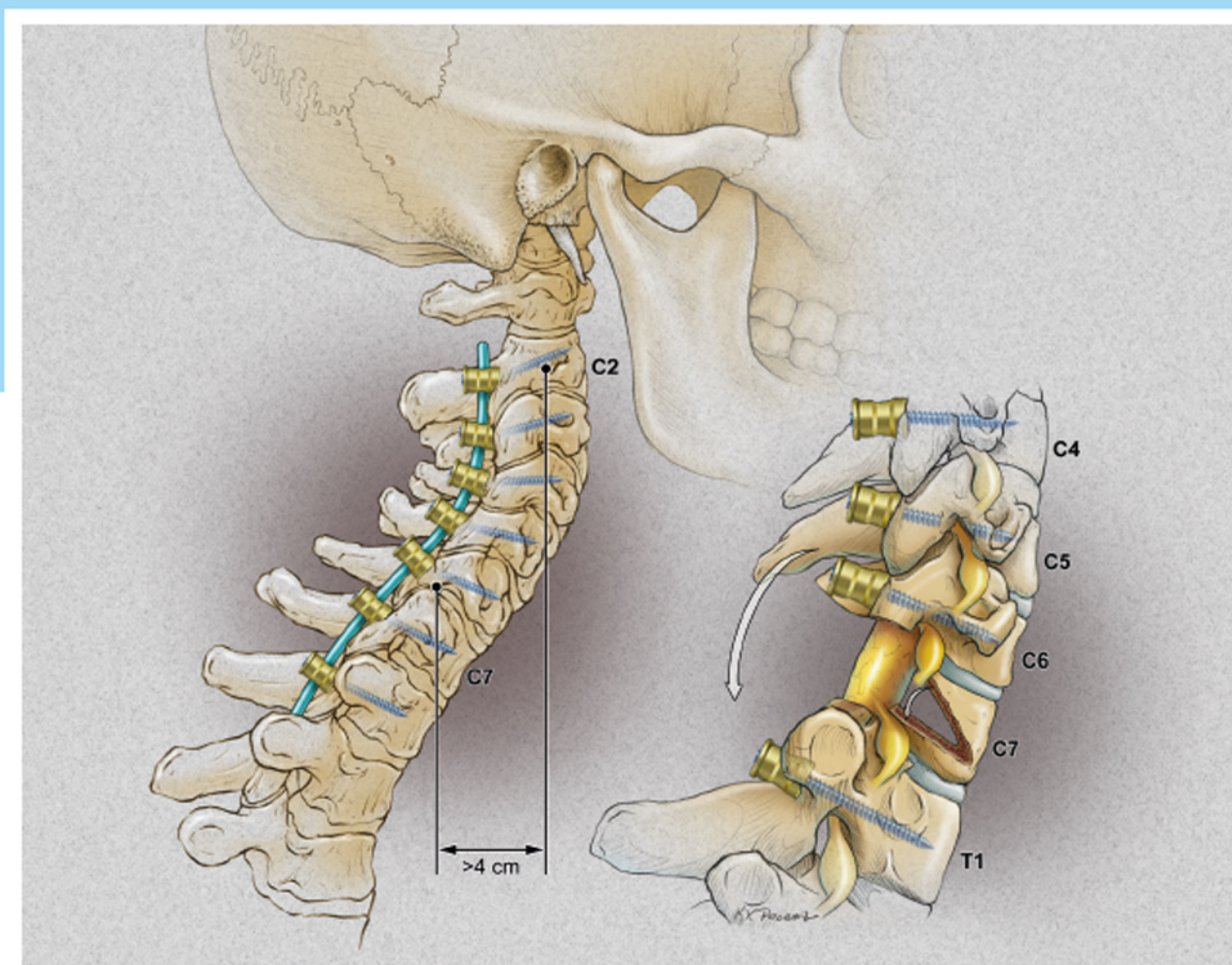


Cervical Spine Deformity Surgery

Christopher P. Ames
K. Daniel Riew
Justin S. Smith
Kuniyoshi Abumi



Cervical Spine Deformity Surgery

Christopher P. Ames, MD

Professor
Clinical Neurological Surgery and Orthopaedic Surgery
University of California, San Francisco
Director of Spinal Deformity Surgery
UCSF Medical Center
San Francisco, California, USA

K. Daniel Riew, MD

Professor of Orthopedic Surgery, Columbia University
Chief, Cervical Spine Surgery & Co-Director, Spine Division
Co-Director, Columbia University Spine Fellowship
Department of Orthopedic Surgery
Columbia University/ New York Presbyterian Hospital
New York, New York, USA

Justin S. Smith, MD, PhD

Harrison Distinguished Professor
Chief of Spine Division
Department of Neurosurgery
University of Virginia
Charlottesville, Virginia, USA

Kuniyoshi Abumi, MD

Director
Sapporo Orthopaedic Hospital-Centre for Spinal Disorders
Professor Emeritus
Hokkaido University
Sapporo, Japan

137 illustrations

Thieme
New York • Stuttgart • Delhi • Rio de Janeiro

Executive Editor: Timothy Hiscock
Managing Editor: Sarah Landis
Director, Editorial Services: Mary Jo Casey
Production Editor: Torsten Scheihagen
International Production Director: Andreas Schabert
Editorial Director: Sue Hodgson
International Marketing Director: Fiona Henderson
International Sales Director: Louisa Turrell
Director of Institutional Sales: Adam Bernacki
Senior Vice President and Chief Operating Officer: Sarah Vanderbilt
President: Brian D. Scanlan
Printer: King Printing Co., Inc.

Library of Congress Cataloging-in-Publication Data

Names: Ames, Christopher P., editor. | Riew, K. Daniel, editor. |
Smith, Justin S., editor. | Abumi, Kuniyoshi, 1948- editor.
Title: Cervical spine deformity surgery / [edited by]
Christopher P. Ames, K. Daniel Riew, Justin S. Smith,
Kuniyoshi Abumi.
Description: New York : Thieme, [2019] | Includes bibliographical
references.
Identifiers: LCCN 2019017956 | ISBN 9781626239012 (hardcover) |
ISBN 9781626239029 (eISBN)
Subjects: | MESH: Cervical Vertebrae–surgery | Spinal
Diseases–surgery
Classification: LCC RD768 | NLM WE 727 | DDC 617.4/71–dc23
LC record available at <https://lccn.loc.gov/2019017956>

© 2019 Thieme Medical Publishers, Inc.
Thieme Publishers New York
333 Seventh Avenue, New York, NY 10001 USA
+1 800 782 3488, customerservice@thieme.com

Thieme Publishers Stuttgart
Rüdigerstrasse 14, 70469 Stuttgart, Germany
+49 [0]711 8931 421, customerservice@thieme.de

Thieme Publishers Delhi
A-12, Second Floor, Sector-2, Noida-201301
Uttar Pradesh, India
+91 120 45 566 00, customerservice@thieme.in

Thieme Publishers Rio de Janeiro,
Thieme Publicações Ltda.
Edifício Rodolpho de Paoli, 25º andar
Av. Nilo Peçanha, 50 – Sala 2508
Rio de Janeiro 20020-906 Brasil
+55 21 3172 2297 / +55 21 3172-1896
www.thiemerevinter.com.br

Cover design: Thieme Publishing Group
Typesetting by DiTech Process Solutions

Printed in the United States of America
by King Printing Co., Inc.

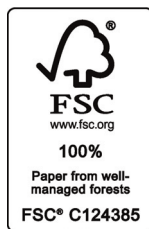
ISBN 978-1-62623-901-2

Also available as an e-book:
eISBN 978-1-62623-902-9

Important note: Medicine is an ever-changing science undergoing continual development. Research and clinical experience are continually expanding our knowledge, in particular our knowledge of proper treatment and drug therapy. Insofar as this book mentions any dosage or application, readers may rest assured that the authors, editors, and publishers have made every effort to ensure that such references are in accordance with **the state of knowledge at the time of production of the book.**

Nevertheless, this does not involve, imply, or express any guarantee or responsibility on the part of the publishers in respect to any dosage instructions and forms of applications stated in the book. **Every user is requested to examine carefully** the manufacturers' leaflets accompanying each drug and to check, if necessary in consultation with a physician or specialist, whether the dosage schedules mentioned therein or the contraindications stated by the manufacturers differ from the statements made in the present book. Such examination is particularly important with drugs that are either rarely used or have been newly released on the market. Every dosage schedule or every form of application used is entirely at the user's own risk and responsibility. The authors and publishers request every user to report to the publishers any discrepancies or inaccuracies noticed. If errors in this work are found after publication, errata will be posted at www.thieme.com on the product description page.

Some of the product names, patents, and registered designs referred to in this book are in fact registered trademarks or proprietary names even though specific reference to this fact is not always made in the text. Therefore, the appearance of a name without designation as proprietary is not to be construed as a representation by the publisher that it is in the public domain.



5 4 3 2 1

This book, including all parts thereof, is legally protected by copyright. Any use, exploitation, or commercialization outside the narrow limits set by copyright legislation without the publisher's consent is illegal and liable to prosecution. This applies in particular to photostat reproduction, copying, mimeographing or duplication of any kind, translating, preparation of microfilms, and electronic data processing and storage.

I dedicate this work to my children Pearson, Sebastian, and Scarlett who have always provided love and balance in my life. I would also like to acknowledge my residents, fellows, and mentees who have stimulated me with their questions and impressed me with their dedication to the care of our complex patients. Finally, I want to express my tremendous gratitude to my patients who have taught me the most in caring for them and provided an example to me of true courage.

–Christopher P. Ames

I dedicate this to my wife, Mary, without whose love and constant support I would not be where I am today, as well as our 3 grown children, Brad, Grant, and Julia. They are the light of our lives, and nothing in this world would be worthwhile without their love, health, and happiness.

–K. Daniel Riew

I would like to extend my gratitude to my mentors who provided me with not only the knowledge base and principles to care for patients with spinal deformities, but also helped to ignite the passion to help move the field forward.

–Justin S. Smith

I dedicate this work to my wife, Noriko. Without her understanding to sacrifice our family time, my complex work of cervical spinal surgery would not have progressed as it has. I would also like to express appreciation for my fellows and colleagues who have provided me with important ideas and always encouraged me to continue my difficult work.

–Kuniyoshi Abumi

Contents

Foreword	ix
Preface	x
Contributors	xi
1. Adult Cervical Spinal Deformity and Comparative Impact on Health	1
<i>Juanita Garces, Davis G. Taylor, Bhargav D. Desai, Christopher I. Shaffrey, Christopher P. Ames, Shay Bess, and Justin S. Smith</i>	
2. Global Sagittal Alignment	9
<i>Tejvir S. Pannu, Frank J. Schwab, and Virginie Lafage</i>	
3. Cervical Spine Alignment	17
<i>Lee A. Tan, K. Daniel Riew, Vincent C. Traynelis, and Christopher P. Ames</i>	
4. Radiographic Measurement	24
<i>Nicholas D. Stekas and Themistocles S. Protopsaltis</i>	
5. Cervical Disability Assessment	30
<i>Nicholas D. Stekas and Themistocles S. Protopsaltis</i>	
6. Cervical Malalignment and Disability Scores	36
<i>Sravisht Iyer, Han Jo Kim, and K. Daniel Riew</i>	
7. Physical Examination of Cervical Deformity	41
<i>Amanda N. Sacino, Corinna C. Zygourakis, and Christopher P. Ames</i>	
8. Cervical Osteotomy Types	48
<i>Marcus D. Mazur, Christopher I. Shaffrey, K. Daniel Riew, Christopher P. Ames, and Justin S. Smith</i>	
9. Technique of Low-Grade Osteotomies for Semi-Rigid Deformities	57
<i>Philippe Bancel</i>	
10. Uncovertebral Joint Osteotomy (Anterior Riew Osteotomy) for Correction of Rigid Cervical Spine Deformity	65
<i>Lee A. Tan, Christopher P. Ames, and K. Daniel Riew</i>	
11. Cervical Pedicle Subtraction Osteotomy for Correction of Sagittal Deformities	69
<i>Winward Choy, Darryl Lau, Cecilia L. Dalle Ore, Heiko Koller, Sang Hun Lee, and Christopher P. Ames</i>	
12. Cervical Opening Wedge Osteotomy	78
<i>Lee A. Tan and Christopher P. Ames</i>	
13. Cervical Pedicle Screw Fixation	85
<i>Sang Hun Lee, Corinna C. Zygourakis, and Christopher P. Ames</i>	
14. Upper Thoracic Osteotomy for Cervical Deformity	100
<i>Sang Hun Lee, Khaled M. Kebaish, and Paul D. Sponseller</i>	

15. Osteotomy in the Thoracolumbar Spine for Cervical Deformity	111
<i>Sang Hun Lee, Ki-Tack Kim, Yong-Chan Kim, Cheung Kue Kim, Hyung Suk Juh, and Khaled M. Kebaish</i>	
16. Congenital Cervical Deformity and Hemivertebra	122
<i>Joshua M. Pahys and Amer F. Samdani</i>	
17. Risk Stratification and Frailty in Complex Cervical Surgery	129
<i>Emily K. Miller and Christopher I. Shaffrey</i>	
18. Surgical and Neurological Complications	135
<i>Brandon B. Carlson, Han Jo Kim, and Justin S. Smith</i>	
19. Medical Complications	144
<i>Flynn Andrew Rowan, Ananth S. Eleswarapu, and Eric Klineberg</i>	
20. Relationship of Cervical Spondylotic Myelopathy to Cervical Deformity	149
<i>Peter G. Passias</i>	
21. C1-C2 Joint Osteotomy and Reduction of Vertical Deformity	157
<i>Jae Taek Hong</i>	
22. Cervical Deformity Classification	171
<i>Jeffrey P. Mullin, Davis G. Taylor, Justin S. Smith, Christopher I. Shaffrey, and Christopher P. Ames</i>	
23. Distal Junctional Kyphosis and Fusion Level Selection	179
<i>Tina Raman, Nicholas D. Stekas, and Themistocles S. Protopsaltis</i>	
24. Fusion Level Selection in Cervical Deformity	184
<i>Anand H. Segar, Deeptee Jain, Peter G. Passias, and Themistocles S. Protopsaltis</i>	
Index	188

Foreword

Cervical Spine Deformity Surgery, edited by Christopher Ames, Daniel Riew, Justin Smith, and Kuniyoshi Abumi, is a work of monumental proportions. The field of cervical deformity surgery is evolving and expanding rapidly. This field has lagged behind its thoracic and lumbar deformity surgery counterpart, predominantly as a result of a focus on complex thoracolumbar deformities in prior decades. Now, with more surgeons focusing on the cervical spine, the field of cervical spine deformity surgery has blossomed. The knowledge base is equally rapidly expanding. Hence, a book that incorporates the newest information regarding the fundamentals and techniques that are unique to the cervical spine is both timely and much needed.

Cervical Spine Deformity Surgery presents the relevant material in an incredibly organized manner. This book provides all one needs to know, and then some, regarding cervical spine deformity surgery—from the basics to the very complex. The book begins with discussions on anatomy, patho-etiology, imaging, sagittal balance, natural history, disability assessment, etc., followed by discussions on the wide variety of nuances associated with the decision-making process and surgical strategy determination. The book then concludes with discussions regarding complications, surgical nuances, etc.

Overall, this book is jam-packed with information and extremely well illustrated. It is up to date and perhaps even a bit futuristic, considering all the bases that have been covered. It serves as both a reference and a comprehensive primer. Of extreme importance, the editors and the authors are all at the very top of the field—representing a who's who of spine surgery, if you will. This book should be on the shelf of all providers and researchers dealing with cervical spine deformities.

I close by emphasizing the extraordinary worth of this book. It is a comprehensive and complete treatise on the subject, elegant in its presentation. Credit this, in part, to the high-quality standards associated with the publisher, Thieme. Finally, this book presents many complex concepts and techniques in a way that makes the complex seem simple. The editors and authors are to be heartily congratulated for a job very well done.

*Edward C. Benzel, MD
Emeritus Chairman of Neurosurgery
Neurological Institute
Cleveland Clinic
Cleveland, Ohio, USA*

Preface

Although cervical spinal deformity can have profound impacts, including pain, disability, and neurologic compromise, considerably less progress has been made in the study of these conditions compared with the more common, well-recognized thoracolumbar deformities. Early studies of cervical deformity focused on small series of patients who underwent procedures that were considered high-risk with resulting substantial morbidity. More recent advances in anesthesia and critical care, surgical techniques, and spinal instrumentation have led to a renewed interest in the surgical treatment of these often complex, high-risk deformities.

Despite the growing interest in providing surgical treatment for cervical deformity patients, there remain few resources that detail its modern clinical assessment, radiographic evaluation, and surgical treatment approaches. Much of this knowledge is experiencing a rapid evolution and is currently spread across the experts in the field with no single reference source. It is against this backdrop that this text was conceived as a concise source of current cervical deformity knowledge compiled from the literature and recognized experts in the field.

The text begins with a background on the marked health impact of cervical deformity and a primer on the clinical and radiographic assessment of these patients. Subsequent chapters detail surgical planning to address these conditions, including the range of osteotomies for correction and technique nuances from the experts. Importantly, multiple chapters address surgical and medical complications associated with these procedures and discuss risk stratification of these often-frail patients. Among the final chapters is a focused discussion of ongoing efforts to create a clinically meaningful comprehensive classification of cervical deformity.

The field of cervical deformity surgery is undergoing rapid advancements, with the ultimate goal of improving the health state and quality of life of those affected. The Editors are deeply grateful to the experts who have contributed to this text and hope that the readers find this work useful as they endeavor to care for their cervical deformity patients.

*Christopher P. Ames, MD
K. Daniel Riew, MD
Justin S. Smith, MD, PhD
Kuniyoshi Abumi, MD*

Contributors

Kuniyoshi Abumi, MD

Director
Sapporo Orthopaedic Hospital-Centre for Spinal Disorders
Professor Emeritus
Hokkaido University
Sapporo, Japan

Christopher P. Ames, MD

Professor
Clinical Neurological Surgery and Orthopaedic Surgery
University of California, San Francisco
Director of Spinal Deformity Surgery
UCSF Medical Center
San Francisco, California, USA

Philippe Bancel, MD

Orthopaedic Surgeon
Spine Department
Arago Institut
Paris, France

Shay Bess, MD

Denver International Spine Center
Presbyterian St. Luke's Hospital and Rocky Mountain
Hospital for Children
Denver, Colorado, USA

Brandon B. Carlson, MD, MPH

Assistant Professor
Department of Orthopedic Surgery
Marc A. Asher, MD Comprehensive Spine Center
University of Kansas Medical Center
Kansas City, Kansas, USA

Winward Choy, MD

Resident
Department of Neurosurgery
University of California, San Francisco
San Francisco, California, USA

Bhargav D. Desai, MD

Resident
Department of Neurosurgery
University of Virginia
Charlottesville, Virginia, USA

Ananth S. Eleswarapu, MD

Assistant Professor
Department of Orthopaedic Surgery
University of Miami
Miami, Florida, USA

Juanita Garces, MD

Assistant Professor
Department of Neurosurgery
St. Mary's Medical Center
Huntington, West Virginia, USA

Jae Taek Hong, MD, PhD

Professor
Department of Neurosurgery
Eunpyeong St. Mary's Hospital
Catholic University of Korea
Seoul, South Korea

Sravisht Iyer, MD

Assistant Attending
Spine Surgery
Hospital for Special Surgery
New York, New York, USA

Deeptee Jain, MD

Spine Surgery Fellow
Department of Orthopaedic Surgery
New York University
New York, New York, USA

Hyung Suk Juh, MD

Clinical Fellow
Department of Orthopedic Surgery
Kyung Hee University
Seoul, South Korea

Khaled M. Kebaish, MD

Division Chief, Orthopaedic Spine Surgery
Professor of Orthopaedic Surgery
Department of Orthopaedic Surgery
The Johns Hopkins University
Baltimore, Maryland, USA

Cheung Kue Kim, MD, PhD

Clinical Fellow
Department of Orthopedic Surgery
Kyung Hee University
Seoul, South Korea

Han Jo Kim, MD

Associate Professor of Orthopaedic Surgery
Director of Spine Fellowship
Hospital for Special Surgery
New York, New York, USA

Ki-Tack Kim, MD, PhD

Professor
Orthopedic Surgery
Kyung Hee University
Seoul, South Korea

Yong-Chan Kim, MD, PhD

Professor
Department of Orthopedic Surgery
Kyung Hee University
Seoul, South Korea

Eric Klineberg, MD

Professor & Vice Chair of Administration
Co-Director of the UCD Spine Center
Adult and Pediatric Spinal Surgery
Department of Orthopaedic Surgery
University of California, Davis
Sacramento, California, USA

Heiko Koller, MD

Professor
Department of Neurosurgery
Technical University Munich (TUM)
Klinikum Rechts der Isar
Munich, Bavaria, Germany

Virginie Lafage, PhD

Senior Director Spine Research
Spine Service
Hospital for Special Surgery
New York, New York, USA

Darryl Lau, MD

Chief Resident
Department of Neurological Surgery
University of California, San Francisco
San Francisco, California, USA

Sang Hun Lee, MD, PhD

Assistant Professor
Department of Orthopedic Surgery
Johns Hopkins University
Baltimore, Maryland, USA

Marcus D. Mazur, MD

Assistant Professor
Department of Neurosurgery
University of Utah
Salt Lake City, Utah, USA

Emily K. Miller, MD

Resident
Department of Physical Medicine and Rehabilitation
Stanford University
Palo Alto, California, USA

Jeffrey P. Mullin, MD, MBA

Assistant Professor
Department of Neurosurgery
University at Buffalo
Buffalo, New York, USA

Cecilia L. Dalle Ore, MD

Resident
Department of Neurological Surgery
University of California, San Francisco
San Francisco, California, USA

Joshua M. Pahys, MD

Clinical Adjunct Associate Professor
Department of Orthopaedic Surgery
Sidney Kimmel College of Medicine at Thomas Jefferson
University
Shriners Hospitals for Children
Philadelphia, Pennsylvania, USA

Tejvir S. Pannu, MD, MS

Spine Research Fellow
Orthopedic Surgery-Spine Service
Hospital for Special Surgery, Weill Cornell Medical College
New York, New York, USA

Peter G. Passias, MD, MS

Associate Professor of Orthopaedic and Neurosurgery
NYU School of Medicine
New York, New York, USA

Themistocles S. Protopsaltis, MD

Chief, Division of Spine Surgery
Associate Professor of Orthopaedic Surgery and
Neurosurgery
Department of Orthopedic Surgery
NYU Langone Health
New York, New York, USA

Tina Raman, MD

Assistant Professor, Spine Surgery
Department of Orthopaedic Surgery
NYU Langone Orthopaedic Hospital
New York, New York, USA

K. Daniel Riew, MD

Professor of Orthopedic Surgery, Columbia University
 Chief, Cervical Spine Surgery & Co-Director,
 Spine Division
 Co-Director, Columbia University Spine Fellowship
 Department of Orthopedic Surgery
 Columbia University/ New York Presbyterian Hospital
 New York, New York, USA

Flynn Andrew Rowan, MD

Assistant Professor
 Department of Orthopedics
 Indiana University
 Indianapolis, Indiana, USA

Amanda N. Sacino, MD, PhD

Resident
 Department of Neurosurgery
 Johns Hopkins Hospital
 Baltimore, Maryland, USA

Amer F. Samdani, MD

Chief of Surgery
 Shriners Hospitals for Children
 Philadelphia, Pennsylvania, USA

Frank J. Schwab, MD

Professor
 Department of Orthopaedic Surgery
 Weil Cornell Medical College
 New York, New York, USA

Anand H. Segar, MBChB, DPhil(Oxon), FRACS

Spine Fellow
 Department of Orthopedic Surgery
 NYU Langone Orthopedic Hospital, NYU Langone Health
 New York, New York, USA

Christopher I. Shaffrey, MD

Chief
 Spine Division
 Departments of Orthopaedic Surgery and Neurosurgery
 Duke University
 Durham, North Carolina, USA

Justin S. Smith, MD, PhD

Harrison Distinguished Professor
 Chief of Spine Division
 Department of Neurosurgery
 University of Virginia
 Charlottesville, Virginia, USA

Paul D. Sponseller, MD

Sponseller Professor and Head, Pediatric Orthopaedics
 Johns Hopkins Medical Institutions
 Baltimore, Maryland, USA

Nicholas D. Stekas, MS

Clinical Researcher
 Department of Orthopedic Surgery
 NYU Langone Orthopedic Hospital
 New York, New York, USA

Lee A. Tan, MD

Assistant Professor
 Department of Neurosurgery
 UCSF Medical Center
 San Francisco, California, USA

Davis G. Taylor, MD

Resident
 Department of Neurosurgery
 University of Virginia
 Charlottesville, Virginia, USA

Vincent C. Traynelis, MD

Professor and Vice Chair
 Department of Neurosurgery
 Rush University Medical Center
 Chicago, Illinois, USA

Corinna C. Zygourakis, MD

Assistant Professor
 Department of Neurosurgery
 Stanford University School of Medicine
 Stanford, California, USA