 Spine and Spinal Cord Injuries 889 <i>Henry H. Bohlman, M.D., and Thomas B. Ducker, M.D.</i>	Section 7 SPINAL CORD 1357
Surgical Techniques for the Treatment of Thoracic, Thoracolumbar, Lumbar, and Sacral Trauma 1003 <i>Alan M. Levine, M.D.</i>	Chapter 43 Intradural Tumors 1359 <i>Frederick A. Simeone, M.D.</i>
Spinal Instrumentation for Thoracic and Lumbar Fractures 1037 <i>Jeffrey A. Goldstein, M.D., Bryan W. Cunningham, M.Sc., Ph.D., and Paul C. McAfee, M.D.</i>	

Chapter 44**Intraspinal Infections** 1373*Ann Marie Flannery, M.D., and Marshall B. Allen, M.D.***Chapter 45****Interventional Neuroradiology of the Spine** 1381*Robert C. Wallace, M.D., and Thomas J. Masaryk, M.D.***Chapter 46****Arteriovenous Malformations of the****Spinal Cord** 1401*Paul C. McCormick, M.D., and Bennett M. Stein, M.D.***Chapter 47****Medical Myelopathies** 1413*Joseph R. Berger, M.D., and Stephen J. Ryan, M.D., M.A.***Chapter 48****Syringomyelia** 1431*Parley W. Madsen, III, M.D., Ph.D., Barth A. Green, M.D., and Brian C. Bowen, M.D., Ph.D.***Section 8****PRINCIPLES AND TECHNIQUES
OF SPINAL SURGERY** 1461**Chapter 49****Surgical Approaches to the Spine** 1463*Rollin M. Johnson, M.D., Michael J. Murphy, M.D., and Wayne O. Southwick, M.D.*

Function and Surgical Anatomy
of the Neck 1463

Surgical Approaches to the Cervical Spine 1485

Surgical Approaches to the Thoracic Spine 1537

Surgical Approaches to the
Lumbosacral Spine 1557

Chapter 50**Spinal Fusion** 1573

Principles of Bone Fusion 1573

George F. Muschler, M.D., and Joseph M. Lane, M.D.

Techniques and Complications of
Bone Graft Harvesting 1589

Lawrence T. Kurz, M.D., L. Carl Samberg, M.D., and Harry N. Herkowitz, M.D.

Augmenters and Alternatives to Autogenous
Bone Graft 1601

Allograft Bone in Spinal Surgery 1601

Gray C. Stahlman, M.D., Edward N. Hanley, M.D., and Eric Phillips, M.D.

Electricity 1607

Neil Kahanovitz, M.D.

Bone Grafts and Bone Graft Substitutes
for Spinal Fusion 1610

*Jeffrey H. Schimandle, M.D., and Scott D. Boden, M.D.***Chapter 51****Lumbar Pseudarthrosis:****Diagnosis and Treatment** 1631*H. Ulrich Bueff, M.D., and David S. Bradford, M.D.***Chapter 52****Spinal Instrumentation** 1641*Todd J. Albert, M.D., Alexander M. Jones, M.D., Richard A. Balderston, M.D., and Alexander R. Vaccaro, M.D.***Chapter 53****Intraoperative Neurophysiologic Monitoring
of the Spinal Cord** 1661*Eric B. Geller, M.D., and Imad M. Najm, M.D.***Section 9****COMPLICATIONS** 1669**Chapter 54****Complications of Spinal Surgery** 1671

Postoperative Infections of the Spine 1671

John G. Heller, M.D., and Marc J. Levine, M.D.

Postlaminectomy Kyphosis of the
Cervical Spine 1687

Thomas S. Whitecloud III, M.D., and James C. Butler, M.D.

Complications Associated With Posterior
Spinal Instrumentation 1694

Patrick J. Connolly, M.D., Bruce E. Fredrickson, M.D., and Hansen A. Yuan, M.D.

Adhesive Arachnoiditis 1705

Gabrielle F. Morris, M.D.

Vascular Complications in Spine Surgery 1711

Jeffery L. Stambough, M.D., and Frederick A. Simeone, M.D.

Neurologic Complications in
Spine Surgery 1724

Jeffrey L. Stambough, M.D., and Frederick A. Simeone, M.D.

Cerebrospinal Fluid Leaks:
Etiology and Treatment 1733

*Gabrielle F. Morris, M.D., and Lawrence F. Marshall, M.D.***Chapter 55****The Multiply Operated Low Back:
An Algorithmic Approach** 1741*Sam W. Wiesel, M.D., Scott D. Boden, M.D., and William C. Lauerman, M.D.***Chapter 56****Redo Disc Surgery—Techniques and Results** 1749*Timothy A. Garvey, M.D., and Ensor E. Transfeldt, M.D.*

**Section 10
REHABILITATION** 1771**Chapter 57
Workers' Compensation As It Affects
the Spine** 1773

Compensation Low Back and Neck Pain 1773
Scott D. Boden, M.D., and Sam W. Wiesel, M.D.

Management of the Workers' Compensation
Patient With Low Back Pain 1783
Dan M. Spengler, M.D.

**Chapter 58
Spinal Functional Restoration: Tertiary
Nonoperative Care** 1791
*Tom G. Mayer, M.D.***Chapter 59
Chronic Pain Management** 1805

Nonsurgical Management of Chronic
Back Pain 1805

*Mark S. Wallace, M.D., Gordon Irving, M.D.,
Joseph Dunn, M.D., and Tony Yaksh, Ph.D.*

Surgical Procedures for the Control of
Chronic Pain 1838

F. Todd Wetzel, M.D.

Index i