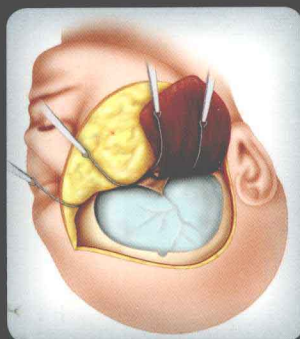
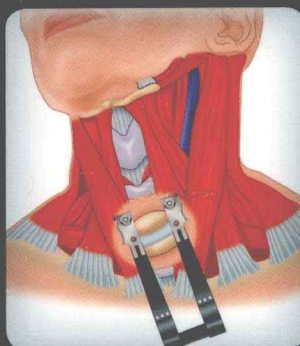
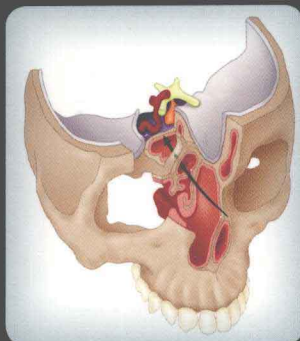


RAHUL JANDIAL
PAUL C. MCCORMICK
PETER M. BLACK



CORE TECHNIQUES IN OPERATIVE NEUROSURGERY

CORE TECHNIQUES IN OPERATIVE NEUROSURGERY

Rahul Jandial, MD, PhD

Assistant Professor
Division of Neurosurgery
City of Hope Comprehensive Cancer Center
Los Angeles, California

Paul C. McCormick, MD, MPH, FACS

Herbert and Linda Gallen Professor of Neurological Surgery
Director, Spine Center
Columbia University Medical Center
New York, New York

Peter M. Black, MD, PhD

Founding Chair, Department of Neurosurgery
Franc D. Ingraham Professor of Neurosurgery, Harvard Medical School
Brigham and Women's Hospital
Department of Neurosurgery
Boston, Massachusetts

ELSEVIER
SAUNDERS

1600 John F. Kennedy Blvd.
Ste 1800
Philadelphia, PA 19103-2899

Core Techniques in Operative Neurosurgery

ISBN: 978-1-4377-0907-0

Copyright © 2011 by Saunders, an imprint of Elsevier Inc.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the Publisher. Details on how to seek permission, further information about the Publisher's permissions policies, and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions.

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods, they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

With respect to any drug or pharmaceutical products identified, readers are advised to check the most current information provided (i) on procedures featured or (ii) by the manufacturer of each product to be administered to verify the recommended dose or formula, the method and duration of administration, and contraindications. It is the responsibility of practitioners, relying on their own experience and knowledge of their patients, to make diagnoses, to determine dosages and the best treatment for each individual patient, and to take all appropriate safety precautions.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

Library of Congress Cataloging-in-Publication Data

Core techniques in operative neurosurgery / [edited by] Rahul Jandial, Paul C. McCormick, Peter McLaren Black.

p. ; cm.

Operative neurosurgery

Includes bibliographical references and index.

ISBN 978-1-4377-0907-0 (hardcover : alk. paper)

1. Nervous system—Surgery. I. Jandial, Rahul. II. McCormick, Paul, 1956– III. Black, Peter McL. IV. Title: Operative neurosurgery.

[DNLM: 1. Neurosurgical Procedures—methods. 2. Central Nervous System Diseases—surgery.

3. Orthopedic Procedures—methods. WL 368]

RD593.C67 2011

617.4'8—dc22

2011009300

Acquisitions Editor: Julie Goolsby

Developmental Editor: Taylor Ball

Publishing Services Manager: Anne Altepeter

Senior Project Manager: Cheryl A. Abbott

Design Direction: Louis Forgione

Marketing Manager: Cara Jespersen

Printed in the United States of America

Last digit is the print number: 9 8 7 6 5 4 3 2 1

Working together to grow
libraries in developing countries

www.elsevier.com | www.bookaid.org | www.sabre.org

ELSEVIER

BOOK AID
International

Sabre Foundation



To my life's greatest and most lasting formative influence
To my best teacher, confidant, and mentor
To my father, Satya Pal Jandial

Rahul Jandial

To Dodi

Paul C. McCormick

I dedicate this book to our world neurosurgery family—faculty, residents,
practitioners, and supporters—who work so hard to make neurosurgery the most
dynamic surgical enterprise on the planet

Peter M. Black

Section Editors

Christopher P. Ames, MD

Associate Professor
Director of Spine Tumor and Deformity Surgery
Department of Neurosurgery
University of California, San Francisco
San Francisco, California

Kim Burchiel, MD, FACS

John Raaf Professor and Chairman of the Department
of Neurological Surgery
Oregon Health and Science University
Portland, Oregon

Joseph D. Ciacci, MD

Program Director, Neurosurgery Residency
Academic Community Director, School of Medicine
Associate Clinical Professor of Surgery
Division of Neurosurgery
University of California, San Diego;
Chief of Neurosurgery, Veterans Administration
Hospital, San Diego
San Diego, California

Steven Giannotta, MD

Chair, Neurological Surgery
Professor of Neurological Surgery
Keck School of Medicine
University of Southern California
Los Angeles, California

George I. Jallo, MD

Professor of Neurosurgery
Director, Clinical Pediatric Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Michael L. Levy, MD, PhD

Professor of Neurosurgery
Chief, Pediatric Neurosurgery
Division of Neurological Surgery
University of California, San Diego;
Rady Children's Hospital of San Diego
San Diego, California

Alfred Ogden, MD

Department of Neurological Surgery
Neurological Institute
Columbia University
New York, New York

Jon Park, MD, FRCS(C)

Chief, Spine Neurosurgery
Associate Professor
Stanford University School of Medicine
Stanford, California

Andrew T. Parsa, MD, PhD

Brain Tumor Research Center
Department of Neurological Surgery
University of California, San Francisco
San Francisco, California

Alfredo Quiñones-Hinojosa, MD

Associate Professor of Neurosurgery and Oncology
Neuroscience and Cellular and Molecular Medicine
The Johns Hopkins University School of Medicine;
Director, Brain Tumor Surgery Program
The Johns Hopkins Bayview Medical Center;
Director, Pituitary Surgery Program
The Johns Hopkins Hospital
Baltimore, Maryland

Rick Abbott, MD

Professor of Clinical Neurosurgery
Department of Neurosurgery
Albert Einstein College of Medicine
Bronx, New York

Frank Acosta, MD

Assistant Professor
Department of Neurosurgery
Cedars-Sinai Medical Center
Los Angeles, California

R. Todd Allen, MD, PhD

Assistant Clinical Professor
Department of Orthopaedic Surgery
University of California, San Diego
San Diego, California

Jorge E. Alvernia, MD

Senior Resident
Department of Neurosurgery
Tulane University Medical Center
New Orleans, Louisiana

Vijay K. Anand, MD

Clinical Professor
Department of Otorhinolaryngology
Weill Cornell Medical College
New York, New York

Carmina F. Angeles, MD, PhD

Clinical Instructor
Department of Neurosurgery
Stanford University Medical Center
Stanford, California

Henry E. Aryan, MD, FACS

Associate Clinical Professor of Neurosurgery
University of California, San Francisco
San Francisco, California;
Chief, Spine Service
Sierra Pacific Orthopedic and Spine Center
Fresno, California

Issam Awad, MD, MSc, FACS, MA (hon)

Director of Neurovascular Surgery
Professor of Surgery, Neurosurgery
University of Chicago Pritzker School of Medicine
Chicago, Illinois

Behnam Badie, MD

Professor and Chief
Division of Neurosurgery
City of Hope Medical Center
Los Angeles, California

Neil Badlani, MD

Orthopaedic Surgery Resident
Department of Orthopaedic Surgery
University of California, San Diego
San Diego, California

Lissa C. Baird, MD

Chief Resident, Division of Neurosurgery
University of California San Diego Medical Center
San Diego, California

H. Hunt Batjer, MD

Department of Neurological Surgery
Northwestern University Feinberg School of Medicine
Chicago, Illinois

Allan J. Belzberg, MD

Associate Professor of Neurological Surgery
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Bernard R. Bendok, MD

Department of Neurological Surgery
Northwestern University Feinberg School of Medicine
Chicago, Illinois

Edward C. Benzel, MD

Department of Neurosurgery
Neurological Institute
Cleveland Clinic
Cleveland, Ohio

Chetan Bettegowda, MD, PhD

Neurosurgery Resident
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

William E. Bingaman, MD

Vice Chairman
Neurological Institute;
Professor of Neurosurgery
Department of Neurosurgery;
Richard and Karen Shusterman Chair in Epilepsy Surgery
Epilepsy Center;
Cleveland Clinic
Cleveland, Ohio

Markus Bookland, MD

Neurosurgery Resident
Department of Neurosurgery
Temple University School of Medicine
Philadelphia, Pennsylvania

Kim Burchiel, MD, FACS

John Raaf Professor and Chairman of the Department
of Neurological Surgery
Oregon Health and Science University
Portland, Oregon

Mohamad Bydon, MD

Resident
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Peter G. Campbell, MD

Neurosurgery Resident
Department of Neurosurgery
Thomas Jefferson University Hospital
Philadelphia, Pennsylvania

Kaisorn L. Chaichana, MD

Neurosurgery Resident
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Saad B. Chaudhary, MD, MBA

Department of Neurosurgery
Neurological Institute
Cleveland Clinic
Cleveland, Ohio

Mike Yue Chen, MD, MS, PhD

Assistant Professor
Department of Surgery
Division of Neurosurgery
City of Hope National Medical Center
Los Angeles, California

Tsulee Chen, MD

Epilepsy Surgery Fellow
Department of Neurosurgery
Neurological Institute
Cleveland Clinic
Cleveland, Ohio

Dean Chou, MD

Associate Professor of Neurosurgery
Associate Director of Spinal Tumor Surgery
Department of Neurological Surgery
University of California, San Francisco
San Francisco, California

Joseph D. Ciacchi, MD

Program Director, Neurosurgery Residency
Academic Community Director, School of Medicine
Associate Clinical Professor of Surgery
Division of Neurosurgery
University of California, San Diego;
Chief of Neurosurgery VASDHS
San Diego, California

Steven R. Cohen, MD, FACS

Director, Craniofacial Surgery
Rady Children's Hospital;
Clinical Professor
Department of Plastic Surgery
University of California, San Diego
San Diego, California

Geoffrey P. Colby, MD, PhD

Resident
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

E. Sander Connolly, Jr., MD

Bennett M. Stein Professor and Vice-Chair
Department of Neurological Surgery
Columbia University
New York, New York

James E. Conway, MD

Neurosurgeon
Baltimore Neurosurgery and Spine Center
Baltimore, Maryland

Ralph G. Dacey, Jr., MD

Henry G. and Edith R. Schwartz Professor and Chairman
of Neurological Surgery
Department of Neurosurgery
Washington University School of Medicine
St. Louis, Missouri

Mahua Dey, MD

Neurosurgical Resident
University of Chicago Pritzker School of Medicine
Chicago, Illinois

Michael J. Dorsi, MD

Chief Resident
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Matthew J. Duenas

Bachelor of Science Candidate, Biology
Stanford University
Stanford, California

Gavin P. Dunn, MD, PhD

Resident
Department of Neurosurgery
Massachusetts General Hospital
Harvard Medical School
Boston, Massachusetts

Christopher S. Eddleman, MD, PhD

Department of Neurological Surgery and Radiology
University of Texas Southwestern Medical Center
Dallas, Texas

Mohamed Samy Elhammady, MD
Resident
Department of Neurosurgery
University of Miami School of Medicine
Miami, Florida

Azadeh Farin, MD
Resident
Department of Neurological Surgery
Keck School of Medicine
University of Southern California
Los Angeles, California

Richard G. Fessler, MD, PhD
Professor
Northwestern University Feinberg School of Medicine
Chicago, Illinois

Howard W. Francis, MD
Associate Professor
Division Otolaryngology-Neurotology
Department of Otolaryngology, Head and Neck Surgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Ryan C. Frank, MD
Craniofacial Fellow
Department of Plastic Surgery
University of California, San Diego
San Diego, California

Justin F. Fraser, MD
Chief Resident
Department of Neurological Surgery
Weill Cornell Medical College
New York, New York

Takanori Fukushima, MD, DMSc
Professor of Neurosurgery
Duke University Medical Center
Duke Raleigh Community Hospital
West Virginia University Medical Center
Morgantown, West Virginia

Gary Gallia, MD
Assistant Professor
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Julio Garcia-Aguilar, MD, PhD
Professor and Chair
Department of Surgery
City of Hope National Medical Center
Los Angeles, California

Ira M. Garonzik, MD
Neurosurgeon
Baltimore Neurosurgery and Spine Center
Baltimore, Maryland

Melanie G. Hayden Gephart, MD, MAS
Neurosurgery Resident
Department of Neurosurgery
Stanford University Hospital and Clinics
Stanford, California

Anand V. Germanwala, MD
Assistant Professor
Department of Neurosurgery
University of North Carolina School of Medicine
Chapel Hill, North Carolina

Christopher C. Getch, MD
Professor of Neurosurgery
Department of Neurological Surgery
Northwestern University Feinberg School of Medicine
Chicago, Illinois

Steven Giannotta, MD
Chair, Neurological Surgery
Professor of Neurological Surgery
Keck School of Medicine
University of Southern California
Los Angeles, California

Paul Gigante, MD
Resident
Department of Neurological Surgery
Columbia University Medical Center
New York, New York

Giuliano Giliberto, MD
Nuovo Ospedale Civile of Modena
Department of Neurosurgery
Modena, Italy

David Gonda, MD
Resident
Division of Neurosurgery
University of California San Diego Medical Center
San Diego, California

Jorge Alvaro Gonzalez-Martinez, MD
Staff, Department of Neurosurgery
Neurological Institute
Epilepsy Center
Cleveland Clinic
Cleveland, Ohio

Robert E. Gross, MD, PhD
Associate Professor
Department of Neurological Surgery
Emory University
Atlanta, Georgia

James S. Harrop, MD
Associate Professor
Chief of Spine and Peripheral Nerve Surgery
Departments of Neurological and Orthopedic Surgery
Thomas Jefferson University Hospital
Philadelphia, Pennsylvania

Adam O. Hebb, MD, FRCSC

Assistant Professor
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Juha Hernesniemi, MD, PhD

Professor and Chairman
Department of Neurosurgery
Helsinki University Central Hospital
Helsinki, Finland

Roberto C. Heros, MD

Professor, Co-Chairman, and Program Director
Department of Neurosurgery
University of Miami School of Medicine
Miami, Florida

Sebastian R. Herrera, MD

Resident
Department of Neurosurgery
University of Illinois at Chicago
Chicago, Illinois

Girish K. Hiremath, MD

Staff Neurosurgeon
Riverside Methodist Hospital
Columbus, Ohio

Allen Ho, BS

Harvard Medical School
Boston, Massachusetts

Samuel A. Hughes, MD, PhD

Chief Resident
Department of Neurological Surgery
Oregon Health and Science University
Portland, Oregon

Daniel S. Hutton, DO

Oregon Neurosurgery Specialists
Sacred Heart Medical Center, RiverBend Campus
McKenzie-Willamette Medical Center
Springfield, Oregon;
Sacred Heart Medical Center, University District
Eugene, Oregon

Robert E. Isaacs, MD

Director of Spine Surgery
Associate Professor
Department of Surgery
Division of Neurosurgery
Duke Medical Center
Durham, North Carolina

Jennifer Jaffe, MPH, CCRP

Clinical Research Associate
Hemorrhagic Stroke Trials Unit
Section of Neurosurgery
University of Chicago Pritzker School of Medicine
Chicago, Illinois

George I. Jallo, MD

Professor of Neurosurgery
Director, Clinical Pediatric Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Jack I. Jallo, MD

Professor and Vice Chair for Academic Services
Director, Division of Neurotrauma and Critical Care
Department of Neurological Surgery
Jefferson Medical College
Philadelphia, Pennsylvania

Rahul Jandial, MD, PhD

Assistant Professor
Division of Neurosurgery
City of Hope Comprehensive Cancer Center
Los Angeles, California

Pawel Jankowski, MD

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

Vijayakumar Javalkar, MD

Fellow
Department of Neurosurgery
Louisiana State University Health Sciences Center
Shreveport, Louisiana

Brian Jian, MD, PhD

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

J. Patrick Johnson, MD, FACS

CEO and Chairman
The Spine Institute Foundation;
Director
California Association of Neurological Surgeons;
Co-Director
Stem Cell Research Program, The Spine Center
Cedars-Sinai Medical Center
Los Angeles, California

James M. Johnston, Jr., MD

Fellow, Pediatric Neurosurgery
Department of Neurosurgery
Washington University School of Medicine
Saint Louis Children's Hospital
St. Louis, Missouri

Michael G. Kaiser, MD

Assistant Professor of Neurological Surgery
Department of Neurological Surgery
Columbia University
New York, New York

Adam S. Kanter, MD

Assistant Professor of Neurological Surgery
University of Pittsburgh;
Director
Neurosurgical Biomechanics Research Lab
Pittsburgh, Pennsylvania

Christopher P. Kellner, BA, MD

Resident
Department of Neurological Surgery
Columbia University Medical Center
New York, New York

Sassan Keshavarzi, MD

Division of Neurosurgery
University of California, San Diego
San Diego, California

Bong-Soo Kim, MD

Assistant Professor of Neurosurgery
Director, Minimally Invasive and Complex Spine
Fellowship Program
Temple University School of Medicine
Philadelphia, Pennsylvania

Kee D. Kim, MD

Associate Professor
Chief, Spinal Neurosurgery
Department of Neurological Surgery
School of Medicine
University of California, Davis
Davis, California

Ryan M. Kretzer, MD

Neurosurgery Resident
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Giuseppe Lanzino, MD

Professor of Neurologic Surgery
Mayo Clinic
Rochester, Minnesota

Michael T. Lawton, MD

Professor of Neurosurgery
Chief, Vascular Neurosurgery
Tong Po Kan Endowed Chair
Department of Neurological Surgery
University of California, San Francisco
San Francisco, California

Marco Lee, MD, PhD

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

Martin Lehecka, MD, PhD

Consultant Neurosurgeon
Department of Neurosurgery
Helsinki University Central Hospital
Helsinki, Finland

Michael L. Levy, MD, PhD

Professor of Neurosurgery
Chief, Pediatric Neurosurgery
Division of Neurological Surgery
University of California, San Diego
Rady Children's Hospital of San Diego
San Diego, California

Jason Liauw, MD

Resident
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Michael Lim, MD

Assistant Professor of Neurosurgery and Oncology
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Timothy Link, MD

Department of Neurological Surgery
The Neurological Institute
Columbia University Medical Center
West Long Branch New Jersey Office
West Long Branch, New Jersey

John C. Liu, MD

Associate Professor
Department of Neurological Surgery
Northwestern University Feinberg School of Medicine
Chicago, Illinois

Richard A. Lochhead, MD

Senior Resident, Neurosurgery
Barrow Neurological Institute
Phoenix, Arizona

Jaliya R. Lokuketagoda, MD, MS, FRCSEd

Instructor
Department of Neurological Surgery
Emory University
Atlanta, Georgia

Daniel C. Lu, MD, PhD

Assistant Professor
Department of Neurosurgery
University of California, Los Angeles
Los Angeles, California

Dzenan Lulic, MD

Department of Neurosurgery
University of South Florida
Tampa, Florida

Ricky Madhok, MD

Chief Resident in Neurological Surgery
Department of Neurological Surgery
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

Geoffrey T. Manley, MD, PhD

Professor and Vice-Chairman
Department of Neurological Surgery
University of California, San Francisco
San Francisco, California

Joseph L. Martinez, MD

Department of Neurosurgery
University of Miami Miller School of Medicine
Miami, Florida

Virgilio Matheus, MD

Department of Neurosurgery
Neurological Institute
Cleveland Clinic
Cleveland, Ohio

Nnenna Mbabuike, MD

Resident
Department of Neurosurgery
Tulane University Medical Center
New Orleans, Louisiana

Michael W. McDermott, MD

Professor of Neurosurgery
Department of Neurological Surgery
University of California, San Francisco
San Francisco, California

Vivek Mehta, BS

The Johns Hopkins University School of Medicine
Baltimore, Maryland

Hal Meltzer, MD

Clinical Professor of Neurosurgery
Division of Neurologic Sciences
University of California, San Diego
Rady Children's Hospital of San Diego
San Diego, California

Jayant P. Menon, MD

Division of Neurosurgery
University of California, San Diego
San Diego, California

Edward A. Monaco, III, MD, PhD

Resident
Department of Neurological Surgery
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

Praveen V. Mummaneni, MD

Associate Professor of Neurological Surgery
Co-Director, Spinal Surgery and Spine Center
University of California, San Francisco
San Francisco, California

Valli P. Mummaneni, MD

Associate Clinical Professor
Department of Anesthesiology
University of California, San Francisco
San Francisco, California

Anil Nanda, MD, FACS

Professor and Chairman
Department of Neurosurgery
Louisiana State University Health Sciences Center
Shreveport, Louisiana

Mika Niemelä, MD, PhD

Associate Professor
Head of Section
Department of Neurosurgery
Helsinki University Central Hospital
Helsinki, Finland

Shahid M. Nimjee, MD, PhD

Neurosurgery Resident
Division of Neurosurgery
Duke University Medical Center
Durham, North Carolina

Christopher S. Ogilvy, MD

Director of Endovascular and Operative Neurosurgery
Robert G. and A. Jean Ojemann Professor of Neurosurgery
Department of Neurosurgery
Massachusetts General Hospital
Boston, Massachusetts

David O. Okonkwo, MD, PhD

Chief of Neurotrauma
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

Alessandro Olivi, MD

Professor of Neurosurgery and Oncology
Director
Division of Neurosurgical Oncology
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

John E. O'Toole, MD

Assistant Professor of Neurosurgery
Rush University Medical Center
Chicago, Illinois

Alexander M. Papanastassiou, MD

Epilepsy Surgery Fellow
Department of Neurosurgery
Yale University School of Medicine
New Haven, Connecticut

Jon Park, MD, FRCS(C)

Chief, Spine Neurosurgery
Associate Professor
Stanford University School of Medicine
Stanford, California

Andrew T. Parsa, MD, PhD

Brain Tumor Research Center
Department of Neurological Surgery
University of California, San Francisco
San Francisco, California

Mick Perez-Cruet, MD, MS

Vice Chairman
 Professor of Neurosurgery
 Department of Neurosurgery
 Director, Spine Program
 Oakland University William Beaumont Medical School
 Michigan Head and Spine Institute
 Royal Oak, Michigan

Erika Anne Peterson, MD

Department of Neurological Surgery
 University of Texas Southwestern
 Dallas, Texas

Randall W. Porter, MD

Director Interdisciplinary Skull Base Program
 Co-Director CyberKnife
 Co-Director Acoustic Neuroma Center
 Department of Neurosurgery
 Barrow Neurological Institute
 Phoenix, Arizona

Mathew B. Potts, MD

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

Alfredo Quiñones-Hinojosa, MD

Associate Professor of Neurosurgery and Oncology
 Neuroscience and Cellular and Molecular Medicine
 The Johns Hopkins University School of Medicine;
 Director, Brain Tumor Surgery Program
 The Johns Hopkins Bayview Medical Center;
 Director, Pituitary Surgery Program
 The Johns Hopkins Hospital
 Baltimore, Maryland

Ivan Radovanovic, MD, PhD

Clinical Fellow in Cerebrovascular Surgery
 Division of Neurosurgery
 Toronto Western Hospital
 University Health Network and University of Toronto
 Toronto, Ontario, Canada

Ahmed Raslan, MD

Neurosurgical Resident
 Department of Neurological Surgery
 School of Medicine
 Oregon Health and Science University
 Portland, Oregon

Shaan M. Raza, MD

Neurosurgery Resident
 Department of Neurosurgery
 The Johns Hopkins University School of Medicine
 Baltimore, Maryland

Pablo F. Recinos, MD

Neurosurgery Resident
 Department of Neurosurgery
 The Johns Hopkins University School of Medicine
 Baltimore, Maryland

Matthew R. Reynolds, MD, PhD

Resident
 Department of Neurological Surgery
 Washington University Medical School
 St. Louis, Missouri

Alejandro Rivas, MD

Otology and Neurotology Fellow
 The Otology Group of Vanderbilt
 Vanderbilt University Medical Center
 Nashville, Tennessee

Nader Sanai, MD

Director, Neurosurgical Oncology
 Division of Neurological Surgery
 Barrow Neurological Institute
 Phoenix, Arizona

Matthias Schulz, MD

Neurosurgeon
 Pediatric Neurosurgery
 Charité Universitätsmedizin Berlin
 Campus Virchow Klinikum
 Berlin, Germany

Theodore H. Schwartz, MD, FACS

Professor of Neurosurgery
 Departments of Neurosurgery, Otolaryngology,
 Neurology, and Neuroscience
 Weill Cornell Medical College
 New York Presbyterian Hospital
 New York, New York

Stephen S. Scibelli, MD

Institute for Spinal Disorders
 Cedars-Sinai Medical Center
 Los Angeles, California

Daniel L. Silbergeld, MD, FACS

Arthur A. Ward, Jr., Professor
 Department of Neurological Surgery
 University of Washington School of Medicine
 Seattle, Washington

Konstantin V. Slavin, MD

Professor
 Department of Neurosurgery
 University of Illinois at Chicago
 Chicago, Illinois

Matthew D. Smyth, MD, FACS, FAAP

Associate Professor of Neurosurgery and Pediatrics
 Washington University
 Saint Louis Children's Hospital
 St. Louis, Missouri

Volker Sonntag, MD

Vice Chair of Neurological Surgery
Alumni Chair for Spinal Surgery
Barrow Neurological Institute;
Clinical Professor, Department of Surgery
University of Arizona;
Vice Chairman, Barrow Neurosurgical Associates
Phoenix, Arizona

Dennis D. Spencer, MD

Harvey and Kate Cushing Professor
Chair, Department of Neurosurgery
Yale University School of Medicine
New Haven, Connecticut

Gary K. Steinberg, MD, PhD

Bernard and Ronni Lacroute Professor of Neurosurgery
and the Neurosciences
Director, Stanford Institute for Neuro-Innovation
and Translational Neurosciences
Chief, Department of Neurosurgery
Stanford University School of Medicine;
Chief, Department of Neurosurgery
Stanford University Hospital and Clinics
Stanford, California

Shirley I. Stiver, MD

Assistant Professor
Department of Neurological Surgery
University of California, San Francisco
San Francisco, California

Sathish Subbaiah, MD

Assistant Professor
Department of Neurosurgery
Mount Sinai Hospital
New York, New York

Michael E. Sughrue, MD

Brain Tumor Research Center
Department of Neurological Surgery
University of California, San Francisco
San Francisco, California

Patrick A. Sugrue, MD

Resident Physician
Department of Neurological Surgery
Northwestern University Feinberg School of Medicine
Chicago, Illinois

Omar N. Syed, MD

Chief Resident
Department of Neurological Surgery
Columbia University Medical Center
New York, New York

Rafael J. Tamargo, MD, FACS

Walter E. Dandy Professor of Neurosurgery
Director, Division of Cerebrovascular Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Ramesh Teegala, MD

International Spine Fellow
Spinal Surgery and Spine Center
University of California, San Francisco
San Francisco, California

Charles Teo, MD

Director, Center for Minimally Invasive Neurosurgery
Sydney, Australia

Nicholas Theodore, MD

Chief, Spine Section
Division of Neurosurgery
Barrow Neurological Institute;
Adjunct Professor School of Life Sciences
Arizona State University
Phoenix, Arizona

Ulrich W. Thomale, MD

Consultant Pediatric Neurosurgeon
Pediatric Neurosurgery
Charité Universitätsmedizin Berlin
Campus Virchow Klinikum
Berlin, Germany

Andrew P. Thomas, BS

Northwestern University
Feinberg School of Medicine
Chicago, Illinois

B. Gregory Thompson, MD

Professor and J.E. McGillicuddy Chair
Departments of Neurosurgery, Radiology,
and Otolaryngology
University of Michigan
Ann Arbor, Michigan

William D. Tobler, MD

Department of Neurosurgery
Neuroscience Institute
College of Medicine
University of Cincinnati
Mayfield Clinic
Cincinnati, Ohio

Nestor D. Tomycz, MD

Department of Neurological Surgery
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

Matthew J. Tormenti, MD

Resident in Neurological Surgery
Department of Neurological Surgery
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

Timothy D. Uschold, MD

Senior Resident, Neurosurgery
Barrow Neurological Institute
Phoenix, Arizona

Prasad Vannemreddy, MCh, MBBS

Fellow
Department of Neurosurgery
University of Illinois at Chicago
Chicago, Illinois

Ram R. Vasudevan, MD

Resident
Department of Neurosurgery
Cedars-Sinai Medical Center
Los Angeles, California

Shoshanna Vaynman, PhD

Research and Education Administrator
The Spine Institute Foundation
Los Angeles, California

Kenneth P. Vives, MD

Associate Professor of Neurosurgery
Director, Section of Stereotactic and Functional
Neurosurgery
Department of Neurosurgery
Yale University School of Medicine
New Haven, Connecticut

M. Christopher Wallace, MD, MSc, FRCSC, FACS

Professor, Department of Surgery
University of Toronto
Head, Division of Neurosurgery
Toronto Western Hospital, University Health Network
Toronto, Ontario, Canada

Michael Y. Wang, MD, FACS

Associate Professor
Departments of Neurological Surgery and Rehabilitation
Medicine
University of Miami Miller School of Medicine
Lois Pope LIFE Center
Miami, Florida

Vincent Y. Wang, MD, PhD

Clinical Instructor
Department of Neurosurgery
University of California, Los Angeles
Los Angeles, California

Marcus L. Ware, MD

Assistant Professor
Department of Neurosurgery
Tulane University Medical Center
New Orleans, Louisiana

Chad W. Washington, MD, MS

Resident
Department of Neurosurgery
Washington University School of Medicine
St. Louis, Missouri

J. Dawn Waters, MD

Resident
Division of Neurosurgery
University of California San Diego Medical Center
San Diego, California

Louis Anthony Whitworth, MD

Associate Professor
Department of Neurological Surgery
Department of Radiation Oncology
University of Texas Southwestern Medical Center
Dallas, Texas

Kamal R.M. Woods, MD

Department of Neurosurgery
Loma Linda University Medical Center
Loma Linda, California

Graeme F. Woodworth, MD

Neurosurgery Resident
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Zilvinas Zakarevicius, MD, PhD

Fellow
Department of Neurosurgery
University of Illinois at Chicago
Chicago, Illinois

Gregory J. Zipfel, MD

Assistant Professor of Neurological Surgery
and Neurology
Department of Neurosurgery
Washington University School of Medicine
St. Louis, Missouri

Benjamin M. Zussman, BS

Jefferson Medical College
Philadelphia, Pennsylvania

Core Techniques in Operative Neurosurgery was conceived with clear recognition of the evolving pedagogical landscape. The presentation of medical information is undergoing a renaissance, and the pressing need and unparalleled opportunity to develop digital medical textbooks are upon us. Soon the concepts of “book editions” and “page length” will become obsolete, as information is continually updated and infinitely linked from digital sources that coalesce. In this transition, neurological surgery—the most challenging and complicated of medical endeavors—should be at the forefront.

The structure of this text consists of two main sections: Cranial and Spinal. Specific design elements have been included to allow for quick reference in preoperative considerations regarding “Indications,” “Contraindications,” and “Planning and Positioning.” Further, thoughtful “Tips from the Masters” and “Bailout Options” are included, which present condensed and accessible pearls that have been distilled from more exhaustive texts, as well as senior

author experience. Both for neophyte students of neurological surgery and for established neurosurgeons seeking a targeted review of operations that may have become an infrequent aspect of their practices, this text intends to serve both as a reference and a conduit to further learning.

My intention is for *Core Techniques to Operative Neurosurgery* to function as a bridge between the best of conventional paper textbooks and the transition toward discrete quanta of information that facilitate delivery through the digital milieu. Indeed, the last punctuation within methods and models of didactic delivery was the printing press, adding accessibility and reproducibility of knowledge previously impossible. Similarly, the transition of paper texts to digital texts will add another indelible exclamation mark in the advancement of didactic methods. My hope is that *Core Techniques in Operative Neurosurgery* will lead that evolution.

Rahul Jandial

Acknowledgments

I would like to thank the Elsevier team that has helped bring this project to fruition: Adrianne Brigido, Julie Goolsby, Cheryl Abbott, and most of all, Taylor Ball.

Rahul Jandial