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Third Edition

SPINAL CORD MEDICINE

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Vernon W. Lin

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Stephen P. Burns
Edelle C. Field-Fote
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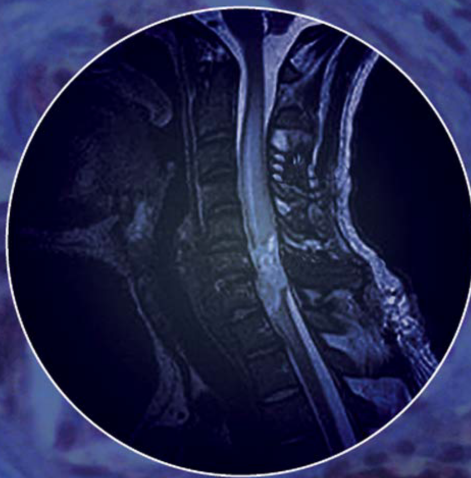

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Spinal Cord Medicine

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To my mother Beverly and in memory of my father Judah, who together taught me that without compassion, knowledge is empty.

To my grandfather, Rabbi Max Kirshblum, who instilled in me the importance of caring for others, especially those who are not being cared for.

To my mentors, who have generously shared their wisdom, and the SCI fellows and residents I have had the pleasure of being involved in training, who have trusted me to guide their clinical growth. I have learned so much from all of them.

To my colleagues at Kessler Institute for Rehabilitation and Rutgers New Jersey Medical School for their steadfast support.

To my patients, who continue to inspire me and give meaning to my work.

Most importantly, to my wife Anna and my children Aryeh and Sepha, Rena and Jonathan, and Max, who truly give meaning to my life.

Steven Kirshblum, MD

To my parents, Dr. Hanchung Gregory and Peilan Grace Lin, who devoted their health careers to the prevention and eradication of tuberculosis in Taiwan (Republic of China).

To my maternal grandmother, Sarah Mao Chao, who received the gospel of Jesus Christ from an American missionary in the Shanxi Province, China in the 1920s.

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To my mentors, colleagues, and patients, who have always inspired me to innovate, collaborate, problem solve, and provide the best care possible for the prevention and treatment of disabling human conditions.

Vernon W. Lin, MD, PhD

Contents

Contributors
Preface
Share Spinal Cord Medicine, Third Edition

PART I. INTRODUCTION

1. History of Spinal Cord Medicine
John F. Ditunno, Jr., William H. Donovan, and Christina V. Oleson

2. Development, Anatomy, and Function of the Spinal Cord
Harry G. Goshgarian

3. Pathology of the Spinal Cord
Ronald C. Kim and Mari Perez-Rosendahl

4. Epidemiology of Spinal Cord Injury
Yuying Chen and Michael J. DeVivo

5. Neurological Assessment and Classification of Spinal Cord Injury
Steven Kirshblum and Ryan Solinsky

6. Imaging of the Spinal Cord
Roland R. Lee and Blaine L. Hart

7. Electrodiagnostic Evaluation of Spinal Cord Disorders
Mark A. Lissens, Ryan Solinsky, and Steven Kirshblum

8. Functional Assessment in Spinal Cord Injury
Marcel P. J. M. Dijkers and Jeanne M. Zanca

9. Predicting Outcomes Following Spinal Cord Injury
Christina V. Oleson and Adam E. Flanders

II. ACUTE SPINAL CORD INJURY MANAGEMENT AND SURGICAL CONSIDERATIONS

10. Prehospital Management of Spinal Cord Injury
William D. Whetstone

11. Management of Trauma Patients With Complex Injuries
Adam D. Fox

12. Neuro-Critical Care Management of Acute Spinal Cord Injury
Beverly Hon, Jing Wang, Peter Yonclas, and Steven Kirshblum

13. Factors Affecting Surgical Decision Making in the Management of Spinal Cord Injury
So Kato, Satoshi Nori, and Michael G. Fehlings

14. Surgical Management for Cervical Spinal Injuries
Christine Hammer, Ravichandra A. Madineni, and James S. Harrop

15. Surgical Management for Thoracolumbar Spinal Injuries
Tristan B. Fried, Hamadi A. Murphy, Joseph S. Butler, Daniel Tarazona, Gregory D. Schroeder, and Alexander R. Vaccaro

III. MEDICAL MANAGEMENT

16. Cardiovascular Dysfunction in Spinal Cord Disorders

Sunil Sabharwal

17. Autonomic Dysfunction and Management
Andrei Krassioukov

18. Respiratory and Sleep Disorders in Spinal Cord Dysfunction
Anthony F. DiMarco

19. Infections in Persons With Spinal Cord Injury
Rabih O. Darouiche

20. Endocrinology and Metabolism of Persons With Spinal Cord Injury
William A. Bauman and Mark S. Nash

21. Nutrition in Spinal Cord Injury
Heather Asthagiri, James Wilson, and Frederick S. Frost

22. Urologic Management and Renal Disease in Spinal Cord Injury
Todd A. Linsenmeyer

23. Gastrointestinal Disorders in Spinal Cord Injury
Lauren F. Vernese, David Chen, and Alan Anschel

24. Sexual Dysfunction and Infertility in Individuals With Spinal Cord Disorders
Stacy Elliott

IV. NEUROLOGICAL AND MUSCULOSKELETAL CARE

25. Pain Management in Persons With Spinal Cord Injury
Thomas N. Bryce

26. Overuse Injuries and Fractures in Spinal Cord Injury
Nathan S. Hogaboom, Leslie R. Morse, and Michael L. Boninger

27. Spasticity Management
Heather W. Walker, Alice Hon, and Marika J. Hess

28. Surgical Restoration of the Hand in Tetraplegia: Tendon and Nerve Transfers
Allan E. Peljovich, Tobias N. von Bergen, Anne M. Bryden, Amy Bohn, and Michael W. Keith

29. Medical Management of Pressure Injuries in Patients With Spinal Cord Disorders
M. Kristi Henzel and Kath Bogie

30. The Surgical Management of Pressure Injuries
Tamara Kemp, Christine Wang, David Mathes, and Kari A. Keys

31. Spine Complications in Patients With Chronic Spinal Cord Injury
Nehaw Sarmey, Bryan S. Lee, and Edward C. Benzel

32. Dual Diagnosis: Spinal Cord Injury and Traumatic Brain Injury
Lisa A. Lombard, Christina Kwasnica, and Monifa Brooks

33. Posttraumatic Syringomyelia and Spinal Cord Tethering
William M. Scelza, Scott P. Falci, and Charlotte Starnes Indeck

34. Acute and Chronic Inflammatory Demyelinating Polyneuropathies
Jay M. Meythaler

35. Nontraumatic Myelopathies
Peter H. Gorman, Henry S. York, Florian P. Thomas, and Stephen S. Kamin

36. Tumors of the Spinal Cord and Spinal Canal
Lee S. Hwang and Edward C. Benzel

37. Spondylotic and Myelopathic Myelopathies
Robert F. Heary, Nitin Agarwal, Zoher Ghogawala, and Nduka Amankulor

38. Multiple Sclerosis
Jodie K. Haselkorn, Lynda Hillman, Kathryn Tortorice, and Alicia Sloan

39. Motor Neuron Disease
Nanette C. Joyce and Gregory T. Carter

V. SPINAL CORD REHABILITATION

40. Spinal Cord Rehabilitation
Jayne Donovan, Steven Kirshblum, Michelle Didesch, and Maggie McNiece

41. Activities of Daily Living and Upper Limb Orthotics
Andrew L. Sherman, Kevin L. Dalal, and Jessica Taylor

42. Advanced Mobility and Strategies to Promote Walking Function After Spinal Cord Injury
Edelle C. Field-Fote, Lauren Nieves, and Clare Hartigan

43. Spinal Orthoses
Amanda L. Harrington and Christine Cleveland

44. Wheelchairs and Seating for People With Spinal Cord Injury
Rory A. Cooper, Rosemarie Cooper, Michael L. Boninger, Emily Teodorski, Tricia Thorman, Tamra Pelleschi, Andrea Sundaram, Brandon Daveler, Deepan C. Kamaraj, and Richard Schein

45. Vocational Rehabilitation for Individuals With Spinal Cord Injury
John O'Neill and Lisa Ottomanelli

46. Sports and Recreation
Jeffrey Rosenbluth, Venessa Lee, Carolyn Campbell, Jennifer Piatt, Sue Sandwick, and Tanja Kari

47. Driver Training After Spinal Cord Injury
Melissa Patopea and Juan L. Asanza

48. Functional Electric Stimulation for Patients With Spinal Cord Injury
Steven W. Brose, Kevin L. Kilgore, Ronald Triolo, Anthony F. DiMarco, Dennis J. Bourbeau, and Greg Nemunaitis

49. Therapeutic Exercise After Spinal Cord Injury
Mark S. Nash and James L. J. Bilzon

50. Home Modifications and Architectural Changes for Spinal Cord Injury Patients
John J. Lee

51. Psychosocial Factors in Spinal Cord Injury
Julia M. P. Poritz and Ann Marie Warren

VI. RECENT ADVANCES IN SPINAL CORD RESEARCH

52. Recent Advances in Spinal Cord Research: Preclinical Spinal Cord Injury, Plasticity, and Repair
Hyun Joon Lee and Keith E. Tansey

53. Clinical Trials for Patients With Acute Spinal Cord Injury
S. Shelby Burks, John Paul G. Kolcun, and Michael Y. Wang

54. Basic Concepts Underlying Activity-Dependent Mechanisms in the Rehabilitation of Sensory-Motor Function After Spinal Cord Injury
V. Reggie Edgerton, Yury Gerasimenko, Parag Gad, and Dimitry Sayenko

55. Functional Magnetic Stimulation
Vernon W. Lin, Xiaoming Zhang, and Dobrivoje S. Stokic

VII. SYSTEM-BASED PRACTICE IN SPINAL CORD MEDICINE AND SPECIAL TOPICS

56. Spinal Cord Injuries and Disorders in Children and Adolescents
Lawrence Cabell Vogel, Randal R. Betz, Mary Jane Mulcahey, and Kathy

Zebracki

57. Women's Health Challenges After Spinal Cord Injuries and Disorders
Amie (Jackson) McLain and Marcalee Sipski Alexander

58. Spinal Cord Injury and Aging
Susan B. Charlifue

59. Primary Care for Persons With Spinal Cord Disorders
Michael Stillman, Daniel Graves, and Steve Williams

60. International Perspectives on Spinal Cord Injury Care
Fin Biering-Sørensen and Steven Kirshblum

Index

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Preface

As the editors of two popular textbooks – *Spinal Cord Medicine* and *Spinal Cord Medicine: Principles and Practice*—each in its second edition, we are thrilled to have joined forces to produce a combined third edition. This comprehensive new text will provide practitioners, researchers and students with a singular advanced, clinically-focused reference in the field of spinal cord medicine.

Since the last editions of our textbooks were published, the field of spinal cord medicine has continued to grow at an unprecedented rate. We have seen significant changes in the epidemiology of spinal cord injury, including, for example, the age and etiology of injury; updates to the classification of spinal cord injury with a reformatted worksheet; newer concepts on surgical intervention post-injury; greater understanding and clarification of prognoses; new medications and surgical interventions to treat medical complications; and technological advances that are transforming imaging techniques and rehabilitation. Given these changes, it became clear that an updated reference was needed to capture the progression in science, treatment, and technology that has impacted patient care and overall quality of life for persons with spinal cord injuries.

We are proud that this third edition merges the most important aspects of each previous individual text and incorporates many of the suggestions from our colleagues. The topics covered, including both traumatic and nontraumatic disorders affecting the spinal cord, follow the blueprint of the subspecialty examination for board certification in Spinal Cord Injury Medicine.

Although space constraints limit the inclusion of every aspect of spinal cord medicine, we have selected what we believe to be the most significant advances

and innovations. As such, this new edition consists of seven sections and 60 chapters with hundreds of figures and tables. This has been an immense, collaborative effort, one that has involved many contributors representing various disciplines from highly respected academic and clinical organizations in our field.

There are no words to adequately express our appreciation to our associate editors for the tireless work in assisting with identifying authors, editing chapters, and helping to keep this project on track. Similarly, we are most grateful to the authors for sharing their expertise and experience. We are indebted to our readers who seek to expand their knowledge in spinal cord medicine. And most of all, we are humbled by the trust our patients with spinal cord disorders place in us.

As always, we welcome feedback from our colleagues in spinal cord medicine and throughout the medical and scientific communities.

Steven Kirshblum, MD
Vernon W. Lin, MD, PhD

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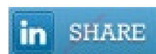
Spinal Cord Medicine, Third Edition



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Introduction

1

History of Spinal Cord Medicine

John F. Ditunno, Jr., William H. Donovan, and Christina V. Oleson

INTRODUCTION

In this journey through the History of Spinal Cord Injury (SCI) Medicine, we examine three distinct periods. The first is characterized by the “not to treat” philosophy that prevailed from ancient times to the nineteenth century, when, for the first time, advances in anesthesiology, surgery, and control of infection made the survival of severe neurological trauma possible. In 1914, the “Great War” awakened military medicine to the challenge of massive casualties, leading to the next historical period which was characterized by an organized approach to restore the wounded to health and function. This phase we explore in depth because it marked the origin of the rehabilitation approach to SCI comprehensive care. Responding to the demands posed by 20th-century warfare, the newly emerging disciplines of orthopedic and neurological surgery developed models of categorical care, which integrated acute medical and surgical treatment with systematic restoration of function through physical training and attention to vocational and recreational capacity. Pioneers in the art and science of physical training (later Physical Medicine and Rehabilitation) established standards in World War I (WWI) reconstruction (rehabilitation) hospitals for triage of the wounded based on severity of disability and set

guidelines for rehabilitation facilities, equipment, and staff. This holistic approach, as adopted by the peripheral nerve injuries centers in WWI, provided the future model for SCI centers. With success through innovative treatment of acute medical complications, the pioneers of SCI centers integrated the restoration of function learned from categorical care and demonstrated that SCI was a condition "to be treated." Survival due to prevention of bladder and skin complications with restoration of mobility, self-care, and return to home and work in veterans injured in WWII represented a revolution in medicine.

The third phase of our journey considers the role of organizations and funding agencies in the development of SCI Medicine. The work of the individual physicians and researchers during WWI and WWII has been enthusiastically embraced by organizations committed to patient care, education, and research. International organizations expanded the frontiers of SCI Medicine, establishing standards for neurological assessment and defining the principal characteristics of SCI centers: care from the moment of injury to lifelong follow-up, large databases of thousands of subjects for clinical research, and standards for professional certification. Consumers have been essential to these developments in patient care and research. The strongest financial base for comprehensive care in the United States exists in military and veterans' facilities, with a few insurers in the Workers Compensation program that direct patients to comprehensive SCI centers. This tradition of limited support was evident in the creation of the first US SCI center in Boston in the 1930 and 1940s. Countries such as Great Britain and Canada with national health services provide a more uniform system of care for veterans and civilians.

PART I: EARLY HISTORY OF SCI CARE (UNTIL 1916)

To appreciate the accomplishments and challenges that face us now and in the future, it is essential to have a comprehensive view of the past, whether the focus is SCI or other areas of medicine. As George Santayana (1863–1952) said, "progress … depends on retentiveness … Those who cannot remember the past are condemned to repeat it" (1). Physicians who treat persons with SCI should be aware of its absorbing past, which can be traced to the discovery of "The Edwin Smith Papyrus" by an American Egyptologist who purchased and named it in 1862 (2). As Hughes explains, it is (a) the first known record extant that can be

called a scientific document, (b) the first known important medical treatise, (c) the first medical document concerned with trauma, and (d) the first documentation of cases of SCI (3). The discovery of the Rosetta stone in 1799, which contained the same hieratic language as the Papyrus as well as the demotic and ancient Greek scripts (now located in the British Museum), enabled Breasted to translate the Papyrus from Hieratic to Greek to English. Two clear cases of SCI are described. The treatment for such conditions that the author (possibly Imhotep) advised was no treatment at all: "an ailment not to be treated." Given the battlefield conditions he described, certainly no treatment was available that could return such a wounded soldier to duty. Unfortunately, that same hopeless attitude persisted down through the millennia as reflected in the writings of Hippocrates, Galen, and physicians of the Middle Ages that are carefully reviewed in a recent text (4). It was not until the early 19th century that a "renaissance of medicine" yielded an interest in SCI, exemplified by the polemics between Sir Astley Cooper, who favored operative intervention, and Sir Charles Bell, who did not (5).

Examples of famous people who sustained an SCI in relatively more recent times include Lord Horatio Nelson (1758–1805), who was felled by a sniper's bullet at the Battle of Trafalgar and sustained a thoracic SCI; James A. Garfield (1831–1881), the 20th president of the United States, who was shot by a disgruntled office seeker and sustained a lumbar SCI, lingered for 80 days but succumbed to death since nothing could be done to extend his life; and General George Patton (1885–1945), who sustained a cervical SCI from a motor vehicle accident shortly after allied victory in the European Theater, and since he knew nothing could cure his paralysis he refused all care and soon after passed away. These cases illustrate the discouraging state of the art that persisted until the 20th century.

At the same time, preludes to the subsequent advances must be recognized because we could not have reached the point where life-saving and life-extending treatments and subsequent improvements in quality of life (QOL) could be offered to people with SCI unless certain barriers were overcome in science overall. Significant progress occurred in the following realms: in the mid- to late 19th century and early 20th century, discoveries in the field of microbiology (e.g., Pasteur [1832–1895] and Koch [1843–1910]) proved that diseases were caused by micro-organisms such that preventing and treating infection notably in the form of drugs could be utilized (e.g., Lister [1827–1912], Halstead [1852–1922], and Fleming [1881–1955]); discoveries of anesthesia

(e.g., Davy [1778–1829], Morton [1819–1858], and Snow [1813–1858]) enabled invasive procedures to be performed painlessly and methodically; in hematology, blood transfusions became a safe option (e.g., Landsteiner [1868–1943] and Weiner [1907–1976]); and discoveries in the field of imaging, including x-ray (Roentgen [1845–1923]), CT scanning (Oldendorf [1925–1992]), and magnetic resonance imaging (MRI-Tesla Unit 1956) (6).

Surgical treatments were also advanced. Damadian and Reid both facilitated diagnosis and improved the accuracy of operative procedures to reduce complications and improve outcomes.

Treatments included both closed, Crutchfield (1900–1972), Nickel (1918–1993), and open reduction and fixation, Harrington (1911–1980), Dubouset, and others. Nevertheless, these discoveries could not have been applied to persons with SCI unless certain pioneers had come along who recognized that tools existed to translate this knowledge and thereby extend life, maintain health, improve QOL, and enable participation in society. These individuals, to be discussed in the context of the century following WWI, include Donald Munro (1898–1978); Sir Ludwig Guttmann (1899–1980), Harry Botterell (1906–1997), Al Jousse (1910–1993), Ernest Bors (1900–1990), Estin Comarr (1915–1996), John Young (1919–1990), and Alain Rossier (1930–2006) (5,7).

PART II. SCI REHABILITATION (1916 TO PRESENT): ORIGINS IN GERMANY AND NORTH AMERICA TO PRESENT

Restoration of function through the rehabilitation of large numbers of severely disabled persons had its origin in WWI and was documented in the English-speaking literature by articles and a handbook on physical therapy (8); these writings describe the standard of care for British, Canadian, and American forces (9). McKenzie and Deavers' work demonstrated that therapeutic exercises, encompassing graded strengthening of weakened/partly paralyzed muscles, mobilization of limbs, training in walking, self-care, dancing, and sports as well as vocational and fitness training, restored function to thousands of wounded soldiers (8,10).

Historians who recently reviewed the German literature document a long tradition of therapeutic exercise originating in spas and employed by German neurologists/neurosurgeons, including Heinrich Frenkel and Otfrid Foerster prior