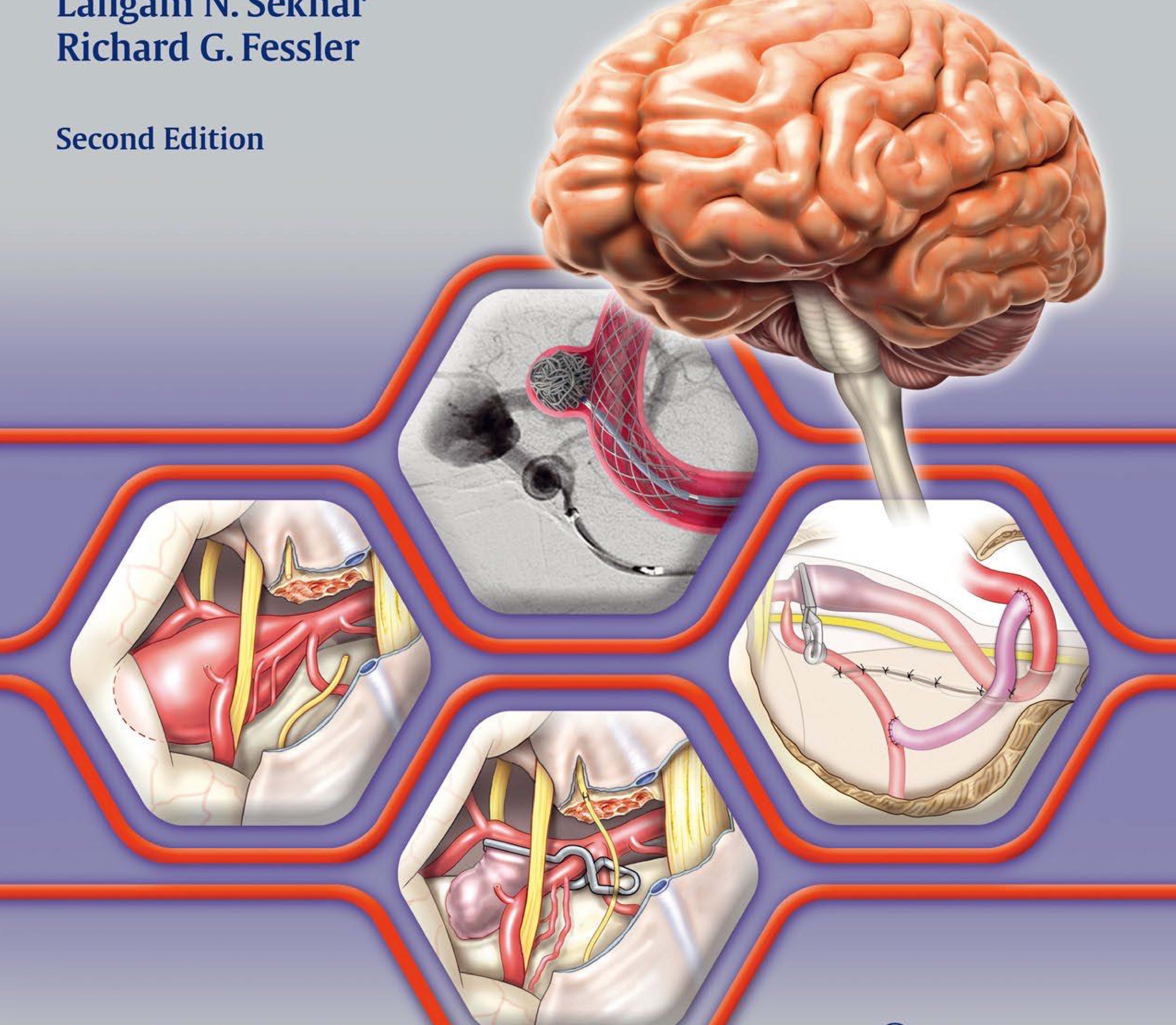
Atlas of Neurosurgical Techniques

Laligam N. Sekhar
Richard G. Fessler

Second Edition



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Atlas of Neurosurgical Techniques

Brain

Volume 1

Second Edition

Laligam N. Sekhar, MD, FACS, FAANS
Professor and Vice-Chairman
Department of Neurological Surgery
Professor of Radiology
Director, Cerebrovascular Surgery
Director, Skull Base Surgery
University of Washington School of Medicine
Harborview Medical Center
Seattle, Washington

Richard G. Fessler, MD, PhD
Professor
Department of Neurosurgery
Rush University Medical Center
Chicago, Illinois

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Thieme Publishers Delhi
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Dedicated to my children, Raja, Daniela, and Krishna, and my wife Gordana,
and to the Divine Force that has guided me, my team, and my patients
during every operation that I have performed. –LNS

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suture has been applied around the puncture site. A 5F dilator is used over the microwire and a J wire inserted through the dilator after removing the microwire. The 8F sheath is introduced into the CCA over the J wire and sutured in place with a skin stitch. The 8F sheath is connected to the venous sheath, and the Rumel tourniquet is applied to achieve flow arrest in the CCA and flow reversal to the femoral vein. After carotid stenting, the 8F sheath is removed and the purse string suture is tied down to close the arteriotomy site.

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Foreword

I awaited this new edition of *Atlas of Neurosurgical Techniques* from Thieme Publishers with great interest. Admittedly, I was curious to see how the authors were going to improve on the masterful first edition. Professors Sekhar and Fessler, not surprisingly, exceeded my expectations. They surpassed the depth, breadth, and final product of the previous edition. Those of us who teach neurological surgery are grateful to fellow educators who are dedicated to illustrating operative techniques in a manner that is transformative. Such is the case with this two-volume set. The field of neurological surgery is changing rapidly, our techniques are more complex, new instruments are emerging, and diverse psychomotor skills are required. Novel and new techniques require an evolution in the authors' ability to communicate these advances. This two-volume set accomplishes this through precise descriptions, high-quality imaging, crisp video, and beautiful art. This new edition does an amazing job of enlightening the reader on both the intellectual framework of what we need to do and the practical technical aspects of how to do it.

How did these authors meet this challenge in the second edition? They did it in three crucial ways. (1) The authors retooled each chapter by employing new expert authors and/or additional perspectives. This is a very bold but important step in reinventing this already gem of a book. (2) The authors stayed ahead of the information curve by suffusing the book with chapters and descriptions of both the endovascular and endoscopic techniques that have transformed our field and improved our patient outcomes. (3) The book is replete with professionally edited videos as well as superlative and accurate art, thereby extending the power of the written word. These high-quality videos and special drawings are imbedded in each chapter and improve the reader's ability to absorb and mimic best surgical practices.

Atlas of Neurosurgical Techniques is a world-class compilation of elegant operative techniques and nuances. It will be used often by neurosurgeons in training and by experienced neurosurgeons who face challenging operative situations weekly. It is required reading for every one of our neurological surgery residents throughout their training. It is written by an army of experts and edited by a team of renowned neurosurgical virtuosos. The two-volume set is logically organized and eminently readable. It is designed with a surgical train of thought for the perioperative and intraoperative considerations for each patient scenario. We owe a debt of gratitude to the authors for their impressive commitment of time and skill in creating this new edition. The authors are to be congratulated for engineering a visually and intellectually appealing format for those of us who celebrate and practice the art of neurological surgery.

Richard G. Ellenbogen, MD, FACS
Professor and Chairman
Theodore S. Roberts Endowed Chair
Department of Neurological Surgery
Director, Neurosciences Institute
University of Washington School of Medicine
Director, American Board of Neurological Surgery
Seattle, Washington

Preface

The first edition of the *Atlas of Neurosurgical Techniques* was created as a project to provide neurosurgical residents and junior faculty with an operative neurosurgical text, similar to Kempe's *Operative Atlas* which the older generation of neurosurgeons grew up with. The first edition was extraordinarily successful and become very popular with its target audience. The book has become a worldwide bestseller in English and was translated into Chinese, Italian, and Turkish; it has also won many awards. When attending international meetings or in hospitals as a visiting professor, I have been approached by residents or junior faculty who extolled the clarity and value of the chapters in the book. This is a testament to the tremendous expertise and teaching ability of the contributing authors, to the artists who produced the drawings, and to everyone at Thieme who brought forth this great work.

My joint editorship with Richard Fessler allowed us to put together chapters covering most areas of neurosurgery, including cranial, spine, and peripheral nerve, which is a special attraction for all who wish to learn the technical aspects of neurosurgery.

Since the publication of the first edition, neurosurgery has advanced in all areas. And new areas of neurosurgery, such as endovascular surgery and endoscopic (or endoscope-assisted) surgery, have become commonplace. Therefore, a major revision of the *Atlas of Neurosurgical Techniques* was undertaken. In addition to comprehensively covering all of neurosurgery, this edition has emphasized video graphic material to enhance learning. Most of the chapters have been rewritten by leaders in each topic area. The addition of new material means that the cranial volume of the Atlas had to be divided into two parts: the first emphasizing general principles and basic techniques, as well as cerebrovascular surgery; and the second emphasizing brain tumors, skull base surgery, craniocerebral trauma, cranial nerve surgery, surgery for pain, and pediatric neurosurgery.

Learning to perform technically excellent neurosurgery is a complex task which takes many years to accomplish. We all start as resident trainees, but the learning continues lifelong. It is equally important to learn when to do an operation and when not to do an operation, when to stop a procedure, when to call for help, and when to refer a patient to another surgeon much more skilled than oneself. A book like this must be considered as part of the learning algorithm which includes mentored training, observation of master surgeons, taking cadaver-based courses, participating in discussions or seminars, and self-evaluation, especially in regards to results and complications. Although virtual reality-based training is being tried, it has not become available for many of the procedures that we do. I believe that every neurosurgeon should continuously improve the results and reduce the complications of the operations over each year of clinical practice, and the time to change is when you reach a plateau or start to decline.

I greatly appreciate all those who have participated in these great works of art: the authors, the artists, and the editorial and production staff. Once again, Jennifer Pryll has turned rough drawings into anatomically correct and aesthetically pleasing figures. The entire editorial and production staff have excelled as usual, which is very important for a book of this nature. None of us would have been able to write these chapters without the operative opportunities provided by our patients, the entire teams of healthcare workers in our respective hospitals, and our teachers and mentors who have taught us many things. I am confident that the next generation of neurosurgeons will continue to advance our field, making it better and safer for our patients.

Laligam N. Sekhar, MD, FACS, FAANS

Contributors

Saleem I. Abdulrauf, MD, FAANS, FACS
Professor and Chairman
Department of Neurological Surgery
Neurosurgeon-in-Chief
St. Louis University Hospital
President, Walker E. Dandy Neurosurgical Society
St. Louis, Missouri

Adib A. Abla, MD
Director of Cerebrovascular Surgery
Assistant Professor
Department of Neurosurgery
University of Arkansas for Medical Sciences College of Medicine
Little Rock, Arkansas

Hussam Abou Al-Shaar
Alfaisal University
Riyadh, Kingdom of Saudi Arabia

Paul D. Ackerman, MD
Department of Neurological Surgery
Loyola University Medical Center
Maywood, Illinois

Nimer Adeeb, MD
California Neurosurgical Institute
Thousand Oaks, California

John R. Adler Jr., MD
Dorothy and Thye King Chan Professor in Neurosurgery, Emeritus
Department of Neurosurgery
Stanford University
Editor-in-Chief Cureus.com
Stanford, California

Ryojo Akagami, MD, BSc, MHSc, FRCSC
Clinical Associate Professor, Program Director
Division of Neurosurgery Institution
University of British Columbia
Vancouver, British Columbia, Canada

Felipe C. Albuquerque, MD
Assistant Director, Endovascular Surgery
Professor of Neurosurgery
Division of Neurological Surgery
Barrow Neurological Institute
Phoenix, Arizona

Cargill H. Alleyne Jr., MD
Marshall Allen Distinguished Chair
Program Director, Neurosurgery Residency Training Program
Director, Neurosurgery Vascular Service
Director, Neurosurgical Intensive Care Unit
Georgia Regents University
Augusta, Georgia

Rami Almefty, MD
Department of Neurological Surgery
Barrow Neurological Institute
Phoenix, Arizona

Ossama Al-Mefty, MD
Director, Skull Base Program
Lecturer, Harvard Medical School
Boston, Massachusetts

Jorge Alvernia, MD
Brain and Spine Surgery
Glenwood Medical Group
West Monroe, Louisiana

Peter S. Amenta, MD
Assistant Professor of Neurosurgery
Department of Neurosurgery
Tulane Medical Center
New Orleans, Louisiana

Vijay K. Anand, MD, FACS
Clinical Professor
Department of Otolaryngology and Neck and Head Surgery
Weill Cornell Medical College
New York Presbyterian Hospital Weill Cornell Medical Center
Consultant
Department of Surgery
Memorial Sloan Kettering Cancer Center
New York, New York

Gerasimos Baltsavias, MD
Interventional Neuroradiology
University Hospital Zurich
Zurich, Switzerland

Daniel L. Barrow, MD
Professor and Chair
Department of Neurosurgery
Emory University School of Medicine
Atlanta, Georgia

H. Hunt Batjer, MD
Lois C. A. and Darwin E. Smith Distinguished Chair in Neurological Surgery
Professor and Chairman
Department of Neurological Surgery
University of Texas Southwestern Medical Center
Dallas, Texas

Zoé Iván Benítez Huerta, MD
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Mitchel S. Berger, MD, FACS, FAANS
Berthold and Belle N. Guggenhime Professor
Chairman, Department of Neurological Surgery
Director, Brain Tumor Research Center
University of California–San Francisco
San Francisco, California

Christopher Bogaev, MD
Neurosurgeon
Neurosurgical Associates of San Antonio
San Antonio, Texas

Frank J. Bova, PhD, FACR, FAAPM, FAIMBE
Albert E. and Birdie W. Einstein Professor of Computer-Assisted Stereotactic Neurosurgery
Department of Neurosurgery
University of Florida
Gainesville, Florida

Derald E. Brackmann, MD
Clinical Professor
Departments of Otolaryngology–Head and Neck Surgery and Neurological Surgery
Associate, House Clinic
University of Southern California
Los Angeles, California

Harley Brito da Silva, MD
Acting Instructor
Department of Neurological Surgery
Harborview Medical Center
University of Washington
Seattle, Washington
Attending Neurosurgeon
Neurosurgical Service
Hospital Geral de Fortaleza
Fortaleza, Brazil

Samuel R. Browd, MD, PhD, FACS, FAANS, FAAP
Associate Professor
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Jeffrey A. Brown, MD
Neurological Surgery, PC
Great Neck, New York

Jeffrey N. Bruce, MD
Edgar M. Housepian Professor of Neurological Surgery
Department of Neurosurgery
Columbia University College of Physicians and Surgeons
New York, New York

Ketan R. Bulsara, MD
Director, Neuroendovascular and Skull Base Surgery
Department of Neurosurgery
Yale University
New Haven, Connecticut

Kim J. Burchiel, MD, FAANS, FACS
John Raaf Professor in Neurological Surgery
Professor and Chair
Department of Neurological Surgery
Oregon Health & Science University School of Medicine
Portland, Oregon

François Caces, MD
Departments of Otology and Neurotology
Ear Causse Clinic
Colombiers, France

Delia Cannizzaro, MD, PhD
Department of Neurosurgery
Sapienza University of Rome
Rome, Italy

C. Michael Cawley, MD, FACS
Associate Professor
Departments of Neurological Surgery and Radiology
Emory University School of Medicine
Atlanta, Georgia

Juanita M. Celix, MD, MPH
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Amitabha Chanda, MBBS, MS, MCh (Neurosurgery)
Consulting Neurosurgeon
Fortis Hospitals
Kolkata, India

Steven D. Chang, MD
Robert C. and Jeannette Powell Professor
Department of Neurosurgery
Stanford University School of Medicine
Stanford, California

Navjot Chaudhary, MD
Department of Neurosurgery
Clinical Assistant Professor
Stanford University School of Medicine
Stanford, California

Randall M. Chesnut, MD, FCCM, FACS, FAANS
Integra Endowed Professor of Neurotrauma
Department of Neurological Surgery
Department of Orthopaedic Surgery
Adjunct Professor, School of Global Health
University of Washington School of Medicine
Harborview Medical Center
Seattle, Washington

Gregory A. Christoforidis, MD
Professor of Radiology and Surgery
Section Chief of Neuroradiology
Department of Radiology
University of Chicago
Chicago, Illinois

Darko Chudy, MD, PhD
Assistant Professor
Department of Neurosurgery
University of Zagreb Medical School
Clinical Hospital Dubrava
Zagreb, Croatia

Jennifer Clancy, BS, BFA
St. Louis University School of Medicine
St. Louis, Missouri

Geoffrey P. Colby, MD, PhD
Assistant Professor
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Daniel L. Cooke, MD
Assistant Professor
Department of Radiology and Biomedical Imaging
University of California–San Francisco
San Francisco, California

Erwin Cornips, MD
Pediatric Neurosurgeon
Maastricht University Medical Center
Maastricht, The Netherlands

William T. Couldwell, MD, PhD
Joseph Yager Professor and Chairman
Department of Neurosurgery
Professor
Department of Surgery
Division of Otolaryngology
University of Utah
Salt Lake City, Utah

Ralph G. Dacey Jr., MD, FACS, FRCSI (Hon)
Henry G. and Edith R. Schwartz Professor
and Chairman
Department of Neurological Surgery
Washington University School of Medicine
St. Louis, Missouri

Jennifer A. Daniel-Johnson, MBBS
Assistant Professor of Laboratory Medicine
University of Washington School of Medicine
Seattle, Washington

Jason M. Davies, MD, PhD
Department of Neurological Surgery
University of California–San Francisco
San Francisco, California

Arthur L. Day, MD
Professor
Department of Neurosurgery
University of Texas Medical School at Houston
Houston, Texas

Franco DeMonte, MD, FRCSC, FACS
Professor, Departments of Neurosurgery–
Head and Neck Surgery
Mary Beth Pawelek Chair in Neurosurgery
University of Texas M. D. Anderson Cancer Center
Houston, Texas

Milind Deogaonkar, MD
Associate Professor
Department of Neurosurgery
The Ohio State University Wexner Medical Center
Columbus, Ohio

Angela F. DiCosola, BS
Research Assistant
Department of Neurosurgery
St. Louis University
St. Louis, Missouri

Jacques E. Dion, MD, FRCPC
Professor and Chief
Division of Interventional Neurosurgery
Professor
Department of Neurological Surgery
Emory University School of Medicine
Atlanta, Georgia

Hamid Djalilian, MD
Associate Professor
Department of Neuotology and Skull Base Surgery
University of California–Irvine School of Medicine
Irvine, California

Angela Moneak Donaldson, MD
Department of Otolaryngology–Head and Neck Surgery
Atlanta Institute for Ear, Nose, and Throat
Atlanta, Georgia

Huy T. Duong, MD
Assistant Offsite Residency Director
Department of Neurosurgery
Kaiser Permanente
Sacramento, California

Florian H. Ebner, MD, PhD
Professor
Department of Neurosurgery
Eberhard-Karis University
Tuebingen, Germany

Richard G. Ellenbogen, MD, FACS
Professor and Chairman
Department of Neurological Surgery
Theodore S. Roberts Endowed Chair
Director, Neurosciences Institute
University of Washington School of Medicine
Seattle, Washington

Jean Anderson Eloy, MD
Professor and Vice Chair
Department of Otolaryngology
Director, Rhinology and Sinus Surgery
Rutgers–New Jersey Medical School
Newark, New Jersey

Ahmed Elsharkawy, MD, PhD
Senior Consultant
Department of Neurosurgery
Tanta University Faculty of Medicine
Tanta, Egypt

Samuel Estronza-Ojeda, MD
Department of Neurosurgery
Medical Sciences Campus
San Juan, Puerto Rico

James J. Evans, MD
Professor of Neurological Surgery and Otolaryngology
Director of Cranial Base and Pituitary Surgery
Thomas Jefferson University
Philadelphia, Pennsylvania

Manuel Ferreira Jr., MD, PhD
Chief of Neurological Surgery UWMC
Co-Director of Skull Base and Minimally Invasive Neurosurgery
Director of Multidisciplinary Pituitary Program
University of Washington School of Medicine
Seattle, Washington

Richard G. Fessler, MD, PhD
Professor
Department of Neurosurgery
Rush University Medical Center
Chicago, Illinois

Stélio da Conceição Araújo Filho, MD
Attending Neurosurgeon
Neurosurgical Service
Hospital Geral de Fortaleza
Consultant Neurosurgeon
Hospital São Carlos
Fortaleza, Brazil

John Flickinger, MD, FACR
Professor of Radiation Oncology and Neurological Surgery
UPMC Cancer Center
University of Pittsburgh School of Medicine
Pittsburgh, Pennsylvania

Bruno C. Flores, MD
Department of Neurological Surgery
University of Texas Southwestern Medical Center
Dallas, Texas

Márcio Ribeiro Studart da Fonseca, MD, MSc
Attending Head and Neck Surgeon
Hospital Cancer do Ceará
Hospital Universitário Walter Cantídeo
Fortaleza, Brazil

Allan H. Friedman, MD
Guy L. Odom Professor of Neurological Surgery
Department of Neurosurgery
Duke University Medical Center
Durham, North Carolina

William A. Friedman, MD
Chairman
Department of Neurosurgery
University of Florida
Gainesville, Florida

Sunil V. Furtado, MB, MS, MCh, DNB
Clinical Instructor
Department of Neurosurgery
Stanford University Medical Center
Stanford, California

Paul A. Gardner, MD
Associate Professor
Department of Neurological Surgery
University of Pittsburgh School of Medicine
Co-Director
Center for Cranial Base Surgery
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

Hani El Garem, MD
Professor of Otolaryngology
University of Alexandria
Alexandria, Egypt

Tomas Garzon-Muvdi, MD, MSc
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

George Georgoulis, MD
Department of Neurosurgery
University of Lyon
Hôpital Neurologique P. Wertheimer
Lyon, France

Basavaraj Ghodke, MD
Professor
Department of Radiology and Neurological Surgery
University Of Washington School of Medicine
Seattle, Washington

Michael Gleeson, MD, FRCS, FRACS, FDS
Professor of Skull Base Surgery
Department of Neurotology
The National Hospital for Neurology
and Neurosurgery
London, England

Atul Goel, MCh (Neurosurgery)
Professor and Chairman
Department of Neurosurgery
Seth G. S. Medical College and King Edward
Memorial Hospital
Mumbai, India

Michael R. Greene, MD, MASc, PEng
Robotics Engineer
Project neuroArm
Department of Clinical Neurosciences
University of Calgary
Calgary, Alberta, Canada
Department of Emergency Medicine
University of British Columbia
Victoria, British Columbia, Canada

Gerardo Guinto, MD
Professor and Chairman
Department of Neurosurgery.
Hospital de Especialidades del Centro Medico
Nacional Siglo XXI
Member of the Centro Neurologico ABC
Mexico City, Mexico

Van Halbach, MD
Clinical Professor of Radiology, Neurology,
and Neurosurgery
University of California–San Francisco
Medical Center
San Francisco, California

Walter A. Hall, MD, MBA
Professor of Neurosurgery
Department of Neurosurgery
State University of New York Upstate
Medical University
Syracuse, New York

Danial K. Hallam, MD, MSc
Associate Professor of Radiology and
Neurological Surgery
Department of Radiology
University of Washington School of Medicine
Seattle, Washington

Brian W. Hanak, MD
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Devon H. Haydon, MD
Center for Neurosurgical and Spine Care
Morton Plant Hospital
Clearwater, Florida

Juha Hernesniemi, MD, PhD
Professor and Chairman
Department of Neurosurgery
Helsinki University Hospital
Helsinki, Finland

Shawn Hervey-Jumper, MD
Assistant Professor
Department of Neurological Surgery
University of Michigan
Ann Arbor, Michigan

John R. Hess, MD, MPH, FACP, FAAAS
Professor
Department of Laboratory Medicine
University of Washington School of Medicine
Seattle Washington

Yoshinori Higuchi, MD, PhD
Department of Neurological Surgery
Chiba University Graduate School of Medicine
Chiba, Japan

Robert N. Holdefer, PhD
Assistant Professor
Department of Rehabilitation Medicine
University of Washington School of Medicine
Seattle, Washington

Eric C. Holland, MD, PhD
Director and Senior Vice President
Department of Human Biology
Director, Solid Tumor Translational Research
Fred Hutchinson Cancer Research Center
Professor
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Kazuhiro Hongo, MD, PhD
Professor and Chairman
Department of Neurosurgery
Shinshu University School of Medicine
Matsumoto, Japan

L. Nelson Hopkins, MD
Distinguished Professor of Neurosurgery
Professor of Radiology
School of Medicine and Biomedical Sciences
University at Buffalo, SUNY
President, Gates Vascular Institute, Kaleida Health
CEO, Jacobs Institute
Co-Director, Toshiba Stroke and Vascular Research Center
Buffalo, New York

Tetsuyoshi Horiuchi, MD
Associate Professor
Department of Neurosurgery
Shinshu University School of Medicine
Matsumoto, Japan

Brian M. Howard, MD
Department of Neurological Surgery
Emory University School of Medicine
Atlanta, Georgia

Kenichi Ishibashi, MD, PhD
Head Physician
Department of Neurosurgery
Osaka City General Hospital
Osaka, Japan

Yoshiyasu Iwai, MD, PhD
Department of Neurosurgery
Osaka City General Hospital
Osaka, Japan

Aditya K. Iyer, MD, MS
Department of Neurosurgery
Stanford University
Stanford, California

Rashid Janjua, MD
Assistant Professor
Department of Neurosurgery, Vascular Surgery, and Interventional Radiology
Wake Forest Baptist Medical Center
Winston-Salem, North Carolina

Jeremiah N. Johnson, MD
Assistant Professor
Department of Neurosurgery
University of Texas Health Science Center–San Antonio
San Antonio, Texas

M. Yashar S. Kalani, MD, PhD
Assistant Professor
Department of Neurological Surgery
Barrow Neurological Institute
Phoenix, Arizona

Chandrasekar Kalavakonda, MBBS, MCh (Neurosurgery)
Head
Department of Neurosurgery
Apollo Hospitals
Chennai, India

Hideyuki Kano, MD, PhD
Research Associate Professor
Director of Clinical Research
Department of Neurological Surgery
University of Pittsburgh
Pittsburgh, Pennsylvania

Yoko Kato, MD, PhD
Professor
Department of Neurosurgery
Fujita Health University
Banbuntane Hotokukai Hospital
Aichi, Japan

Prashant Kelkar, MD
Neuroscience Institute
Swedish Medical Group
Seattle, Washington

Elias Kfoury, MD, RPVI
Michael E. DeBakey Department of Surgery
Baylor College of Medicine
Houston, Texas

Louis J. Kim, MD
Associate Professor
Department of Neurological Surgery
University of Washington School of Medicine
Chief of Neurosurgery
Harborview Medical Center
Seattle, Washington

Gregory A. Kinney, PhD
Associate Professor
Director, Neurophysiological Monitoring
Department of Rehabilitation Medicine
University of Washington School of Medicine
Seattle, Washington

Andrew L. Ko, MD
Assistant Professor
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Douglas Kondziolka, MD, MSc, FRCSC, FACS
Professor of Neurosurgery
Vice-Chair, Clinical Research (Neurosurgery)
Professor of Radiation Oncology
Director, Center for Advanced Radiosurgery
New York University Langone Medical Center
New York, New York

Maria Koutourousiou, MD
Assistant Professor of Neurosurgery
Director of the Skull Base Program
Department of Neurosurgery
University of Louisville
Louisville, Kentucky

Giuseppe Lanzino, MD
Professor of Neurological Surgery and Radiology
Mayo Clinic
Rochester, Minnesota

Michael T. Lawton, MD
Professor and Vice-Chairman, Neurological Surgery
Professor, Anesthesia and Perioperative Care
Chief of Vascular Neurosurgery
Tong-Po Kan Endowed Chair
Director, Center for Cerebrovascular Research
University of California–San Francisco
San Francisco, California

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

Martin Lehecka, MD, PhD
Associate Professor
Department of Neurosurgery
Helsinki University Hospital
Helsinki, Finland

Michael R. Levitt, MD
Assistant Professor
Department of Neurological Surgery and Radiology
University of Washington School of Medicine
Seattle, Washington

Elad I. Levy, MD, MBA, FACS, FAHA
Professor and Chair of Neurosurgery
Professor of Radiology
School of Medicine and Biomedical Sciences
University at Buffalo, SUNY
Medical Director
Neuroendovascular Services at Gates Vascular Institute, Kaleida Health
Co-Director, Gates Stroke Center, Kaleida Health
Co-Director, Toshiba Stroke and Vascular Research Center
Buffalo, New York

Mark E. Linskey, MD
Associate Clinical Professor
Department of Neurological Surgery
Surgical Director, Comprehensive Brain Tumor Program
University of California–Irvine School of Medicine
Irvine, California

James K. Liu, MD, FACS, FAANS
Associate Professor of Neurological Surgery
Director, Center for Skull Base and Pituitary Surgery
Co-Director, Endoscopic Skull Base Surgery Program
Director, Surgical Neuro-Oncology and Brain Tumor Center
Departments of Neurological Surgery and Otolaryngology-Head and Neck Surgery
Neurological Institute of New Jersey
Rutgers University–New Jersey Medical School
Newark, New Jersey

Christopher M. Loftus, MD, Drhc (Hon), FAANS
Chair, AANS International Programs
Treasurer, WFNS
Professor and Chairman
Department of Neurosurgery
Professor of Neurology
Loyola University Stritch School of Medicine
Maywood, Illinois

Mario Messina Lopez, MD
Centro Médico Nacional de Occidente, IMSS
Guadalajara, Mexico

L. Dade Lunsford, MD
Lars Leksell and Distinguished Professor of Neurosurgery
University of Pittsburgh
Director, The Center for Image Guided Neurosurgery
University of Pittsburgh Medical Center, Presbyterian
Pittsburgh, Pennsylvania

Jacques Magnan, MD
Professor Emeritus
Department of Otolaryngology—Head and Neck
Hopital Nord
University of Aix-Marseille
Marseille, France

Hossein Mahboubi, MD
Department of Otolaryngology–Head and Neck Surgery
University of California–Irvine School of Medicine
Irvine, California

Ghaus M. Malik, MD
Executive Vice-Chair
Department of Neurosurgery
Henry Ford Health System
Detroit, Michigan

Alireza Mansouri, MD
Division of Neurosurgery
University of Toronto
Toronto, Ontario, Canada

Alessandra Mantovani, MD
Acting Instructor
Department of Neurosurgery
Stanford University
Stanford, California

Joseph C. Maroon, MD
Clinical Professor and Vice-Chairman
Department of Neurosurgery
Heindl Scholar in Neuroscience
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

D. Jay McCracken, MD
Department of Neurological Surgery
Emory University School of Medicine
Atlanta, Georgia

Cameron G. McDougall, MD, FRCSC
Director of Endovascular Neurosurgery
Lou and Evelyn Grubb Chair for Neurovascular Research
Barrow Neurological Institute
Phoenix, Arizona

Sean McEvoy, MD
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Theodore R. McRackan, MD
Assistant Professor
Department of Otolaryngology–Head and Neck Surgery
Director, Skull Base Surgery Program
Medical University of South Carolina
Charleston, South Carolina

Antonio Cesar de Melo Mussi, MD
Staff Neurosurgeon
Hospital Governador Celso Ramos
Florianopolis, Brazil

Jose Maria Sampaio Menezes Jr., DDS
Attending Oral and Maxillofacial Surgeon
Santa Casa da Misericórdia de Fortaleza
Instituto Doutor José Frota
Fortaleza, Brazil

Julia Metzner, MD
Associate Professor of Anesthesiology
Department of Anesthesiology and Pain Medicine
University of Washington School of Medicine
Seattle, Washington

Fredric B. Meyer, MD
Professor and Enterprise Chair
Department of Neurologic Surgery
Mayo Clinic
Rochester, Minnesota

Basant K. Misra, MBBS, MS (General Surgery), MCh (Neurosurgery), Diplomate National Board (Neurosurgery)
Consultant and Head
Department of Neurosurgery and Gamma Knife Radiosurgery
P. D. Hinduja National Hospital and Medical Research Centre
Mumbai, India

Hidemi Miyazaki, MD, PhD
Lecturer, Graduate School of Medicine
Department of Otolaryngology–Head and Neck Surgery
Kyoto University
Kyoto, Japan

Kris S. Moe, MD, FACS
Professor and Chief
Division of Facial Plastic and Reconstructive Surgery
Departments of Otolaryngology and Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Matthew E. Mollman, MD
Researcher
Department of Neurosurgery
Washington University School of Medicine
St. Louis, Missouri

Edward A. Monaco III, MD, PhD
Assistant Professor
Department of Neurological Surgery
University of Pittsburgh School of Medicine
Pittsburgh, Pennsylvania

Jacques J. Morcos, MD
Professor of Clinical Neurosurgery and Otolaryngology
University of Miami Miller School of Medicine
Miami, Florida

Akio Morita, MD, PhD
Professor and Chairman
Department of Neurological Surgery
Nippon Medical School
Tokyo, Japan

Martin M. Mortazavi, MD
California Neurosurgical Institute
Thousand Oaks, California

Ryan P. Morton, MD
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Goran Mrak, MD, PhD
Assistant Professor in Neurosurgery
Head, Department of Neurosurgery
Clinical Hospital Centre Zagreb
University of Zagreb School of Medicine
Zagreb, Croatia

Raghu Mudumbai, MD
Associate Professor
Department of Ophthalmology
University of Washington School of Medicine
Seattle, Washington

Dipankar Mukherjee, MD, FACS, RVT, RPVI
Chief, Division of Vascular Surgery
Inova Fairfax Hospital
Falls Church, Virginia
Associate Professor of Surgery
Virginia Commonwealth University
Richmond, Virginia
Associate Professor of Surgery
Division of Neurosurgery
George Washington University
Washington, DC

Yasuo Murai, MD, PhD
Assistant Professor
Department of Neurological Surgery
Nippon Medical School
Tokyo, Japan

Peter Nakaji, MD
Professor of Neurosurgery
Neurosurgery Residency Program Director
Barrow Neurological Institute
Phoenix, Arizona

Sabareesh K. Natarajan, MD, MS
Clinical Assistant Instructor
Department of Neurosurgery
School of Medicine and Biomedical Sciences
University at Buffalo, SUNY
Buffalo, New York

Jayson A. Neil, MD
Midwest Neurosurgery Associates
Kansas City, Missouri

John D. Nerva, MD
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Breno Nery, MD
Adjunct Physician
Division of Neurosurgery
Ribeirão Preto Medical School
Ribeirão Preto, Brazil

Ajay Niranjan, MD, MBA
Associate Professor
Director, Brain Mapping Center
Department of Neurological Surgery
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

Tetsuhiro Nishihara, MD, PhD
Director
Nishihara Clinic
Tokyo, Japan

Gustavo Nogueira, MD
Chairman
ENT–Surgery Department
Neurological Institute of Curitiba
Curitiba, Brazil

Mohsen Nouri, MD
Neurosurgeon, Sina Hospital
Ahvaz Jondishapour University of Medical Sciences
Karoon, Iran

Jeffrey G. Ojemann, MD
Professor of Neurological Surgery
Richard G. Ellenbogen Chair of Pediatric Neurosurgery
Seattle Children's Hospital
Seattle, Washington

Evandro de Oliveira, MD, PhD
Professor of Neurosurgery
State University of Campinas
UNICAMP Director
Institute of Neurological Sciences
Sao Paulo, Brazil

Joshua W. Osbun, MD
Acting Instructor
Department of Neurosurgery
Emory University
Atlanta, Georgia

Marc Otten, MD
Assistant Professor
Department of Neurological Surgery
Columbia University Medical Center
New York, New York

Alexandre N. Ottoni, MD
Department of Neurosurgery
Neurological Institute of Curitiba
Curitiba, Brazil

J. J. van Overbeeke, MD
Professor and Chairman Department of Neurosurgery
Academic Hospital Maastricht
Masstricht, The Netherlands

Robert Oxford, MD
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Donato Pacione, MD
Assistant Professor
Department of Neurosurgery
New York University School of Medicine
New York, New York

Min S. Park, MD, FAANS
Assistant Professor of Neurosurgery
Adjunct Assistant Professor of Radiology
University of Utah Health Care
Salt Lake City, Utah

Emil A. Pastrana-Ramirez, MD
Attending Physician-Neurosurgery
Centro Avanzado de Neurociencias
Hospital HIMA San Pablo
Caguas, Puerto Rico

Sunil J. Patel, MD, FAANS
Chairman
Department of Neurosurgery
Medical University of South Carolina
Charleston, South Carolina

Daniel Pieper, MD (deceased)
Professor of Neurosurgery
Oakland University William Beaumont School of Medicine
Royal Oak, Michigan

Gustavo Pradilla, MD
Assistant Professor
Department of Neurological Surgery
Emory University School of Medicine
Chief of Neurosurgery Service
Grady Memorial Hospital
Director, Cerebrovascular Research Laboratory
Atlanta, Georgia

Harshad R. Purandare, MS, Mch, DNBE
Consultant Neurosurgeon
Department of Neurosurgery
Jupiter Hospital
Thane, India

Rohan Ramakrishna, MD
Assistant Professor of Neurological Surgery
Weill Cornell Medical College
New York Presbyterian Hospital
New York, New York

Ricardo Ramina, MD, PhD
Chairman
Department of Neurosurgery
Neurological Institute
Curitiba, Brazil

Shaan M. Raza, MD
Assistant Professor
Departments of Neuorsurgery and Head and Neck Surgery
Skull Base Tumor Program
University of Texas M. D. Anderson Cancer Center
Houston, Texas

Renuka K. Reddy, BS
Department of Neurological Surgery
Rutgers-New Jersey Medical School
Newark, New Jersey

Kevin Reinard, MD
Department of Neurosurgery
Henry Ford Hospital
Detroit, Michigan

Ali Rezai, MD
Director, Neuroscience Program
Stanley and Jodi Ross Chair in Neuromotion
Associate Dean of Neurosciences
Professor of Neurosurgery and Neuroscience
Director, Center for Neuromodulation
The Ohio State University
Columbus, Ohio

Albert L. Rhoton Jr., MD
R. D. Keene Family Professor and Chairman Emeritus
Department of Neurosurgery
College of Medicine
University of Florida
Gainesville, Florida

Kim L. Rickert, MD
Assistant Professor
Department of Neurosurgery
University of Texas Southwestern–Dallas
Dallas, Texas

Luigi Rigante, MD
Catholic University of the Sacred Heart
Rome, Italy
for the Department of Neurosurgery
University of Tübingen
Tübingen, Germany

Jason Rockhill, MD, PhD
Associate Professor
Department of Radiation Oncology
University of Washington School of Medicine
Seattle, Washington

Ana Rodríguez-Hernández, MD
Attending Neurosurgeon
Department of Neurological Surgery
Vall d'Hebron University Hospital
Barcelona, Spain

Robert C. Rostomily, MD
Professor
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Sarwat Salim, MD, FACS
Professor of Ophthalmology
Chief of Glaucoma Service
Medical College of Wisconsin
Milwaukee, Wisconsin

Amir Samii, MD, PhD
Professor of Neurosurgery
Vice-President
International-Neuroscience Institute
Hannover, Germany
Director
Intraoperative Mapping and Visualization of the Human Brain Program
Leibniz Institute of Neurobiology
Magdeburg, Germany

Matthew R. Sanborn, MD
Department of Endovascular Neurosurgery
Maine Medical Center
Portland, Maine

Raymond Sawaya, MD
Professor and Chairman
Department of Neurosurgery
University of Texas M. D. Anderson Cancer Center
Houston, Texas

Theodore H. Schwartz, MD, FACS
Professor of Neurosurgery, Otolaryngology, and Neuroscience
David and Ursel Barnes Professor of Minimally Invasive Neurosurgery
Director, Anterior Skull Base and Pituitary Surgery, Epilepsy Research Laboratory
Weill Cornell Medical College
New York Presbyterian Hospital
New York, New York

R. Michael Scott, MD
Professor of Neurosurgery
Harvard Medical School
Fellows Family Chair in Pediatric Neurosurgery
Neurosurgeon-in-Chief, Emeritus
Department of Neurosurgery
Boston Children's Hospital
Boston, Massachusetts

Laligam N. Sekhar, MD, FACS, FAANS
Professor and Vice-Chairman
Department of Neurological Surgery
Professor of Radiology
Director, Cerebrovascular Surgery
Director, Skull Base Surgery
University of Washington School of Medicine
Harborview Medical Center
Seattle, Washington

Chandranath Sen, MD
Professor
Department of Neurosurgery
New York University Langone Medical Center
New York, New York

Pradeep Setty, DO
Department of Neurosurgery
Detroit Medical Center
Detroit, Michigan

Deepak Sharma, MBBS, MD, DM
Virginia and Prentice Bloedel Professor
Chief of Neuroanesthesiology and Perioperative Neurosciences
Departments of Anesthesiology and Pain Medicine and Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Sajjan Sharma, MS, MCh
Department of Neurosurgery
Hayat Hospital
Assam, India

Adnan H. Siddiqui, MD, PhD, FAHA
Vice-Chairman and Professor of Neurosurgery
Professor of Radiology
Director of Neuroendovascular Fellowship Program
School of Medicine and Biomedical Sciences
University at Buffalo, SUNY
Director, Neurosurgical Stroke Service, Kaleida Health
Director, Training and Education, Jacobs Institute
Director, Toshiba Stroke and Vascular Research Center
Buffalo, New York

Daniel L. Silbergeld, MD, FAANS, FACS
The Arthur A. Ward Jr. Professor
Department of Neurological Surgery
University of Washington School of Medicine
Seattle, Washington

Marc Sindou, MD, PhD
Department of Neurosurgery
University of Lyon
Hôpital Neurologique P. Wertheimer
Lyon, France

Walavan Sivakumar, MD
Department of Neurosurgery
University of Utah
Salt Lake City, Utah

Edward R. Smith, MD
Co-Director
Cerebrovascular Surgery and Interventions Center
Director
Pediatric Cerebrovascular Surgery
Department of Neurosurgery, Vascular Biology Program
Boston Children's Hospital
Harvard Medical School
Boston, Massachusetts

Kenneth V. Snyder, MD, PhD
Assistant Professor of Neurosurgery, Radiology, and Neurology
School of Medicine and Biomedical Sciences
University at Buffalo, SUNY
Co-Director, Toshiba Stroke and Vascular Research Center
Buffalo, New York

Robert F. Spetzler, MD
Director
Department of Neurosurgery
Barrow Neurological Institute
Phoenix, Arizona

Toma Spiriev, MD
Department of Neurosurgery
University of Tübingen
Tübingen, Germany

Gary K. Steinberg, MD, PhD
Bernard and Ronni Lacroute–William Randolph Hearst Professor of Neurosurgery and the Neurosciences
Chairman, Department of Neurosurgery
Stanford University School of Medicine
Stanford, California

George P. Stevens, BFA
Department of Neurological Surgery
St. Louis University Hospital
St. Louis, Missouri

Dinko Štimac, MD, PhD
Professor and Chairman
Department of Neurosurgery
University Hospital Rijeka
Rijeka, Croatia

Garnette R. Sutherland, MD, FRCSC
Professor of Neurosurgery
Department of Clinical Neurosciences
University of Calgary
Calgary, Alberta, Canada

Jamal M. Taha, MD
Neurosurgeon
Riverhills Neuroscience
Montgomery, Ohio

Rafael J. Tamargo, MD, FAANS, FACS
Walter E. Dandy Professor of Neurosurgery
Professor of Neurosurgery and of Otolaryngology–Head and Neck Surgery
Director, Division of Cerebrovascular Neurosurgery
Vice-Chairman, Department of Neurosurgery
Neurosurgery Co-Director, Neurosciences Critical Care Unit
Department of Neurosurgery
The Johns Hopkins University School of Medicine
Baltimore, Maryland

Marcos Tatagiba, MD, PhD
Professor
Chairman and Director
Department of Neurosurgery
University of Tübingen
Tübingen, Germany

Helder Tedeschi, MD
Neurosurgeon
Department of Neurosurgery
University of Campinas
Campinas, Brazil

Luke Tomycz, MD
Staff Neurosurgeon
Pediatric Surgery Subspecialists
Dell Children's Medical Center
Austin, Texas

Miriam M. Treggiari, MD, PhD, MPH
Professor
Departments of Anesthesiology and Perioperative Medicine
Oregon Health & Science University
Portland, Oregon

Nef ze Turan, MD
Department of Neurosurgery
Emory University School of Medicine
Atlanta, Georgia

Ali Hassoun Turkmani, MD
Department of Neurosurgery
University of Texas at Houston
Houston, Texas

Anton Valavanis, MD
Professor and Chairman
University Hospital of Zurich
Zurich, Switzerland

W. A. Vandergrift III, MD
Associate Professor
Department of Neurosurgery
Medical University of South Carolina
Charleston, South Carolina

Chad W. Washington, MS, MD, MPHS
Assistant Professor
Department of Neurological Surgery
University of Mississippi Medical Center
Jackson, Mississippi

Vincent D. Wekesa, MD
Department of Surgery
College of Health Sciences
University of Nairobi
Kenyatta National Hospital
Nairobi, Kenya

Hung Tzu Wen, MD
Assistant Professor
Division of Neurosurgery
Hospital das Clínicas, College of Medicine
University of São Paulo
São Paulo, Brazil

Jonathan White, MD
Professor of Neurosurgery
University of Texas Southwestern Medical Center
Dallas, Texas

Yasuhiro Yamada, MD, PhD
Lecturer
Department of Neurosurgery
Fujita Health University
Banbuntane Hotokukai Hospital
Nagoya City, Japan

Kazuhiro Yamanaka, MD, PhD
Associate Professor
Department of Neurosurgery
Osaka City University Graduate School of Medicine
Osaka, Japan

Tong Yang, MD, PhD
Staff Pediatric Neurosurgeon
Department of Neurosurgery
Sanford Health Fargo Medical Center
Fargo, North Dakota

Gregory J. Zipfel, MD, FAHA, FACS
Associate Professor and Residency Program Director
Department of Neurological Surgery
Washington University School of Medicine
St. Louis, Missouri

Ibrahim M. Ziyal, MD
Professor
Department of Neurosurgery
Marmara University School of Medicine
Istanbul, Turkey

Glossary of Abbreviations

AABB, American Association of Blood Banks
ABO, blood groups (A, B, AB, O)
ACA, anterior cerebral artery
AChA, AChoA, AChor, anterior choroidal artery
AComm, anterior communicating artery
ACP, anterior clinoid process
ADP, adenosine diphosphate
AHA, American Heart Association
AICA, anterior inferior cerebellar artery
AmbC, ambient cistern
AN, aneurysm
Ant temp a, anterior temporal artery
AP, anteroposterior
aPCC, activated prothrombin complex concentrates
AT, antithrombin
AVM, arteriovenous malformations
BAEP, brainstem auditory evoked potential
BA, Bas A, basilar artery
BT, basilar tip
CA, intracellular calcium
CaRESS, carotid revascularization using endarterectomy or stenting systems
CAS, carotid angioplasty and stenting
CAVATAS, Carotid and Vertebral Transluminal Angioplasty Study
CBF, cerebral blood flow
CBV, cerebral blood volume
CCA, common carotid artery
CCF, carotid-cavernous fistulas
CEA, carotid endarterectomy
CenV, central vein
ClinSeg, clinoidal segment
CM, cavernous malformations
CmaA, callosomarginal artery
CMAP, compound muscle action potential
CMD, cerebral microdialysis
CO, carotid-ophthalmic
COM, carotid-oculomotor membrane
CP, cerebellopontine
CPP, cerebral perfusion pressure
CREST, Carotid Revascularization Endarterectomy versus Stenting Trial
CruC, crural cistern
CSF, cerebral spinal fluid
CT, CTP, computed tomagraphy
CTA, computed tomography angiogram
CVP, central venous pressure
CVS, cardiovascular system
CXR, chest x-ray
DACA, distal anterior cerebral artery
DAVF, dural arteriovenous fistulas
DCI, delayed cerebral ischemia
Deepsylv, deep sylvan vein
DR, dural ring
DSA, digital subtraction angiography
DVA, developmental venous anomaly
EACA, epsilon amino-caroic acid
EC, extracranial
ECA, external carotid artery
ECIC, extracranial-intracranial
EKG, electrocariography
EMG, electromyographic activity
EPD, embolic protection device
EVA-35, endarterectomy versus stenting in patients with symptomatic severe carotid stenosis
F, French
FDA, Food and Drug Administration
FFP, fresh frozen plasma
FIO_2, fractional inspired oxygen
FLAIR, fluid-attenuated inversion recovery
FrSylV, frontal sylvan vein
FTOZ, frontotemporal-orbitozygomatic
GDC, Guglielmi detachable coil
GIA, giant intracranial aneurysm
GSPN, greater superficial petrosal nerve
Hb, hemoglobin
Hct, hematocrit
HLA, human leukocyte antigens
IAC, internal auditory canal
IADSA, intra-arterial digital subtraction angiography
IC, intracranial
ICA, internal carotid artery
ICG, intraoperative indocyanine green
ICH, intracerebral hemorrhage
ICP, intracranial pressure
ID, inner diameter
I, II, III, etc., cranial nerves are expressed by capital roman numerals
IF, inferior fornix
INR, international normalization ration
IT, inferior trunk
IU, international units
LAO, left anterior oblique
LRC, lateral retrocantal approach
LSA, lenticulostriate arteries
LSR, lateral spread response
MAP, mean arterial pressure
MCA, middle cerebral artery
MedFrV, medial frontal vein
MEP, motor-evoked potentials

MI, myocardial infarction
MRA, magnetic resonance angiogram
MRI, magnetic resonance imaging
mRS, modified Rankin score
MRV, magnetic resonance venography
µC, microcoloumb
µS, microsecond
NA, N/A, not available
nBCA, *N*-butyl 2-cyanoacrylate
NCS, Neurocritical Care Society
NO, nitric oxide
OA, occipital artery
ONP, oculomotor nerve palsy
OphA, OphArt, ophthalmic artery
OphSeg, ophthalmic segment
OS, optic strut
PC, posterior clinoid
PCA, posterior cerebral artery
PcaA, contralateral pericallosal artery
PCC, prothrombin complex conentrates
PCP, posterior clinoid process
PCoA, PCom, posterior communicating artery
PED, pipeline embolization device
PGE2, prostaglandin Es
PGI2, prostaglandin I2
PICA, posterior inferior cerebellar artery
Post Com A, posterior communicating artery
PRBC, packed red blood cells
PreCenV, precentral vein
PT, prothrombin time
PVA, polyvinyl alcohol
QuadC, quadrigeminal cistern
RAG, radial artery graft
RAO, right anterior oblique
RBC, red blood cells
RHV, rotating hemostatic valve
S, symptomatic
SAH, subarachnoid hemorrhage
Saph, saphenous
SAPPHIRE, stenting and angioplasty with protection in patients at high risk for endarterectomy
SCA, superior cerebellar artery
sEMG, spontaneous electromyographic activity
SEP, somatosensory evoked potential
SHA, superior hypophyseal artery
SLC, superior lid crease
SIADH, syndrome of inappropriate antidiuretic hormone
SOF, superior orbital fissure
SPACE, stent-protected angioplasty versus carotid endarterectomy
Supsylv, superficial sylvan vein
ST, superior trunk
STA, superficial temporary artery
STA-SPA, superficial temporal artery-posterior cerebellar artery
STA-SCA, superficial temporal artery-superior cerebellar artery
Suphypart, superior hypophyseal artery
Supraclin, supraclinoid
SVG, saphenous vein graft
TACO, transfusion-associated circulatory overload
TCD, transcranial Doppler
TBI, traumatic brain injury
tcMEP, transcranial motor-evoked potential
tEMG, triggered electromyographic activity
TF, tissue factor
Th Perf A, posterior thalamoperforating arteries
TIA, transient ischemic attack
TIVA, total IV anesthesia
TLR, target lesion revascularization
TONES, transorbital endoscopic approaches
TRALI, transfusion-related acute lung injury
TTP, time to peak
U, units
V, large pressure wave visible in electrocardiograms
VA, Vert a, vertebral artery
VBA, vertebrobasilar arteries
VBJ, vertebrobasilar junction
VEP, visual evoked potentials
VWf, Von Willebrand factor
VOGM, vein of Galen malformations
WBC, white blood cells
WBDP, whole-blood derived platelets
WFNS, World Federation of Neurosurgical Societies
WHO, World Health Organization

Section I General Principles and Basic Techniques

1 General Techniques of Cranial Exposure

Tong Yang, Huy T. Duong, Alessandra Mantovani, and Laligam N. Sekhar

The aims of cranial exposure are to create a safe passage to reach an intracranial pathology while minimizing the need to traverse critical neurovascular structures, to provide an adequate working space to address the pathology while limiting excessive retraction of the surrounding tissues, and to achieve the goals of surgery while avoiding significant cosmetic disfigurement. The history of modern neurosurgery reflects the continued advancements in the understandings of anatomy, tools of surgery, and outcomes of patients.

1.1 Operating Room Setup

1.1.1 Communication and Team Effort

If we compare cranial surgery to an orchestral performance, the surgeon is the conductor who needs to ensure the harmonious integrations of the actions of all the staff involved in the case, which includes the anesthesia team, the scrub and circulating nurses, the residents, and neuromonitoring personnel. The surgical plan should be discussed with the anesthesiologist before the operation, and any medical problems of the patient should be appropriately evaluated before the operation. Any special needs, such as burst suppressor, adenosine-induced cardiac arrest, and so forth, should be discussed with the anesthesiologist. The scrub team should be aware of the operative plan, and all needed equipment and instruments should be prepared before the surgery. Circulating and scrubbing personnel should be experienced in neurosurgical cases, and especially in complex procedures, so that they can anticipate a surgeon's needs, follow the progression of the case, and be apt at handling specialized surgical instruments and equipment. A surgical engineer in the operating room is an essential addition to the team, for modern neurosurgery has much complex equipment, some of which may fail and cause problems during the case, requiring an engineer for troubleshooting (**Fig. 1.1**). Continual communication throughout the case is necessary to ensure that the entire team focuses on the procedure and solves problems arising during the case. A quiet environment with limited distractions and properly positioned monitors to broadcast the progression of the case facilitates a smooth team effort. Preoperative imaging should be displayed where the surgeon can easily study it intraoperatively for details if needed.

1.1.2 Green, Yellow, Red System during Surgery

A system of green, yellow, and red signals has been devised by the senior author (LNS) in collaboration with a neuroanesthesiologist to signify alert levels during the surgery. A green level implies a lower level of alertness, such as craniotomy opening or closure. Good communication and standardized quality measures are maintained. However, some joviality, including a low

Fig. 1.1 Nelson Argana, the surgical engineer working at Harborview Medical Center in Seattle, is checking the surgical microscope and the stereotactic guidance machine before an operation.

level of music, may be permitted. A yellow level means that the surgeon is working under the surgical microscope or the endoscope. We usually turn the music off in such a case. Both the attending surgeon and anesthesiologist must be in the immediate vicinity of the patient, and the level of communication must be at its highest. A red level indicates a state of emergency—for example, excessive bleeding from the wound resulting from a ruptured aneurysm; adenosine-induced cardiac arrest; dissection of a complex aneurysm; temporary occlusion for a bypass procedure requiring burst suppression; or cardiac arrest in the patient. The attending surgeon should be scrubbed, and the anesthesiologist should be in the room. The level of communication should be higher. The circulating and scrub nurses should anticipate the needs of the surgical team. An additional circulator might need to be called into the room, and existing equipment, especially the suction machine, should be checked.

1.1.3 Ergonomics and Equipment

Numerous kinds of equipment are needed in a complex cranial case. The operating room can get crowded quickly accommodating all that is needed, so ensuring sterility of the operative field might be challenging. Preoperative planning with the operating room staff is vital to ensure that the surgeon gets the equipment needed during the correct stage of the planned procedure. Additionally, the placement of the equipment must be properly planned to optimize available space (**Fig. 1.2**). We usually open and close a craniotomy with the surgeon standing, whereas the microscopic portion is usually done with both the surgeon and the assistant seated comfortably (**Fig. 1.3**). Endoscopic surgery is also usually performed standing. The operating table is set at a height at which the surgeon can comfortably perform the surgery with elbows bent and shoulders relaxed while sitting. Considerations should also ensure that scrub personnel can reach the surgeon and the scrub table without obstruction and swiftly (**Fig. 1.4**). When the surgeon is working under the microscope or holding an endoscope, a stable arm rest or side table should be considered to steady the operating hands, decrease fatigue, and facilitate handing over of surgical instruments. Adjustable chairs are routinely used for microsurgical cases to ensure the surgeon's comfort (**Fig. 1.3** and **Fig. 1.5**).

Operating Table

Neurosurgical operating tables have special requirements, needing to go lower than standard operating tables do while tilting up and down and rotating from side to side. When intraoperative angiography is needed, a radiolucent table is preferred. Patients are normally positioned on the table with the table reversed 180° so that the foot end is at the head of the patient. This arrangement will accommodate the Mayfield (Schaerer Mayfield Holding AG; Nidau, Switzerland) or Doro (Eschmann; West Sussex, UK) head rests. The senior author has also designed side rail–attached bolsters to support the patient after the patient is appropriately positioned. The patient's body and legs are usually also taped, and a "tilt test" is performed by turning the table from side to side and tilting it up and down. After the patient is placed in pin head rests, the neck should not be flexed by flexing the table; rather, a Trendelenburg or a reverse Trendelenburg position is used to raise or lower the head.

Microscope and Endoscope

The operating microscope should be turned on and checked before the procedure. Depending on the side and site of the surgery, the observer's viewing optics need to be placed in the correct position and set at the correct viewing mode before the microscope is balanced. For surgeons who use a mouthpiece to control the microscope, and for operations employing neuronavigation or needing intraoperative indocyanine green (ICG) angiography, the needed attachment and functional compatibilities should be checked before the procedure. An endoscope, if used, needs to be white balanced and focused to ensure adequate imaging quality. The irrigation system for the endoscope needs to be checked to ensure that the scope is being cleared when the system is activated.

Bipolar Cautery

Bipolar diathermy is an indispensable tool in modern cranial surgery. Depending on the structures needing coagulation, one can choose different settings of current. Bipolar forceps having different lengths, and different tip diameters and angles may be used (**Fig. 1.6** and **Fig.1.7**). An integrated irrigation attachment,

Fig. 1.2 This operating room has been set up for a right-sided craniotomy. The microscope is positioned at the head of the bed, and the power outlets for the monopolar and bipolar cauteries, electric drill, and ultrasonic aspirator are positioned at the foot of the operating table, stacked on shelves to save space. The anesthesiologist and her equipment are located on the side, opposite the side of the surgery.

Fig. 1.3 A typical room setup for a craniotomy during the microsurgical portion of the case under the microscope. The senior surgeon (LN Sekhar) is sitting on an adjustable chair that has been draped with sterile coverings. The scrub technician (Molly Merritt) is on his right with commonly used microinstruments set up on an adjustable table, easily accessible by both the surgeon and the scrub technician. The scrub technician also has easy access to the back tables behind her to reach for other instruments as needed.

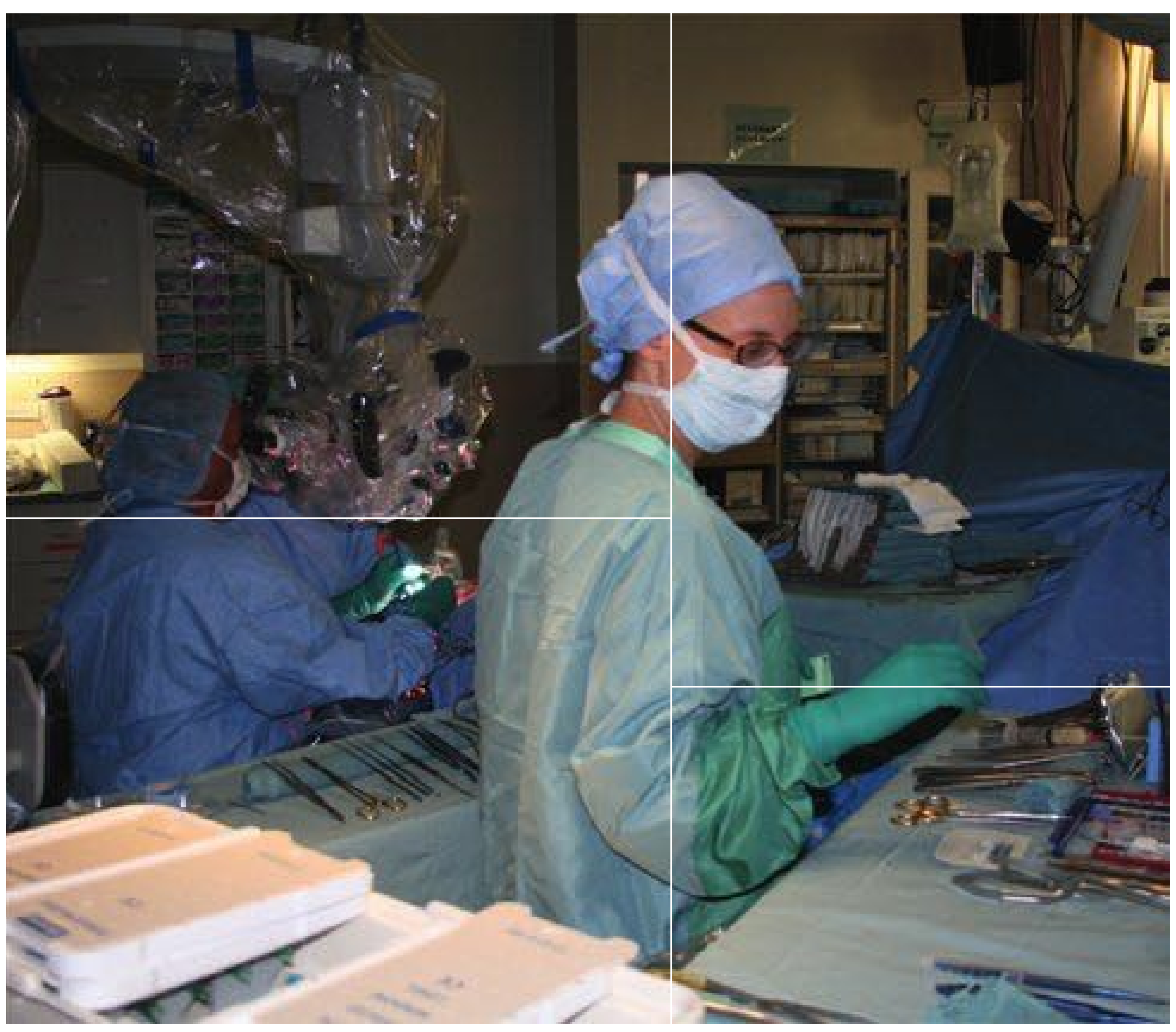


Fig. 1.4 Another view of the room setup during the microsurgical portion of a craniotomy. The scrub technician can easily access the table holding routinely used microinstruments to her left, as well as the back tables, where more instruments are located, to her right. The table behind her back has racks of aneurysm clips placed on top.

Fig. 1.5 An intraoperative view showing the adjustable chair for the assistant (Dr. HT Duong). The chair is draped with sterile coverings.

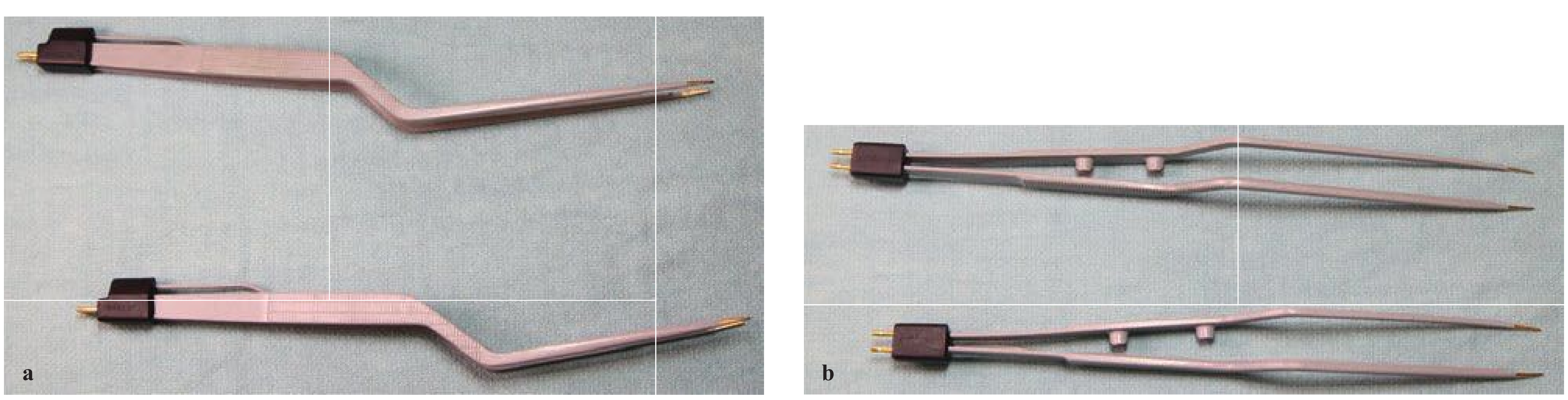


Fig. 1.6 (**a,b**) Short and long irrigating bipolar cautery forceps.

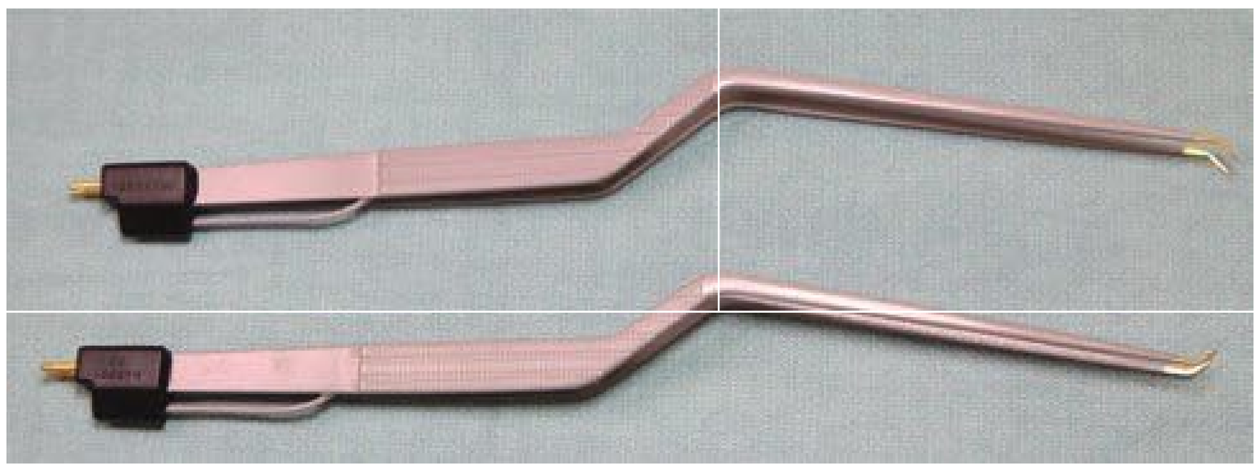


Fig. 1.7 Irrigating bipolar cautery forceps with downward- or upward-bending tips.

preferred by the senior author, is used to avoid sticking and also to clean the field. A nonsticking tip is also useful along with the irrigation. Alternatively, a nonsticking bipolar forceps may be employed, with the assistant providing irrigation. The bleeding point should be identified precisely by suction and/or gentle pressure before coagulation. Short bursts of coagulation are preferred over excessive prolonged charring of the tissue but should be balanced by sufficient duration of coagulation to ensure complete cessation of bleeding.

Surgical Drills

Surgical drills can be either air-powered or electrically powered (**Fig. 1.8, Fig. 1.9,** and **Fig. 1.10**). The turn-on switch can be controlled either by hand or by foot. Although it is a matter of personal preference, we like the foot-controlled mode for allowing greater precision during the surgery. A perforator or an acorn drill bit is used to create initial bur holes. Continued irrigation should be present when using a perforator to ensure that bone dust does not clog the tip and risk impairing the stopping mechanism.[1] For delicate drilling of bony structures near critical structures, finer bits, including rough and fine diamond drill bits, should be used to ensure precision and safety. An irrigation attachment to the drill or irrigation provided by an assistant is necessary to remove bone dust and to decrease/avoid thermal injury. We also use an ultrasonic bone curette (**Fig. 1.11**) (Sonopet, Stryker; Kalamazoo, Michigan, USA) for bone removal in delicate areas and near critical structures. Ultrasonic and thermal injuries should be considered when the curette is used very close to a critical neurovascular structure. In contrast to the high-speed drills, cottonoids must be used to protect arteries or cranial nerves close to the tip of the Sonopet vibrating piece. We are very cautious using the ultrasonic bone curette to open the optic canal, for some cases of blindness have been reported as being related to the use of the curette, making a diamond drill better for this purpose. For procedures involving the removal of the nasal orbital bone, an orbitotomy, or an orbitozygomatic osteotomy, a reciprocating saw is used to cut the anterior margins of the bone.

Other Commonly Used Equipment

For tumor removal, different ultrasonic aspiration systems can be used for debulking. This tool can also be used for removal of brain tissue during tumor or epilepsy surgery. Depending on the consistency of the tissue and the area of resection, different strengths of aspiration can be set to ensure adequate suction and safety to the surrounding tissue at the same time (**Fig. 1.11** and **Fig. 1.12**). In some cases, the handheld CO_2 laser may be useful for precise removal and to reduce the bleeding (**Fig. 1.13**).

Neuronavigation has been used often to help design the original exposure site, to facilitate the localization of critical neurovascular structures, and to guide the identification of the underlying pathology, especially if it is a small lesion in an otherwise eloquent area. The location of the navigation system should be planned preoperatively so that the surgeon can comfortably see the guidance images intraoperatively, and the line of sight between the navigation camera and the patient or microscope is not obscured by other equipment in the room. Confirmative checks should be done to show the accuracy of the navigation to avoid misguidance. Rescue reference points may be set up on the patient's skull within the surgical field to achieve correction if the image guidance is found to be inaccurate intraoperatively.

Duplex ultrasound can also be used to locate a tumor during surgery and to supplement the neuronavigation system. A micro-Doppler probe is routinely used to evaluate the flow through an artery, graft, or vein during cerebral vascular and some tumor cases.

Surgical Instruments

There are numerous tools and instruments for cranial surgery. Depending on the nature of the case, the operating room staff should be alerted of any special instruments needed for the case before the procedure starts. For the initial opening, relatively large instruments, such as periosteal elevators, Kerrison and Leksell rongeurs, and Penfield, Edison, and Sacks dissectors, are used to elevate the musculocutaneous flap, remove the bone, and separate the dura from the skull (**Fig. 1.14**). For finer bony work, such

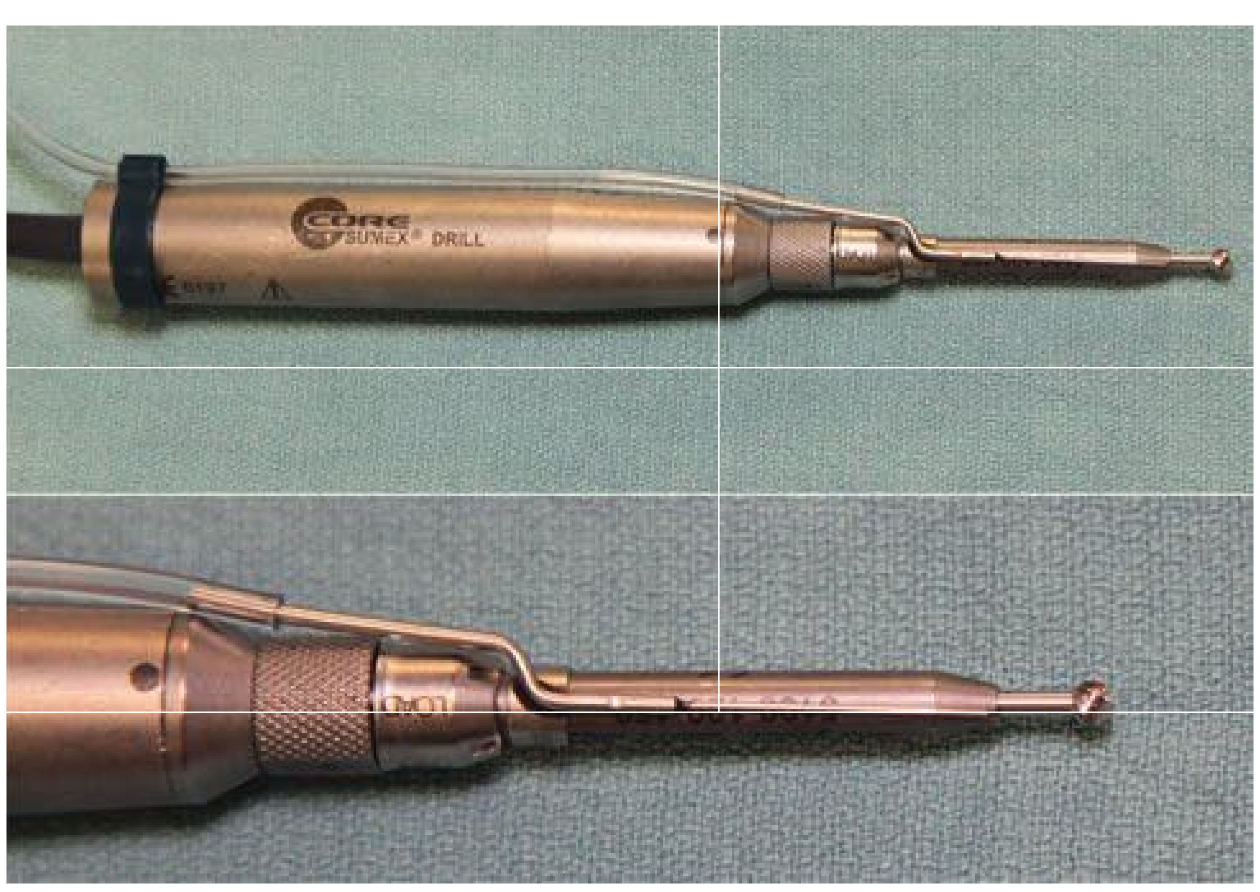


Fig. 1.8 An electrically powered foot-controlled drill with an attached 3-mm coarse-cutting bur, as well as the irrigation attachment.

Fig. 1.9 Various drill bit attachments for the drill. A perforator attachment is on the bottom, and the craniotome attachment is in the middle.

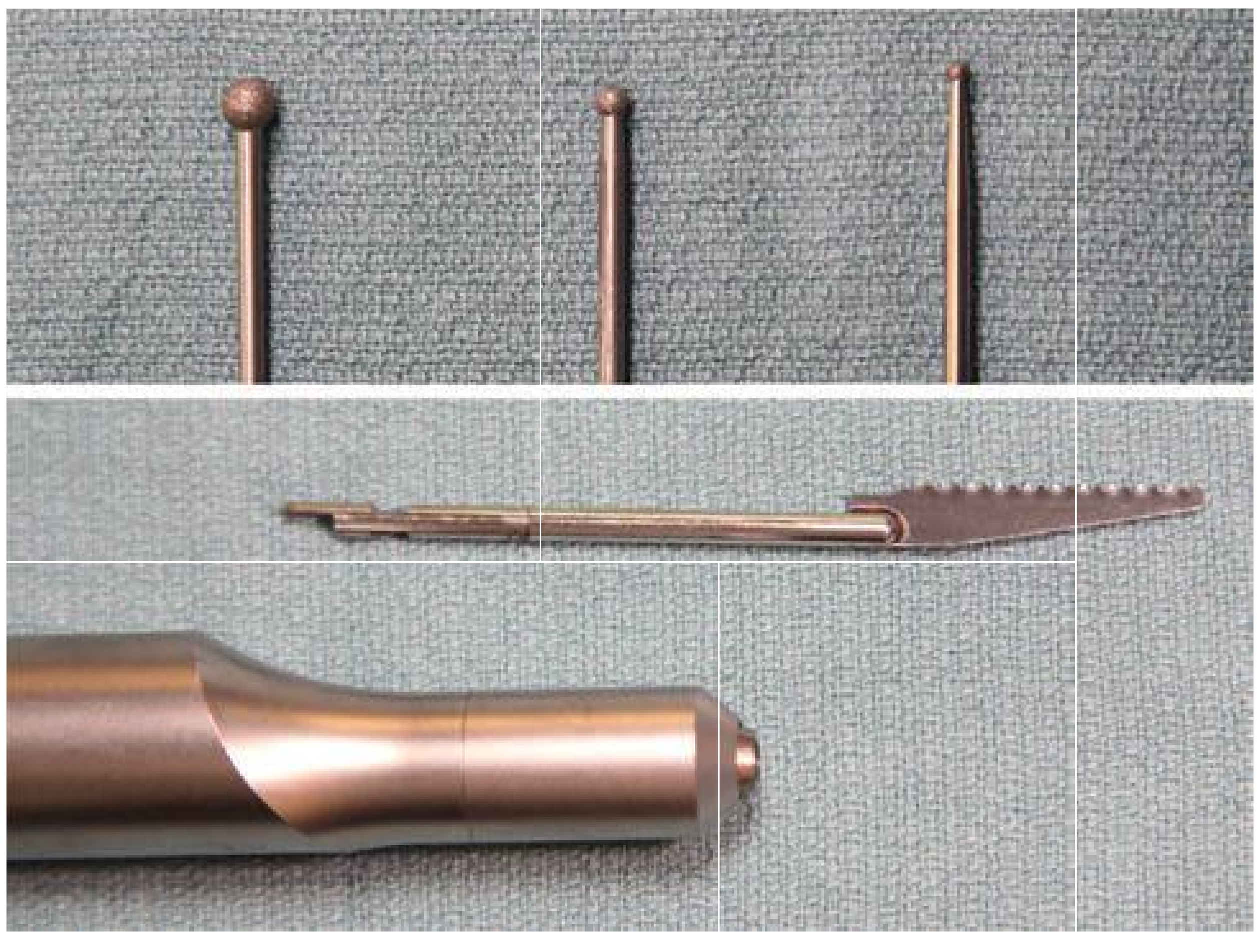


Fig. 1.10 Various sizes of diamond cutting bits. A reciprocating saw tip is at the bottom, used for osteotomies of the skull base.

Fig. 1.12 The Cavitron Ultrasonic Surgical Aspirator (CUSA) (Cooper Medical; Stamford, Connecticut, USA) for soft tissue aspiration, such as brain or tumor tissue.

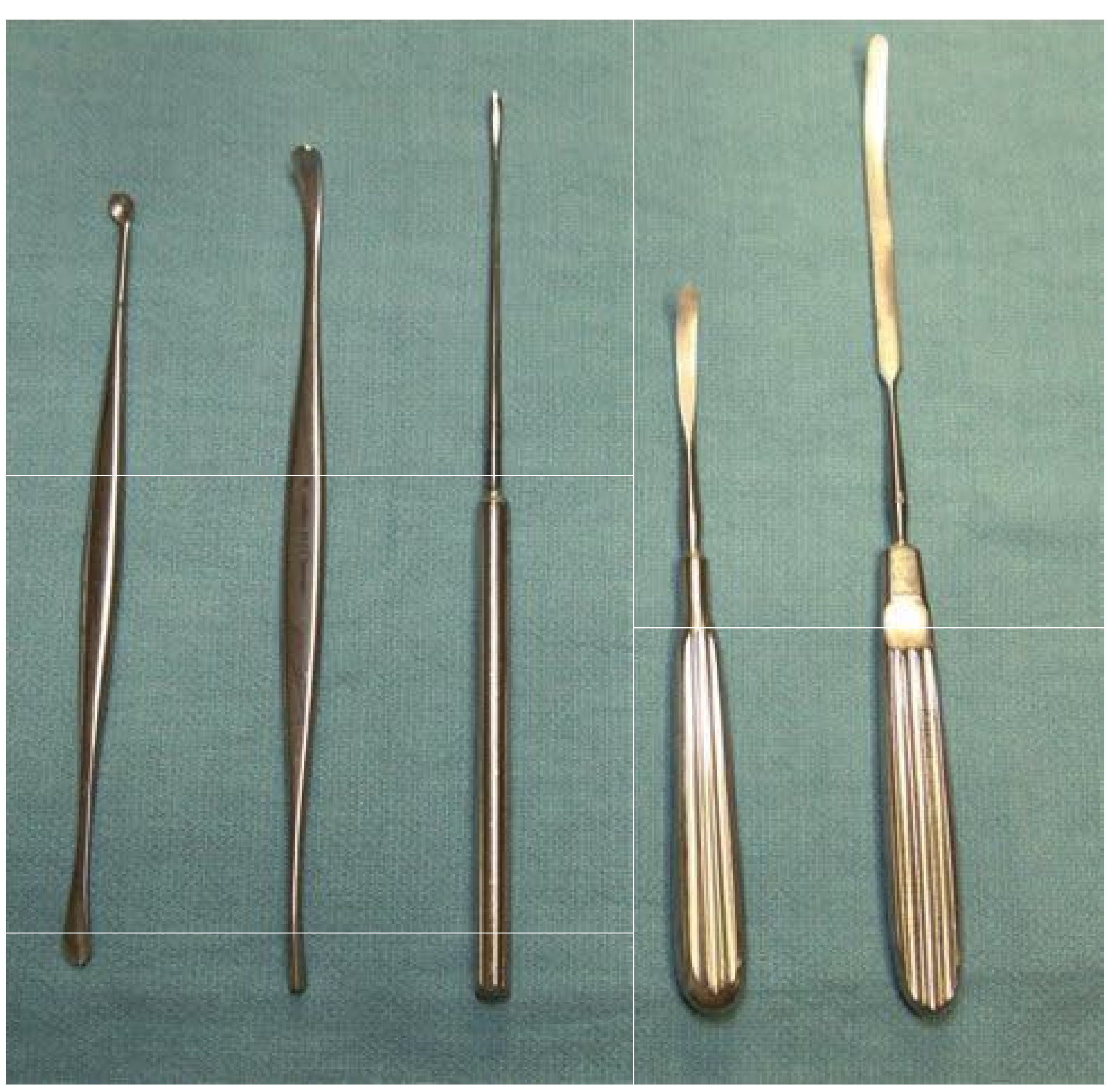


Fig. 1.14 Some of the commonly used instruments for the initial opening. From left to right: Penfield 1, 3, 4; Edison dissector; and Sacks dissector.

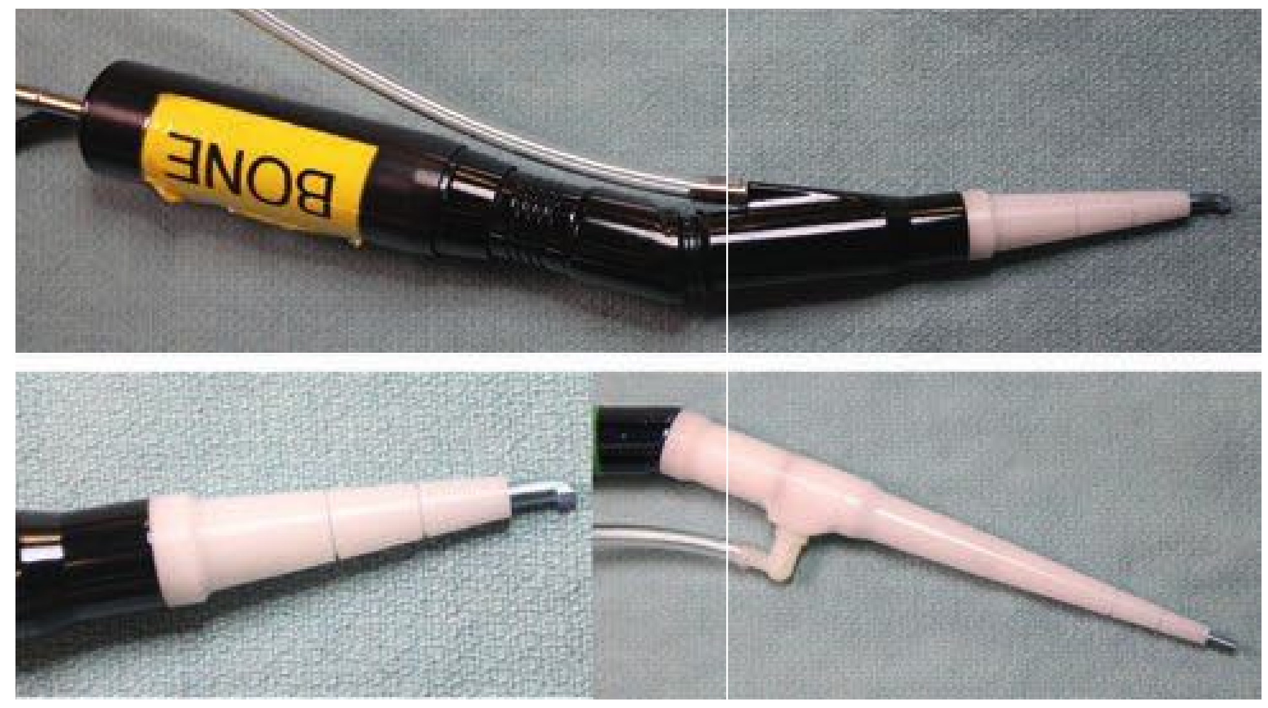


Fig. 1.11 The ultrasonic bone curette tip (top panel and bottom left). A soft tissue attachment is also available (bottom right) for aspiration of soft tissue, such as brain or tumor tissue.

Fig. 1.13 The Omniguide contact CO_2 laser, which can be used to remove some tumors.

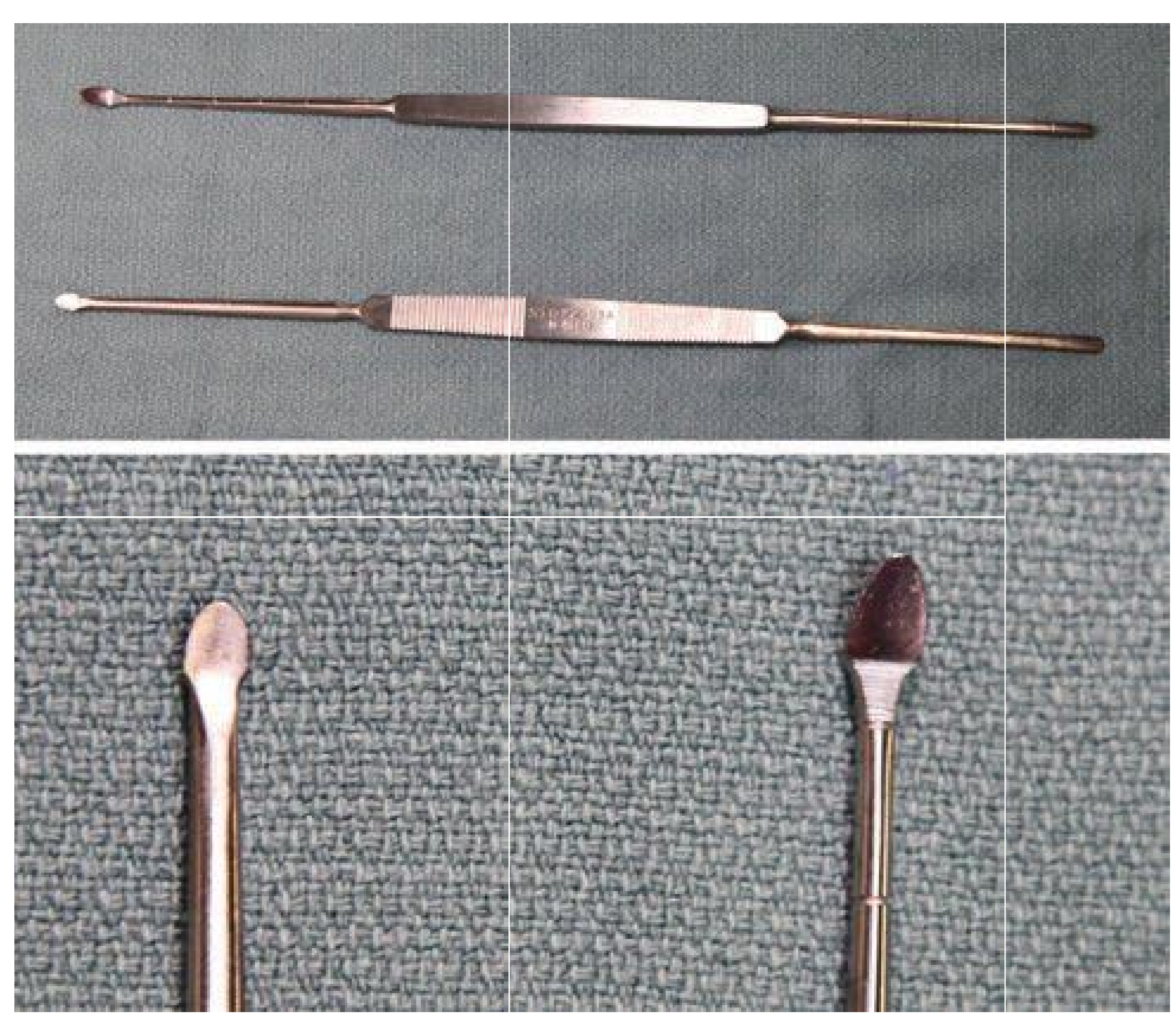


Fig. 1.15 Cottle elevators having either a straight (bottom left) or a bent tip (bottom right).

as unroofing of the superior orbital fissure (SOF), a Cottle elevator (**Fig. 1.15**) or Sekhar or Lempert rongeur can be used. After the dura is opened, micro surgical instruments are typically used. Commonly used Rhoton microinstruments include numbers 3, 6, 9, and 16 for dissections under the microscope (**Fig. 1.16**). Spetzler tumor forceps are routinely used for tumor dissection (**Fig. 1.17**). A diamond arachnoid knife (**Fig. 1.18**), sickle knife, or number 11 blade can be used to open the arachnoid linings of various cisterns. Micro scissors, straight or curved (**Fig. 1.19**), are also routinely used to transect structures. Aneurysm clips (Aesculap; Center Valley, Pennsylvania, USA; Mizuho America; Union City, California, USA), both temporary and permanent, are needed for vascular cases, including aneurysm, arterial venous malformation (AVM), and bypass procedures (**Fig. 1.20**). Various configurations of the clip may be needed depending on the anatomy of the aneurysm. The clip applier (**Fig. 1.21** and **Fig. 1.22**) can either have a locking mechanism or not, based on the surgeon's preference. For bypass procedures, micro needle holder (**Fig. 1.23** and **Fig. 1.24**; Scanlan International; St. Paul, Minnesota, USA), fine sutures (6–0 or 7–0 Prolene [**Fig. 1.25**] for extracranial vessels and 8–0 to 10–0 nylon [**Fig. 1.26**] for intracranial vessels), and tying forceps (**Fig. 1.27** and **Fig. 1.28**; Scanlan International) are needed to handle the small needle and delicate suture. Extended ring curettes are needed for transsphenoidal cases.

Self-retaining retractors are used for brain retraction as necessary. They are typically attached to the operating table or to the head holder (**Fig. 1.29**). A cottonoid patty with an appropriately cut piece of rubber glove (a "rubber dam") is routinely placed between the retractor blade and the underlying neural tissue to limit direct damage (**Fig. 1.30a,b**). The retractor must be stable to provide a reliable working field, but the retraction force should not be excessive, to avoid damaging the retracted tissue. With experience, the surgeon can learn the amount of retraction pressure that can be used, as well as the tension and the extent of the brain that can be retracted. It is generally best to allow the brain to retract by gravity, or intermittently with instru-

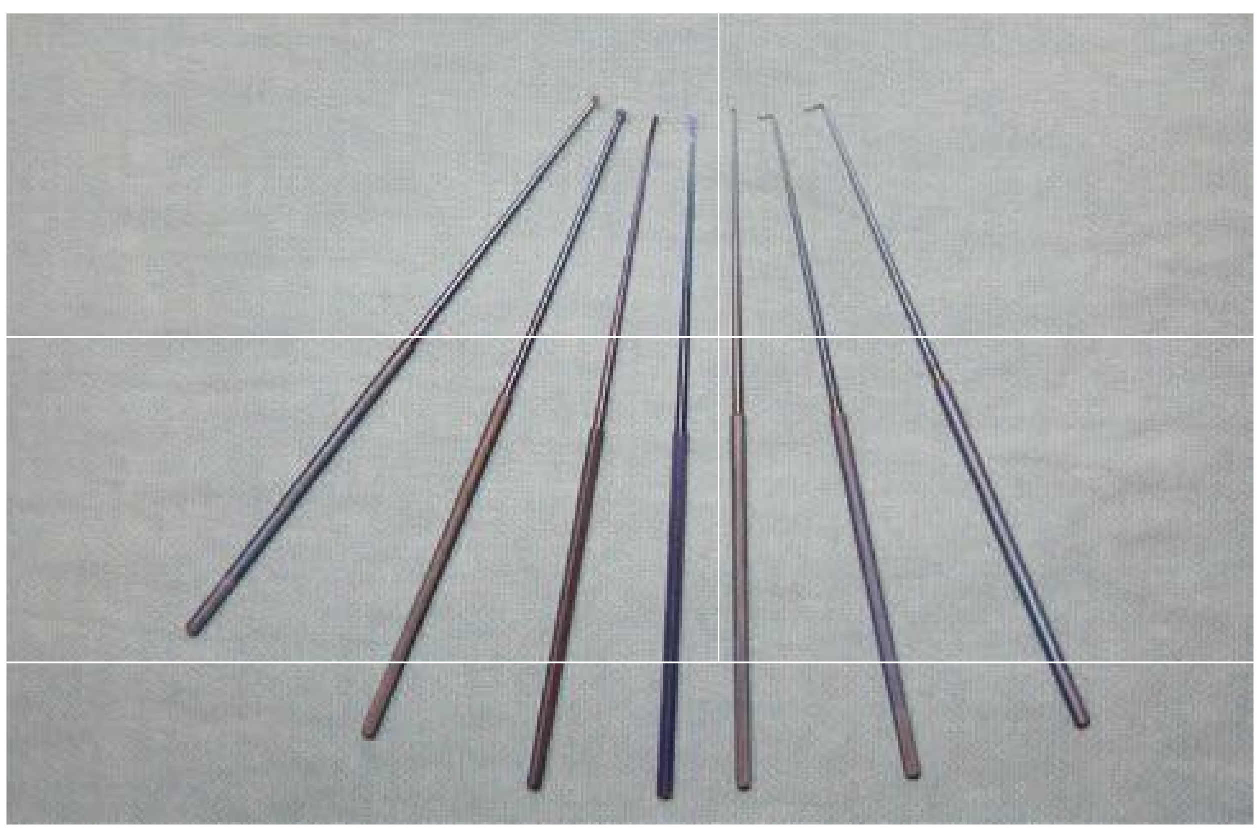


Fig. 1.16 Commonly used Rhoton micro instruments. From left to right: Rhoton 2, 3, 6, 7, 9, 16, 17.

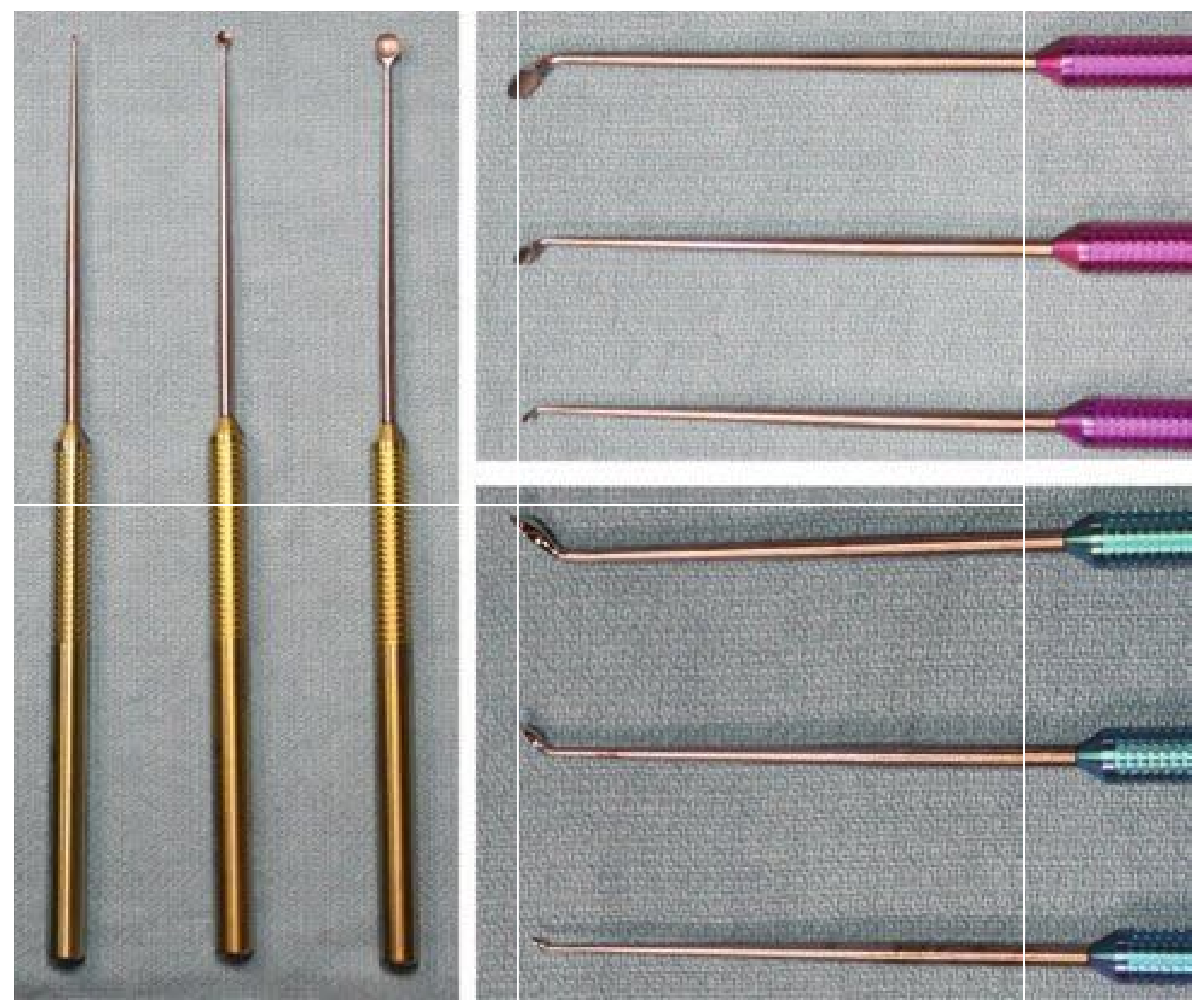


Fig. 1.17 Spetzler tumor curettes of various tip sizes: straight tip (left) and bent tip (right).

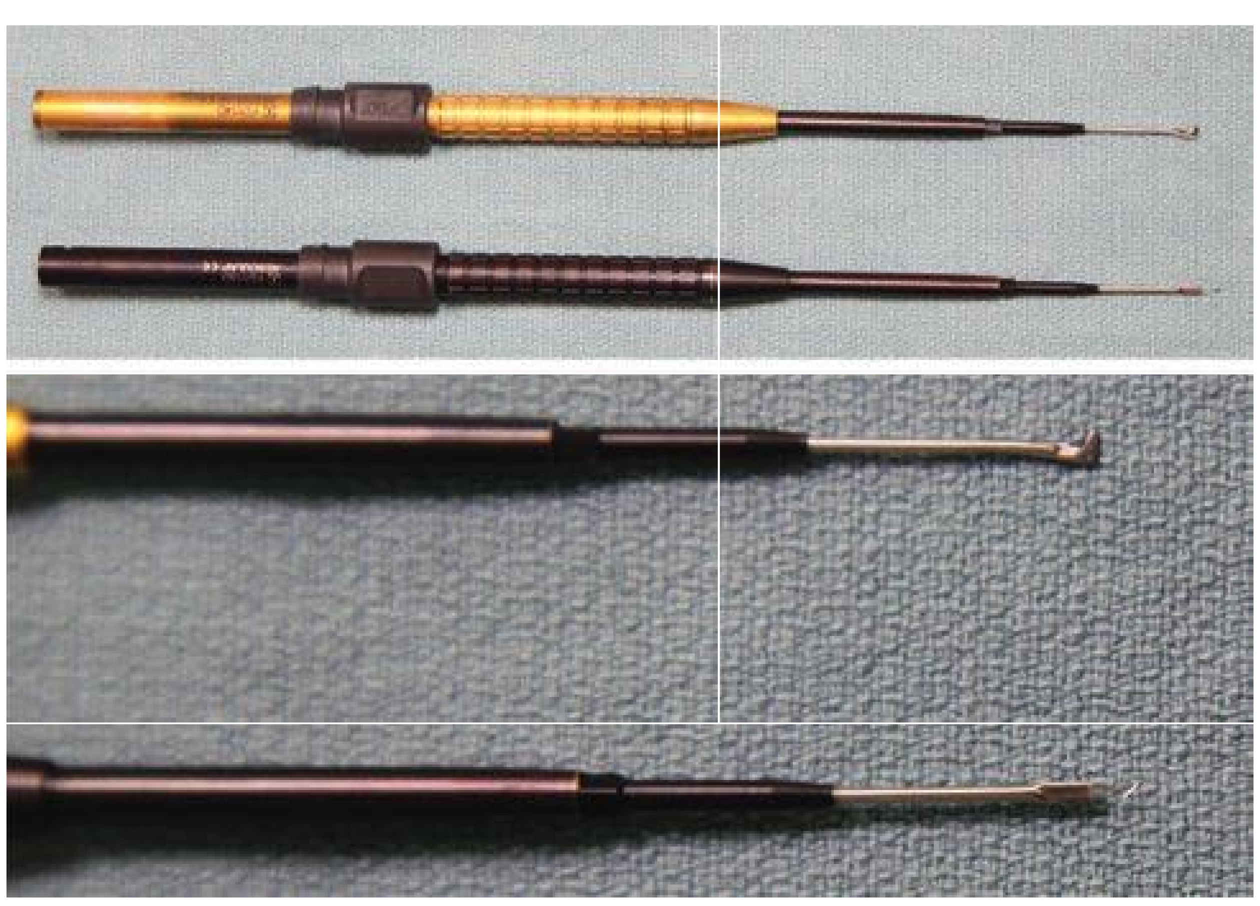


Fig. 1.18 Diamond arachnoid knives. Side cutting on top and straight on the bottom.

Fig. 1.19 Micro scissors with either straight or curved blades.

Fig. 1.20 Some examples of aneurysm clips, with permanent ones in the upper row and temporary ones in the lower.

Fig. 1.21 Aneurysm clip appliers and remover (top in the upper panel and on the right in the bottom panel).

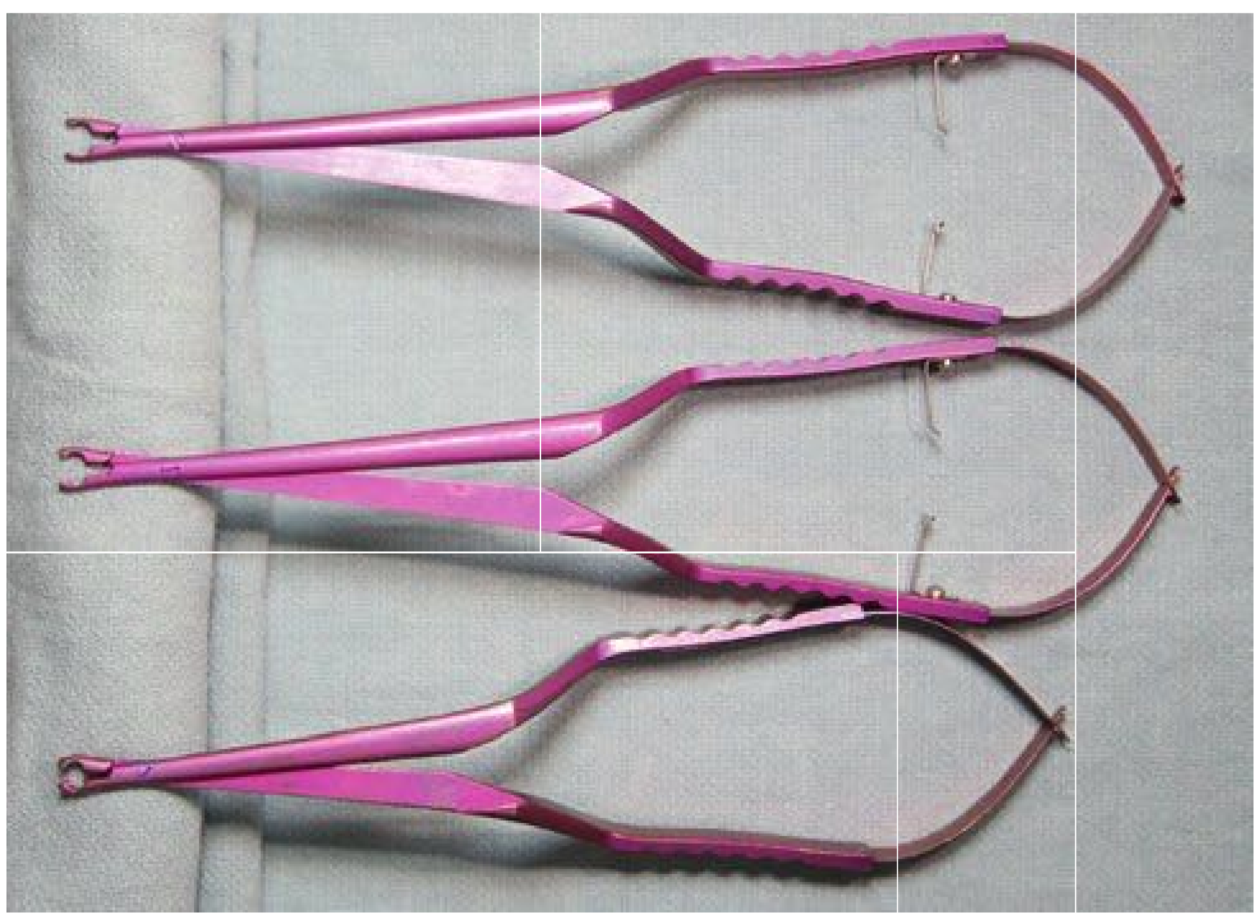


Fig. 1.22 Minianeurysm clip appliers and remover (top).

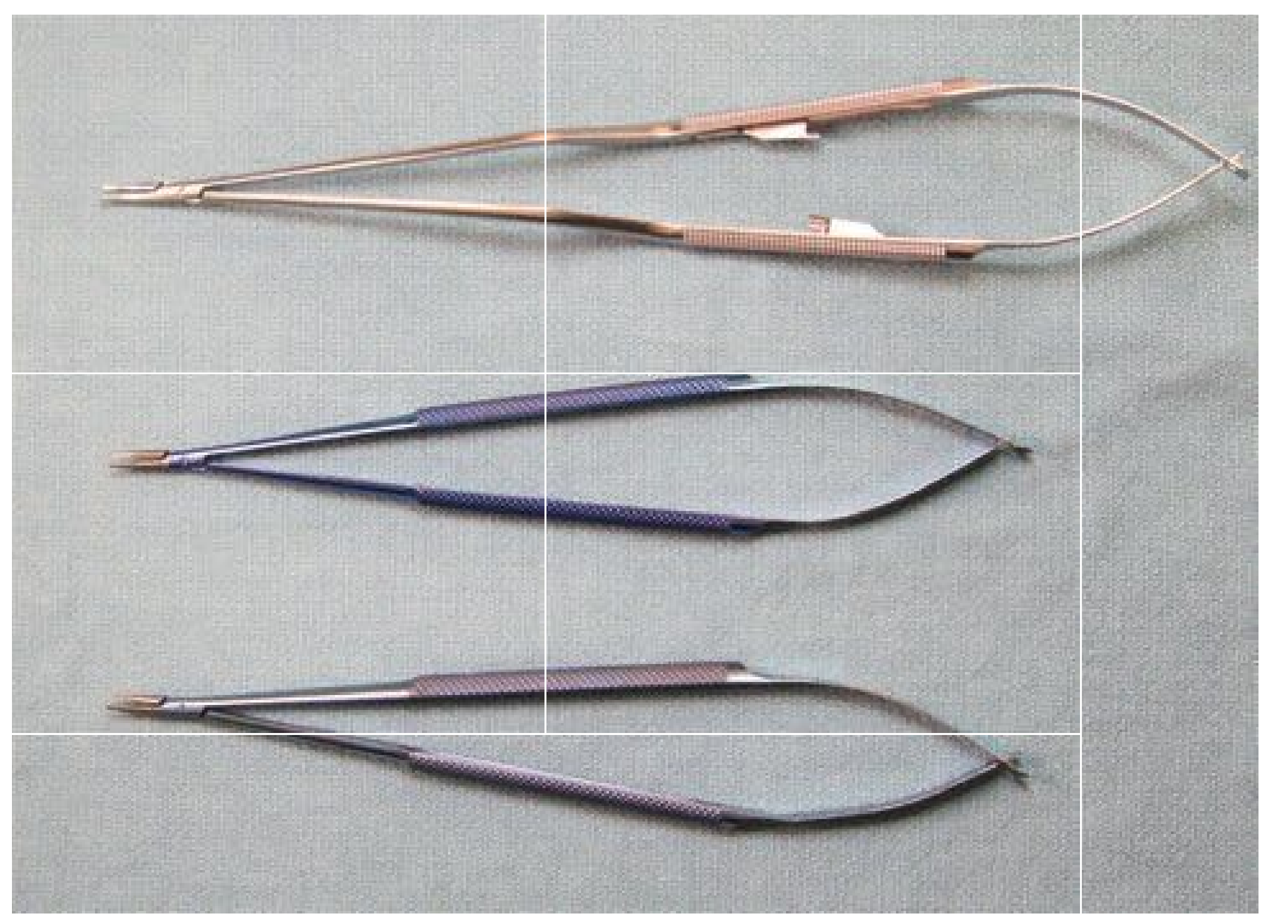


Fig. 1.23 Micro needle holders of various sizes.

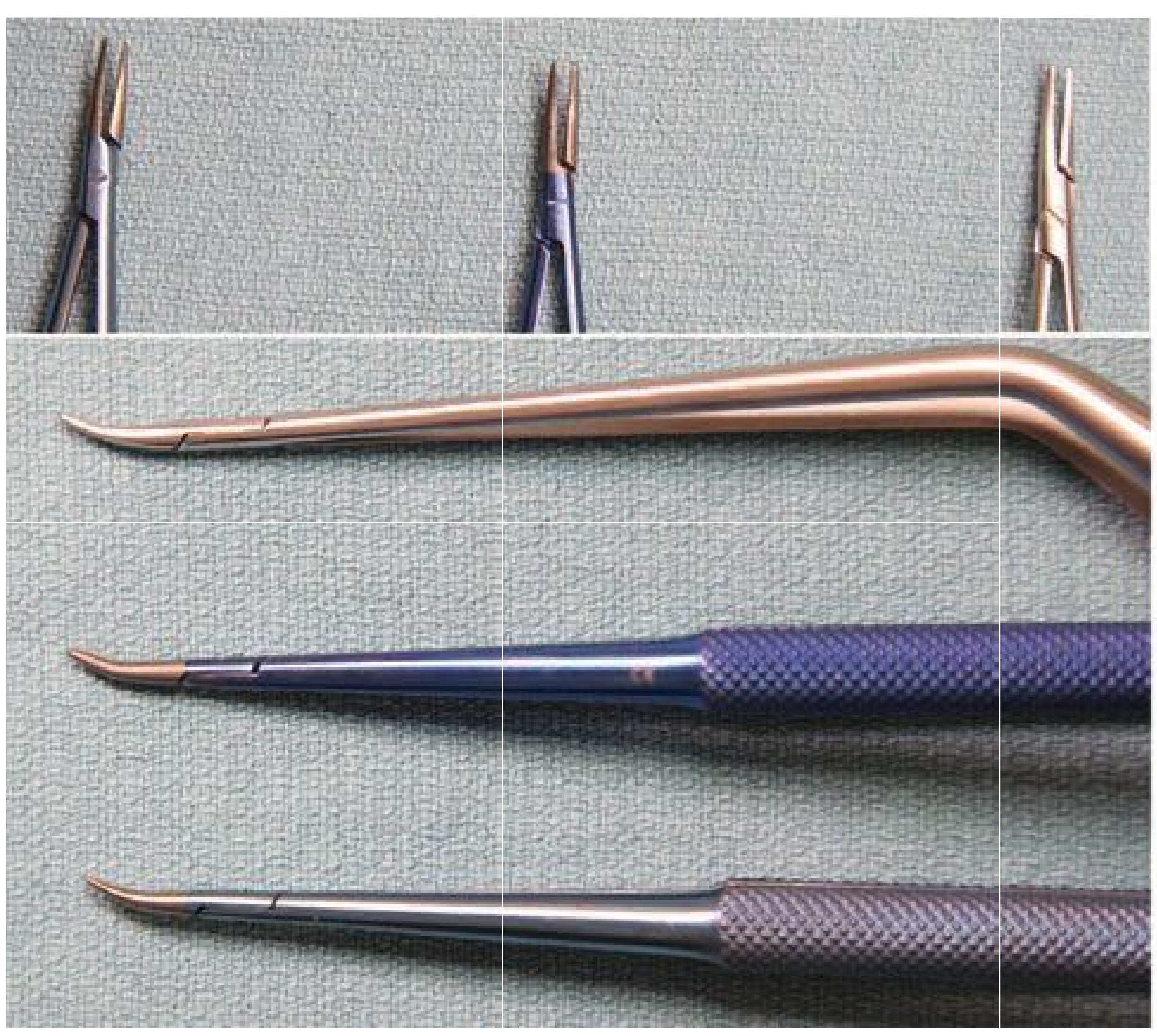


Fig. 1.24 Close-ups of various micro needle holders.

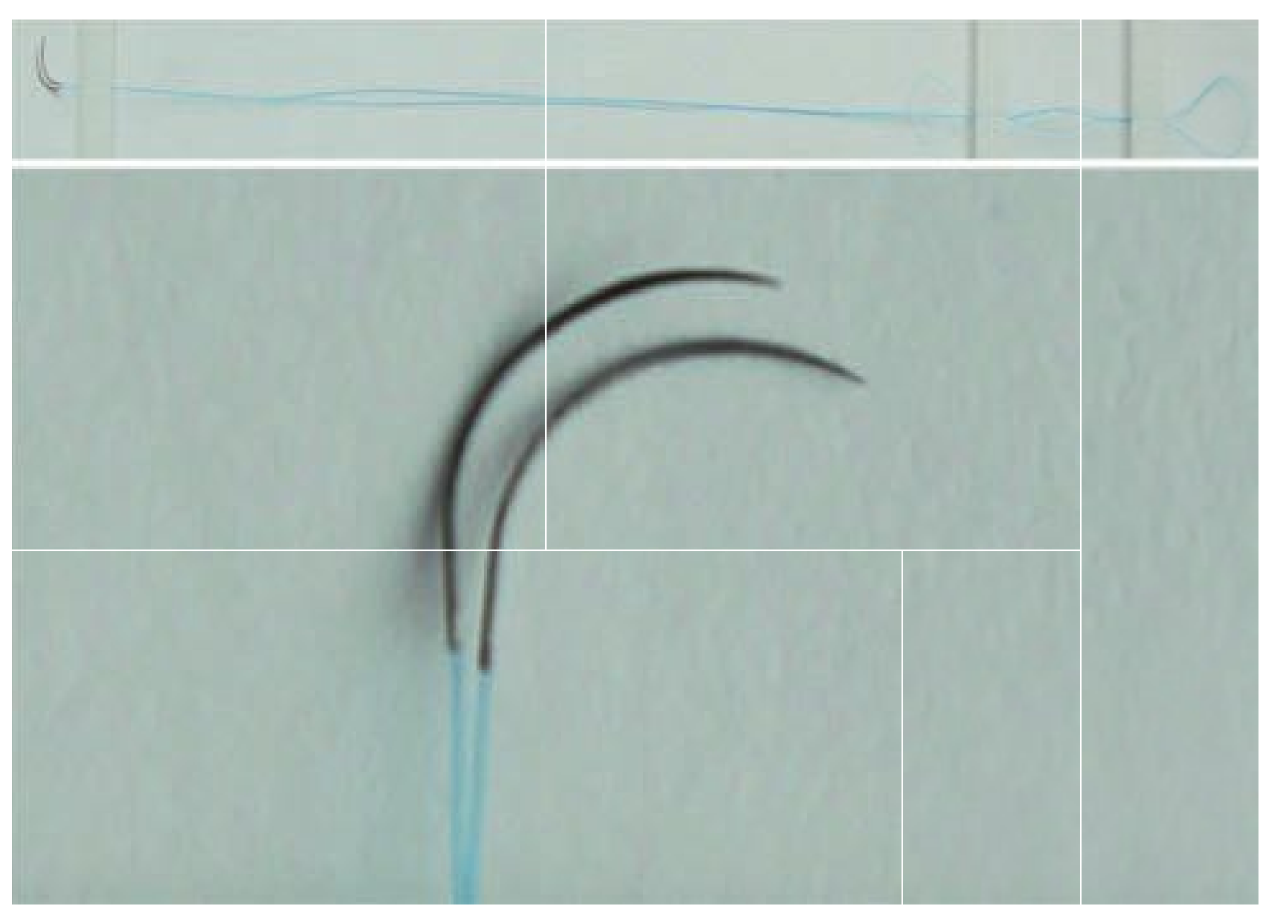


Fig. 1.25 7–0 Prolene suture for extra cranial suturing.

ments held in the surgeon's hand,[2] avoiding any self-retaining retractor. Diuretics, proper head position, cerebrospinal fluid drainage (cisternal opening, lumbar drains, ventriculostomy), good neuroanesthetic techniques, and adequate bony exposures will greatly soften the brain, allowing for minimal brain injury. If the brain is tight or if excessive retraction may be necessary, the resection of small amounts of noneloquent brain should be performed to avoid damaging large brain areas.

Suction tips can have various sizes and shapes. For microsurgical procedures, suction tips with small apertures and having thumb-adjustable side holes should be used to provide suction, gentle temporary retraction, and dissection/resection. The tip of the suction may be tapered or blunted (with a sleeve) at the tip to provide atraumatic suction (**Fig. 1.31**).

Fig. 1.26 8–0, 9–0, and 10–0 nylon sutures for intracranial bypasses.

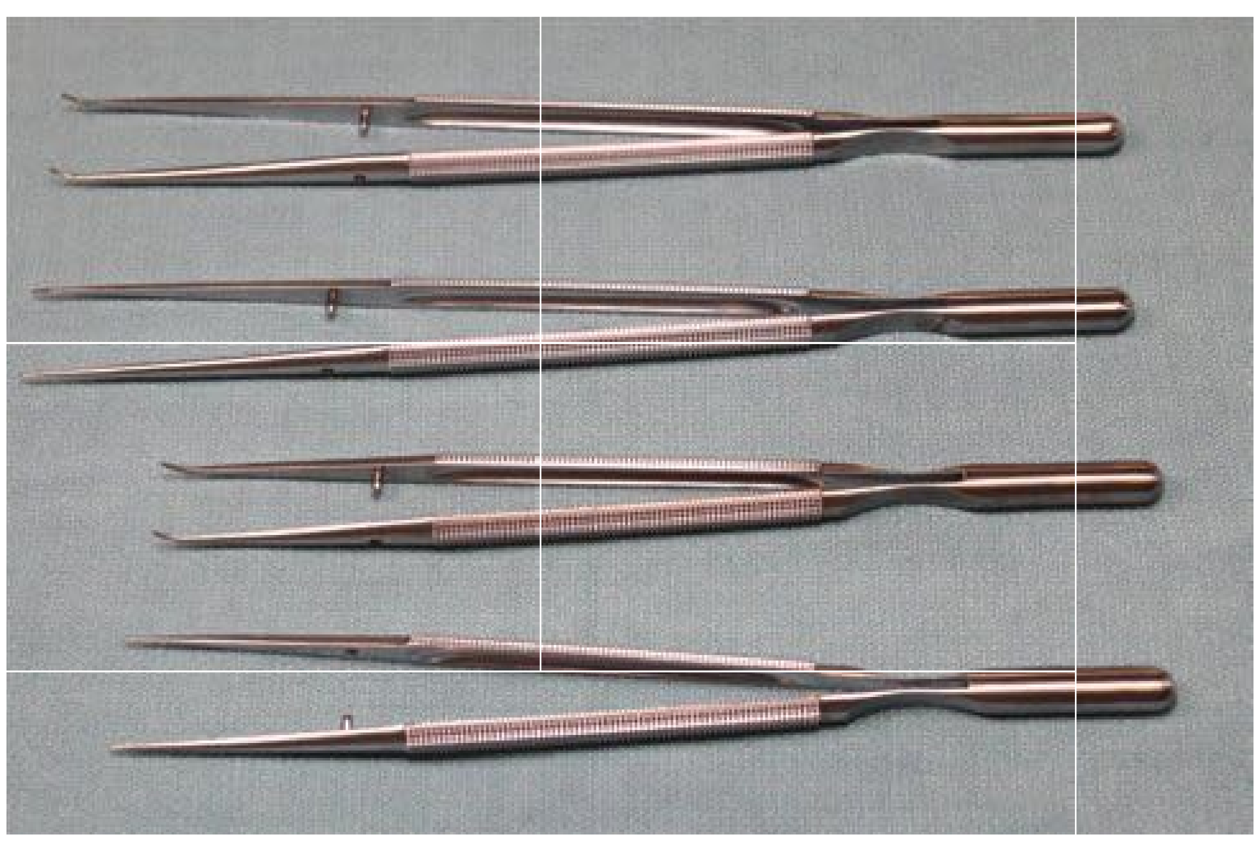


Fig. 1.27 Long tying forceps for bypass cases.

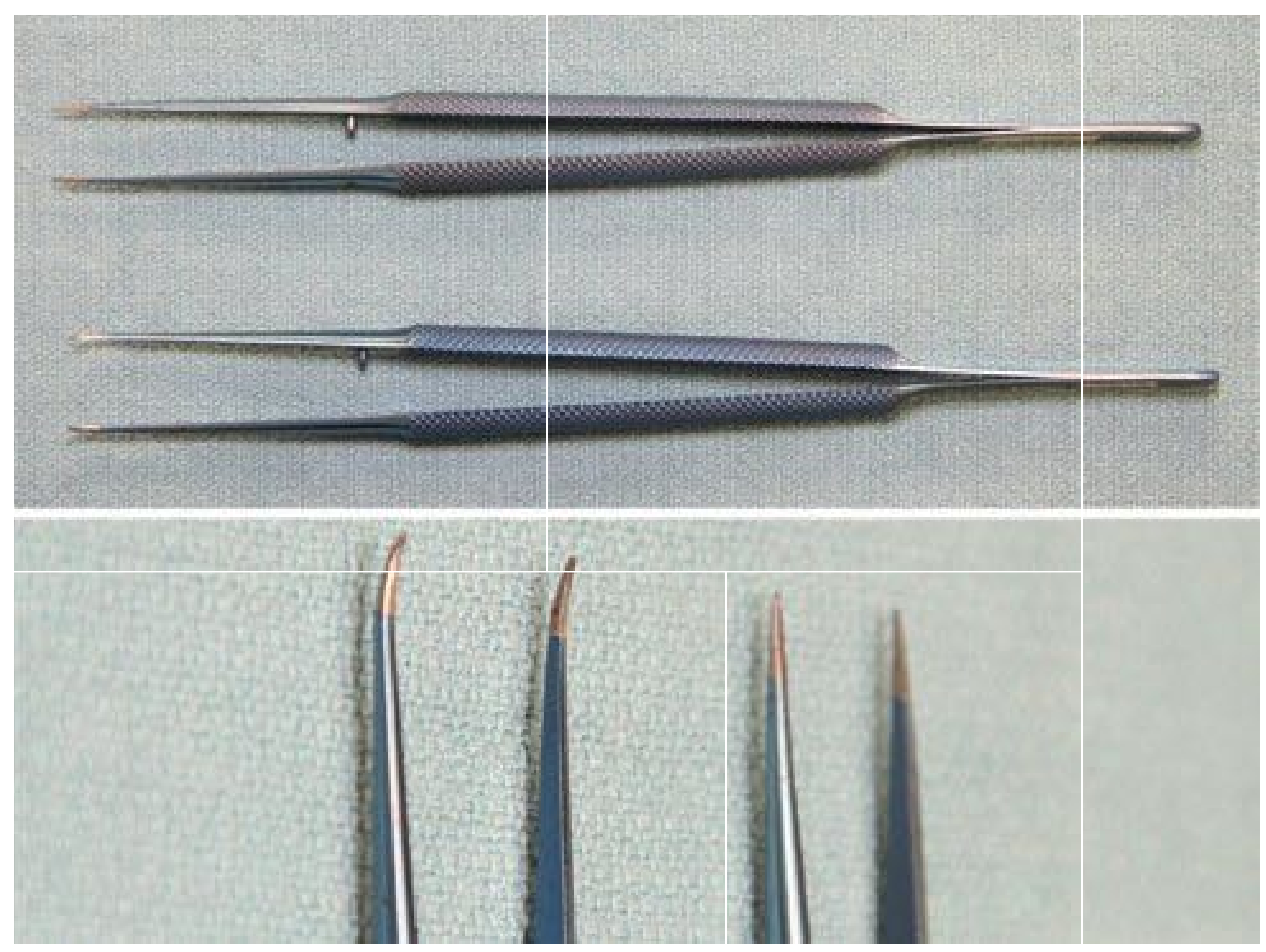


Fig. 1.28 Short tying forceps for bypass cases.

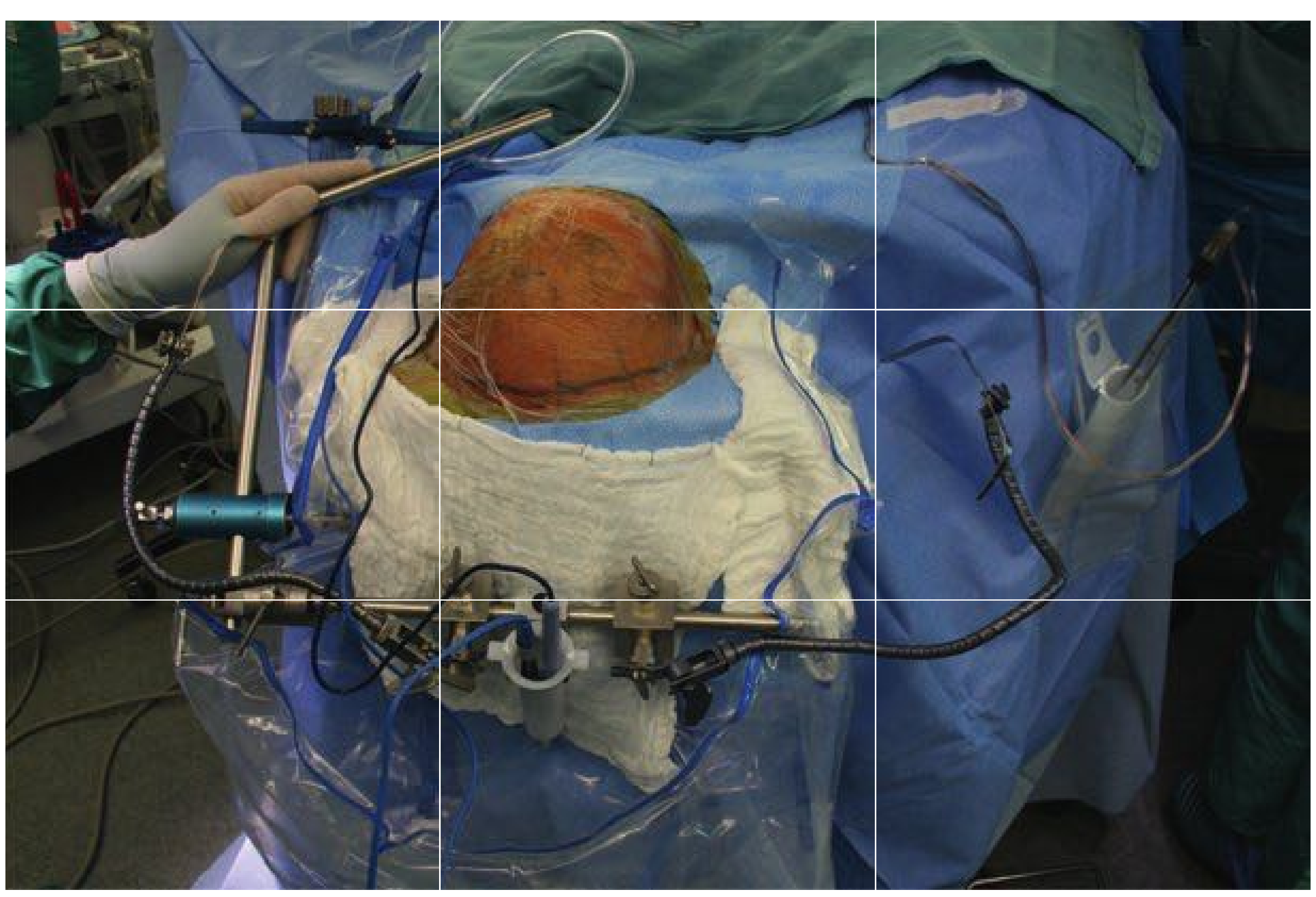


Fig. 1.29 Brain retractors attached to the head rest arm and set in position during an operation.

Fig. 1.30 (**a**) An appropriately cut piece of rubber glove and (**b**) cottonoid patties. They are usually placed between the retractor blade and the underlying neural tissue to limit direct damage.

Fig. 1.31 Micro suction tips. Tapered or expanded atraumatic blunt tip.

Ancillary Services

For many cranial surgeries, neurophysiologic monitoring is needed, including motor evoked potentials (MEPs), somatosensory evoked potentials (SEPs), and brainstem auditory evoked potentials (BAER). In addition, direct intrafield stimulation of a cranial nerve or electrocorticography (ECOG) may be needed. Communications between the surgeon, the monitoring team, and the anesthesiologist are crucial to ensure a safe and effective procedure. For vascular cases, intraoperative transcranial Doppler (TCD), retrograde jugular bulb pressure, oxygen tension monitoring, and intraoperative catheter angiogram may be needed.

1.2 Security and Stabilization of the Head

Except in the case of young children,[3] the head of the patient is typically secured by a three-point pinned head holder for any cranial cases using microsurgical techniques, because without a secure fixation, any potential movement will translate into a large excursion under the microscope and can lead to devastating injury to the patient if occurring while the surgeon is working on a critical neurovascular structure. Before applying the head holder, preoperative scans and history should be reviewed and the patient should be examined to determine whether there is abnormally thin skull from chronic hydrocephalus or previous craniotomy or craniectomy with associated skull defect, as well as the size of the frontal sinus and degree of aeration of the mastoid, the presence of a bypass graft or potential donor vessel along the scalp (such as superficial temporal artery [STA] or occipital artery [OA] or a radial artery/saphenous vein graft), or previous surgical scars. The pins should be inserted along the plane of an imaginary head band to provide good mechanical support, to avoid very thin portions of the squamous bone, and to avoid the bulk of an underlying muscle, such as the temporalis. The head holder should be locked and proper force applied (typically 60–80 lbs for an adult patient). If intraoperative catheter angiogram is planned, radiolucent head holder and a special radiolucent table are needed. All the connections to the bed attachment should be double-checked after positioning of the patient to ensure stability. Neuronavigation attachments must be securely connected if used. The C-clamp of the head holder should be free of attachments, such as an external ventricular drain (EVD) or monitoring leads, before draping so that when the self-retaining retractor base is secured to the C-clamp it does not pinch anything important. The pins should also be inserted so that the field provided is adequate for the purpose of the procedure. Ideally, the incision should not be very close to a pin site; rarely, the patient may have to be taken off the pins at the end of the case before the scalp can be closed without tension. Sometimes, a patient's head position may need to be changed because of excessive head turning and major venous occlusion, causing brain swelling. A patient's "slipping out of pins" is a rare event and can be avoided by careful pinning, taking into account position and tension.

1.3 Patient Position

Depending on the location of the lesion and the surgical approach chosen, the patient can be positioned supine, lateral, prone, or semi-sitting.[4] After the patient is in a satisfactory position, all the pressure points are padded, and the patient is secured to the operating bed by numerous tapes and belts. We also use custom-made operating table side rail–attached padded bolsters to provide extra support and security. A "tilt test" is performed to ensure that neither the patient nor any part of the patient's body will slide off the table when the table is tilted left or right, in preparation for what may be needed intraoperatively.

1.3.1 Supine Position

The supine position (**Fig. 1.32, Fig. 1.33,** and **Fig. 1.34**) is commonly used for cranial procedures involving the anterior or middle fossa. The patient can be straight supine if the approach is along the midline. If the lesion is unilateral along the sylvian fissure, the head is turned 30° to the contralateral side to avoid obscuration by the temporal lobe due to gravity. For lesions close to the opticocarotid cistern or the upper clival basilar artery, the head is typically turned 45° to bring the lesion into the surgeon's line of sight under the microscope. When the lesion is near the anterior communicating artery, optic chiasm, or anterior third ventricle, the head should be turned ~ 60° away from the side of pathology. For pathology near the tentorial notch or posterior temporal region, the patient's head may need to be turned up to 70°, if the neck is flexible on preoperative exam, there is not a markedly asymmetry of venous drainage through the transverse sinuses, and there is no elevation of jugular venous pressure when monitored (**Fig. 1.35**). When the head needs to be turned more than 45°, it is prudent to place a large roll behind the shoulder and back of the patient to avoid excessive neck turning and potential compression of major arteries and veins. For patients who are obese or who have a short neck, preoperative test of the suppleness of the neck, as well as of the ability of the patient to tolerate a planned position, may be necessary. There are three axes along which the patient's head can be positioned: flexion/extension in the sagittal plane, bending in the coronal

Fig. 1.32 Head-on view of supine position: A thin strip of hair is shaved over the planed bicoronal incision line. All pressure points are padded.

Fig. 1.33 A side view of the supine position. The custom-made side rail–attached bolster can be seen on the side of the patient.

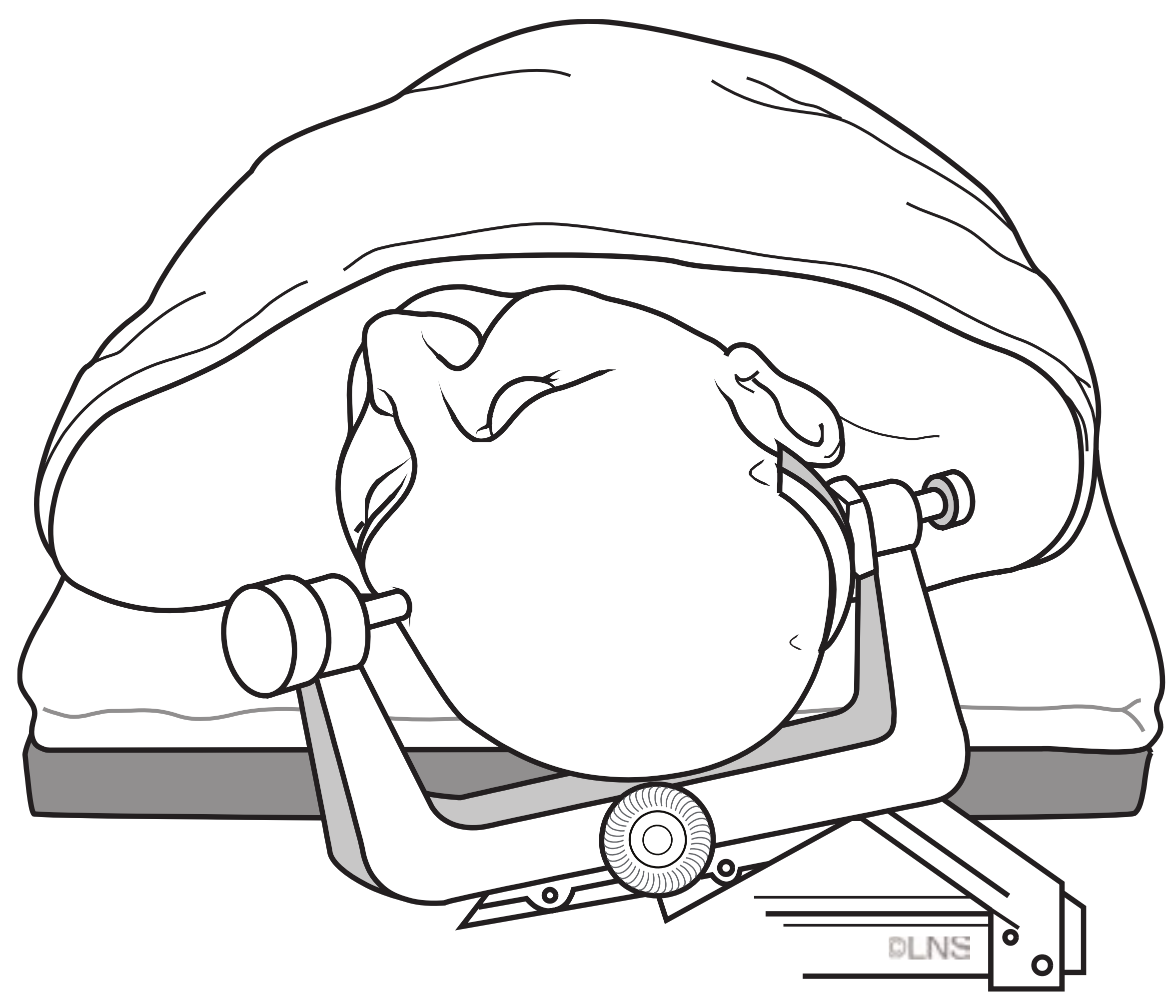


Fig. 1.34 The supine position, which may be used for a frontotemporal approach.

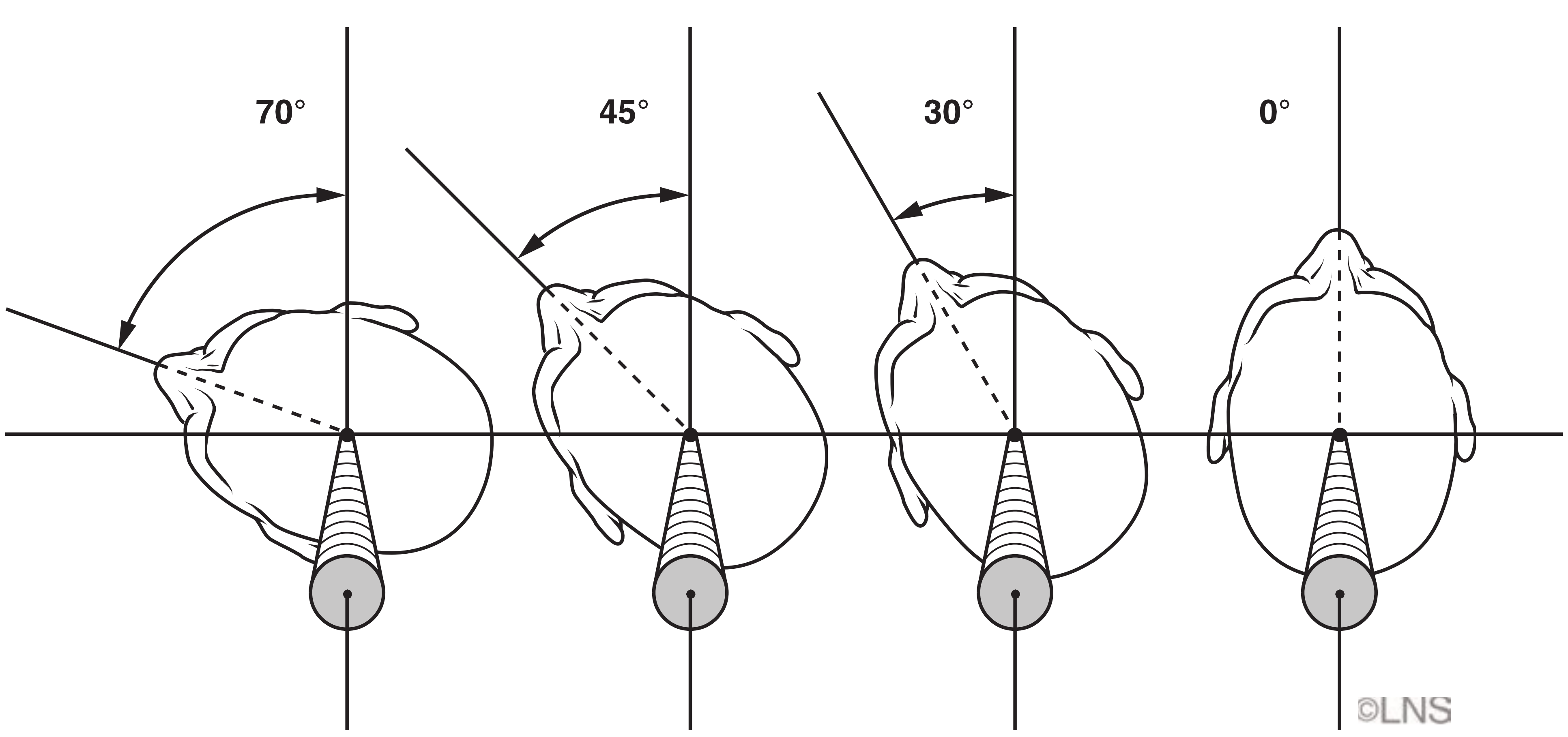


Fig. 1.35 The axis of head rotation and its effect on head position.

plane, and rotation in the axial plane. The goals of the position are to bring the area of interest into the direct line of sight of the surgeon, creating maximal operative space within the restraints of the patient's body habitus, and to avoid extreme neck or body position that can lead to vessel compression, nerve palsy, or skin pressure ischemia. The patient's head is typically extended for basal lesions and flexed forward for posterior frontal or parietal lesions (**Fig. 1.36, Fig. 1.37a,b,** and **Fig. 1.38**).

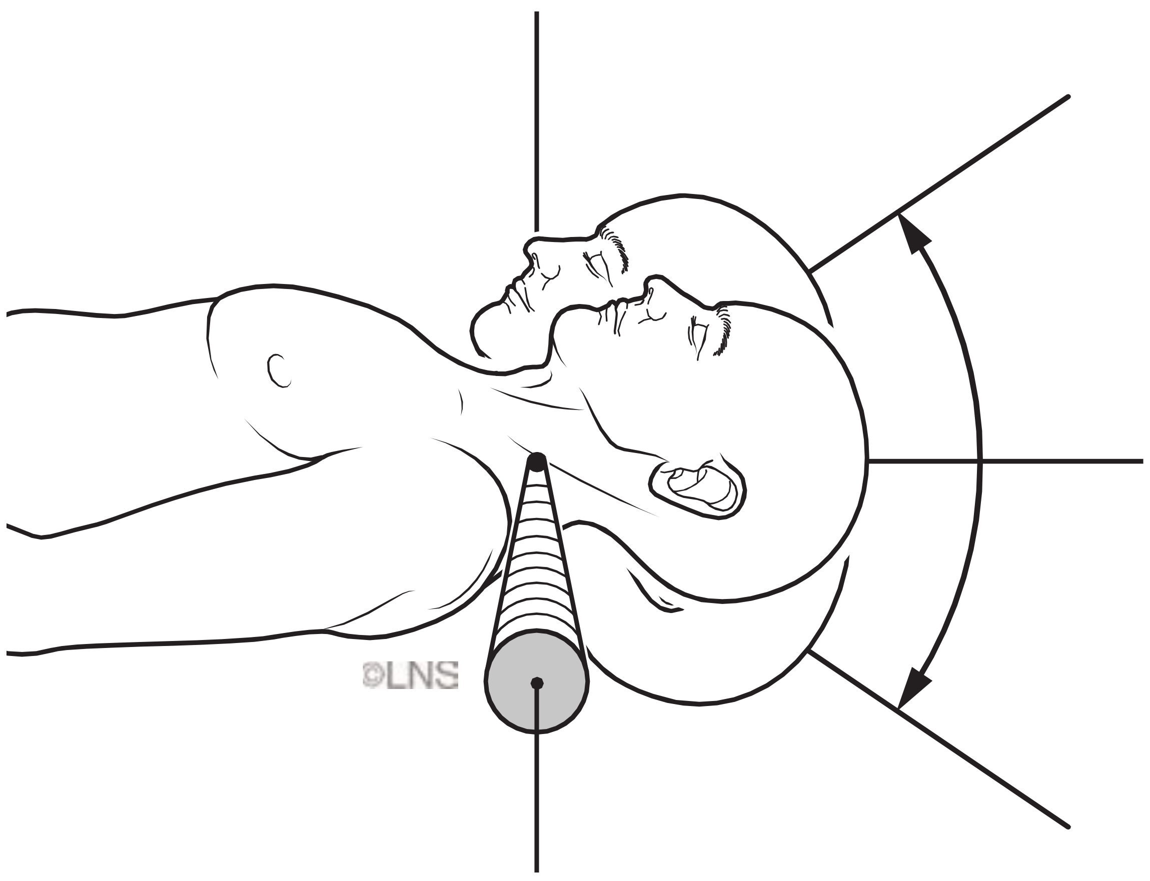


Fig. 1.36 The axis of anterior or posterior head flexion.

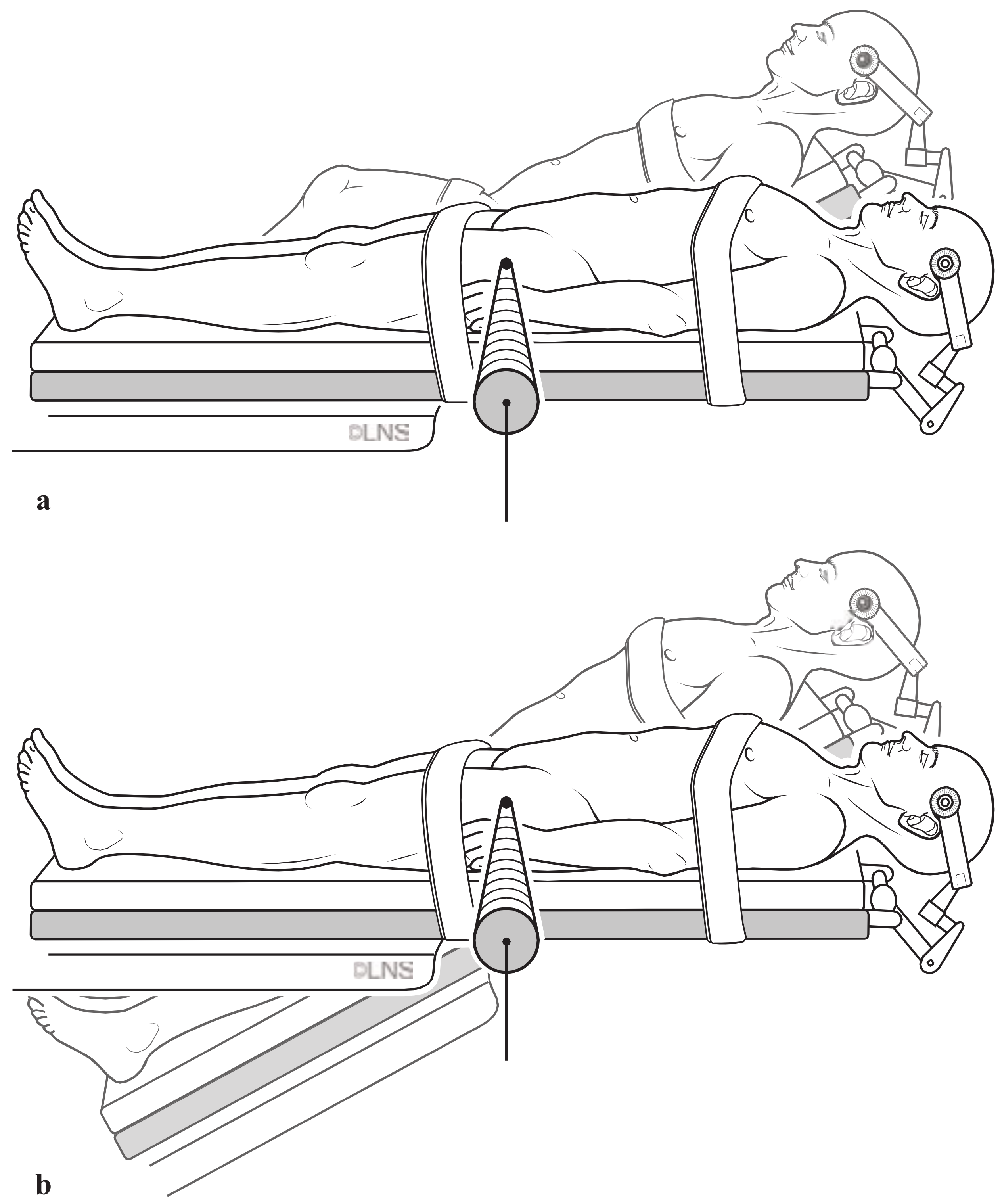


Fig. 1.37 (**a**) The flexion of the patient's body at the hip and its effect on elevation of the head. (**b**) Elevation of the head by tilting the table up and down.

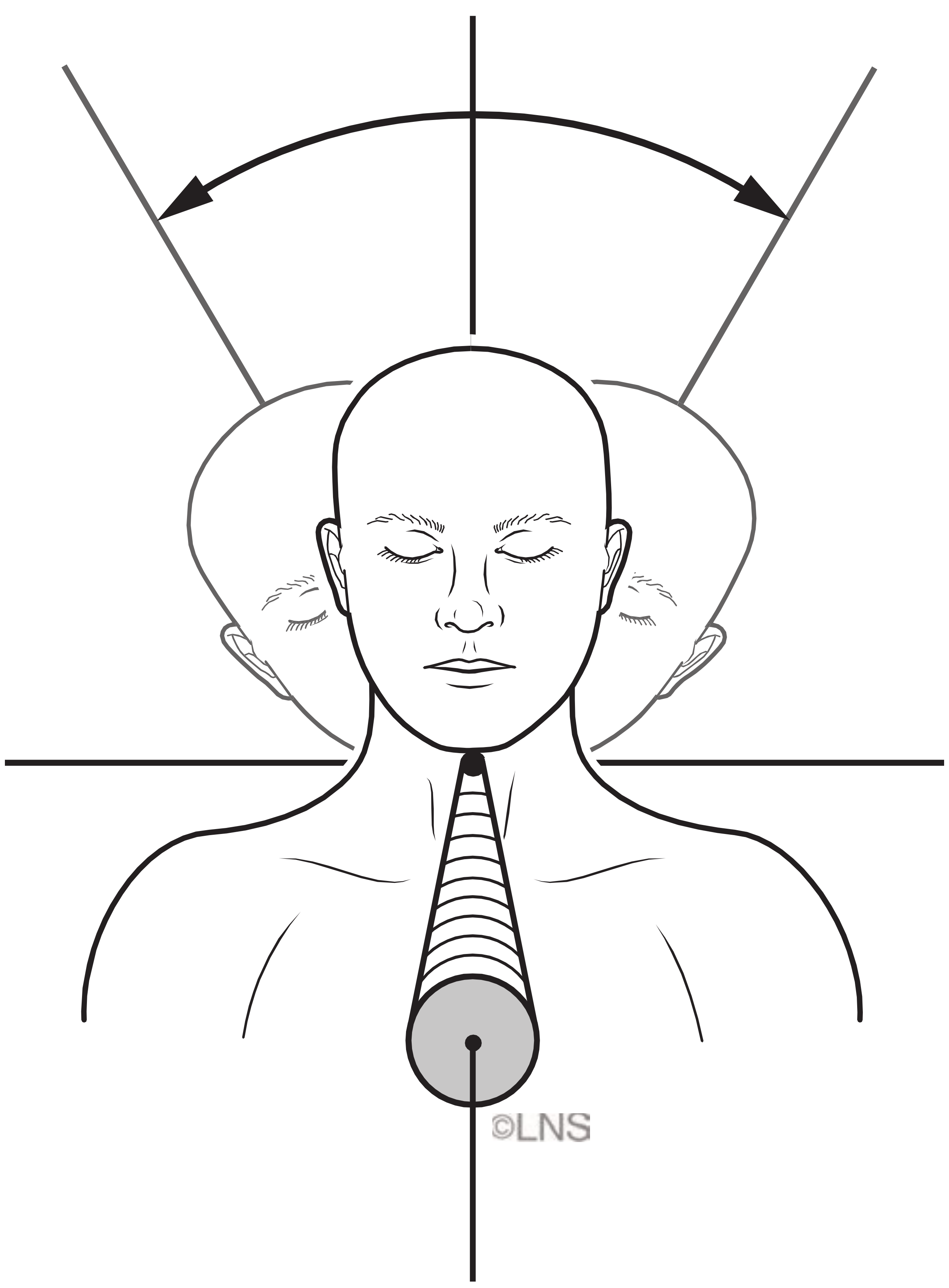


Fig. 1.38 The axis of lateral flexion of the head on the body.

1.3.2 Lateral Position

The lateral position (**Fig. 1.39, Fig. 1.40, Fig. 1.41, Fig. 1.42,** and **Fig. 1.43a,b**) can be used for petrosal or posterior fossa lesions located away from the midline. An axillary roll can be placed under the dependent axilla for procedures shorter than 4 hours, or the arm can be placed off the bed and can be supported by an arm sling. The head is positioned optimally in three intersecting planes, as already described. Excessive flexion in the sagittal plane should be avoided to avoid risking compromised ventilation (at least two fingers' breadth between the mandible and the sternum). The head can be bent toward the floor in the coronal plane to open the space between the head and shoulder. Rotation away in the axial plane from the surgeon facilitates viewing of the internal auditory canal (IAC), whereas rotating toward the surgeon helps viewing of the brainstem. Excessive flexion and rotation of the head may also occlude the vertebral artery if it is very dominant on one side and cause quadriparesis or quadriplegia for unidentified reasons. Neurophysiological monitoring should be used to prevent major complications.

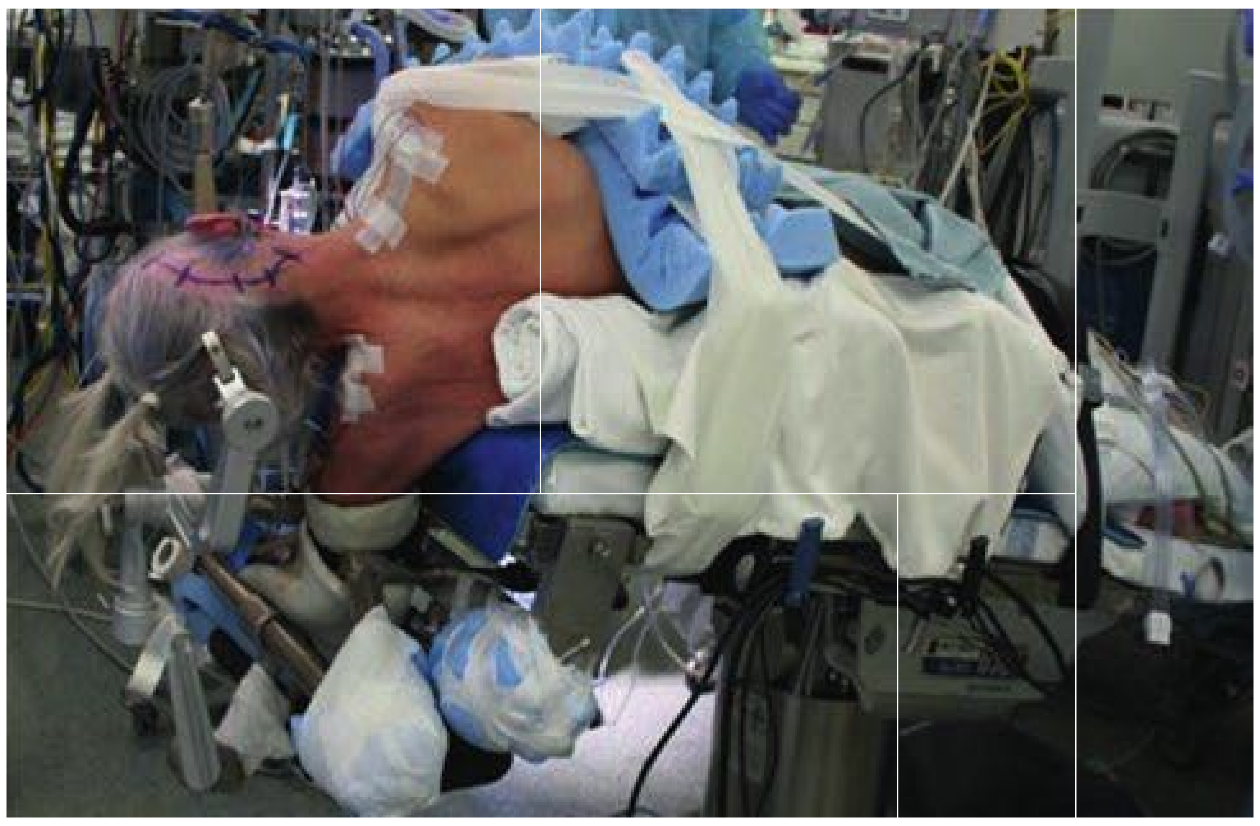


Fig. 1.39 Side view of lateral position in a patient undergoing petrosal approach.

Fig. 1.40 Side view of another patient positioned in lateral position for petrosal approach.

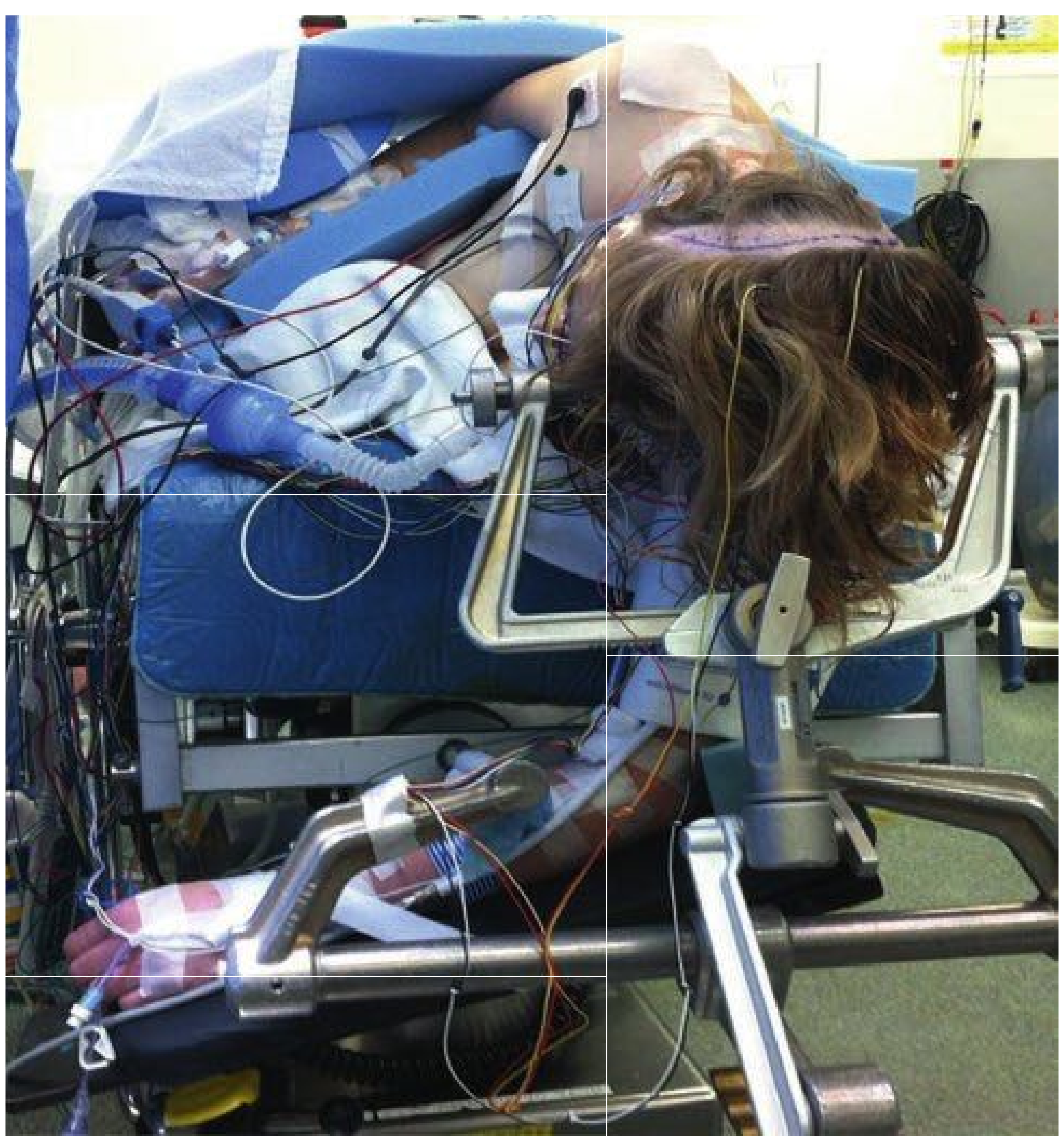


Fig. 1.41 Head-on view of a patient in the lateral position, the lower arm supported by an arm board.

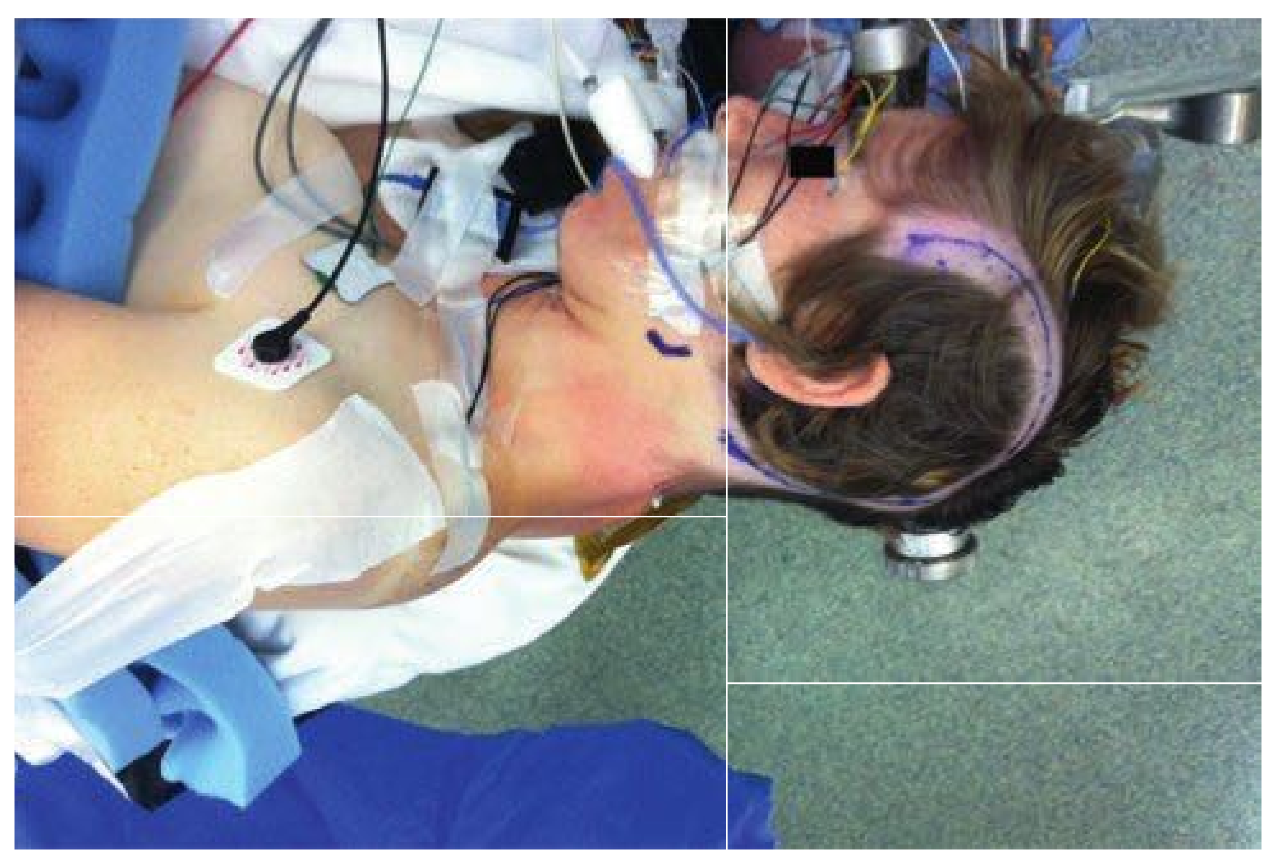
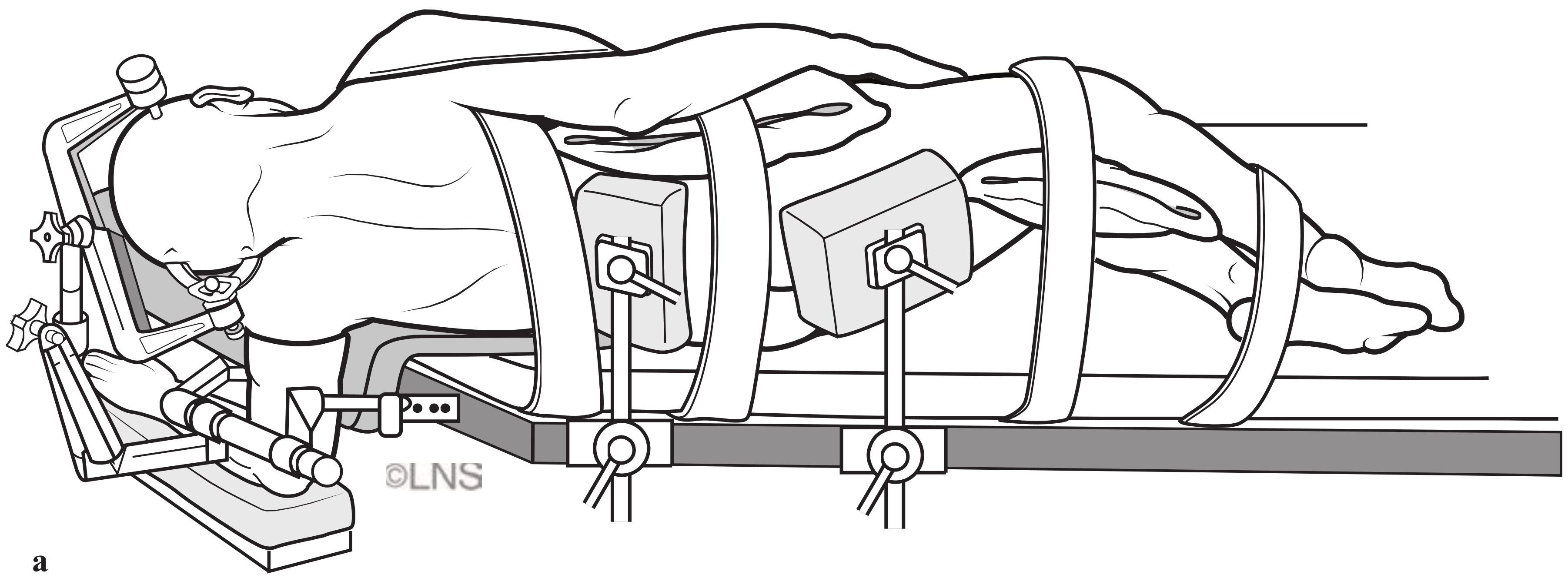
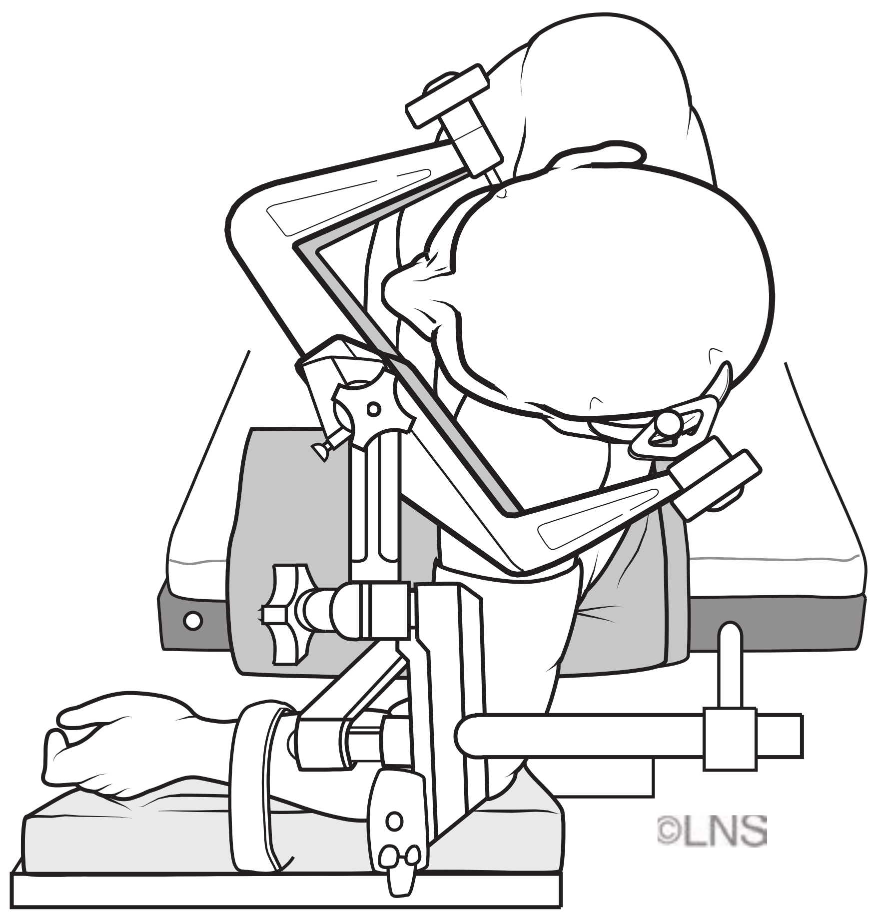


Fig. 1.42 Head-on view of a patient in the lateral position for a petrosal approach, with the planned incision seen.



a



b

Fig. 1.43 **(a,b)** The lateral position. The patient's arm and chest must be well padded.

1.3.3 Prone Position

The straight prone position (**Fig. 1.44, Fig. 1.45, Fig. 1.46,** and **Fig. 1.47a,b)** is used for lesions in the midline posterior fossa or the occipital region. If there is laterality to the lesion, a lateral position can also be used in which the dependent arm is supported by an arm sling off the operative table and the upper arm is draped over the body atop a pillow. Flexion and tuck of the chin is maximized without airway compromise (two fingers' breadth between the mandible and the sternum) to open the cranial–cervical junction.

Fig. 1.44 Side view of a patient in a straight prone position.

Fig. 1.45 Head-on view of a patient in a straight prone position, her body rested on gel chest rolls.

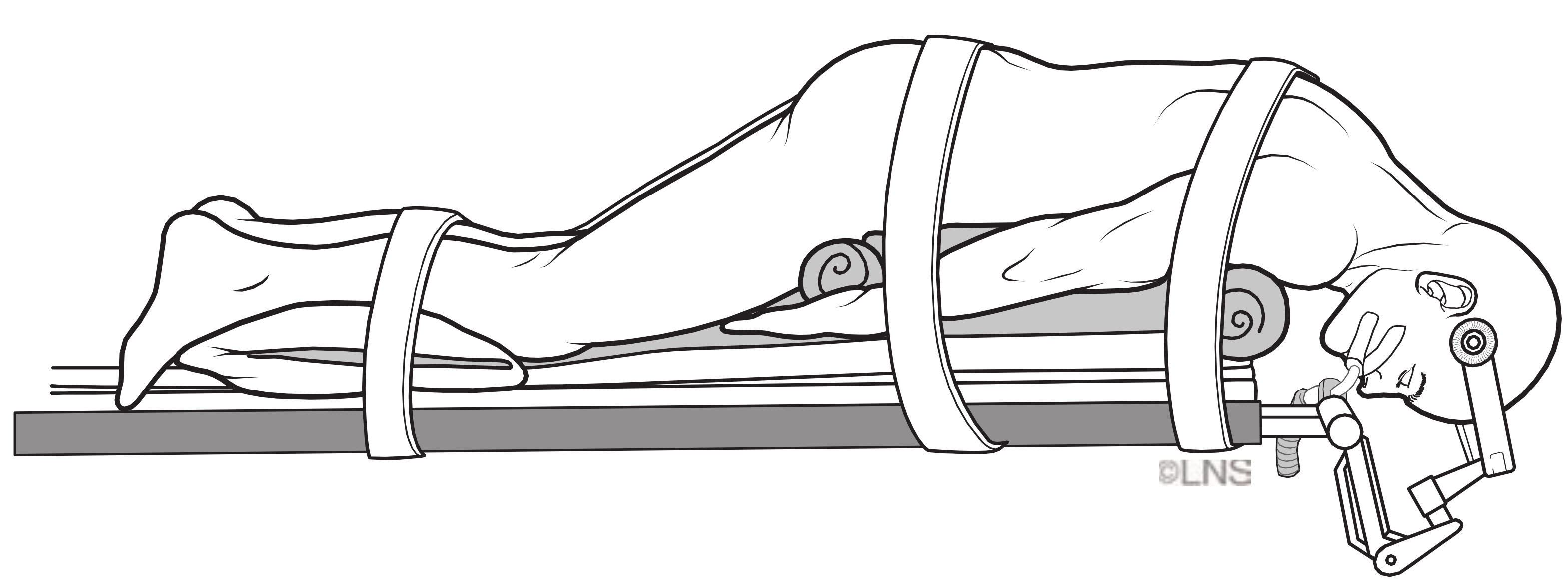


Fig. 1.46 The prone position. In this case, the surgeon can be seated near the vertex of the head or can stand near the side.

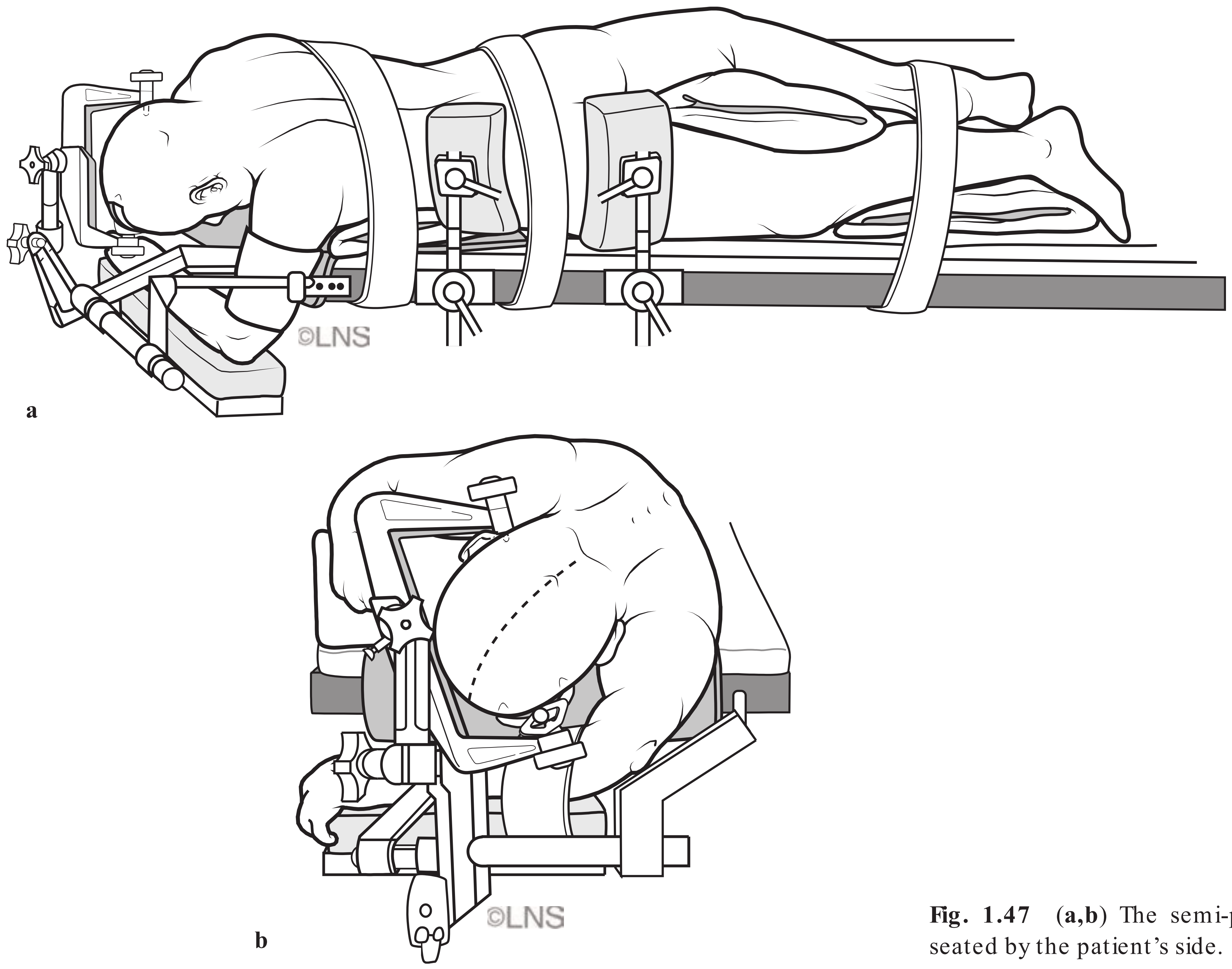


Fig. 1.47 **(a,b)** The semi-prone position. The surgeon can be seated by the patient's side.

1.3.4 Sitting Position and Semi-Sitting Position

The sitting position (**Fig. 1.48**) can be useful for pineal or dorsal brainstem lesions to decrease bleeding in the surgical field and to facilitate exposure by gravity. However, this position has a higher risk of causing air emboli, and the surgeon needs to be in an operative position with extended arms, causing increased tendency to fatigue and decreased accuracy of the movements. We find that the lateral position can serve the purpose as well as the sitting position does. If the semi-sitting position is used, the feet should be elevated above the heart, and the head should not be flexed or turned excessively, as already discussed.

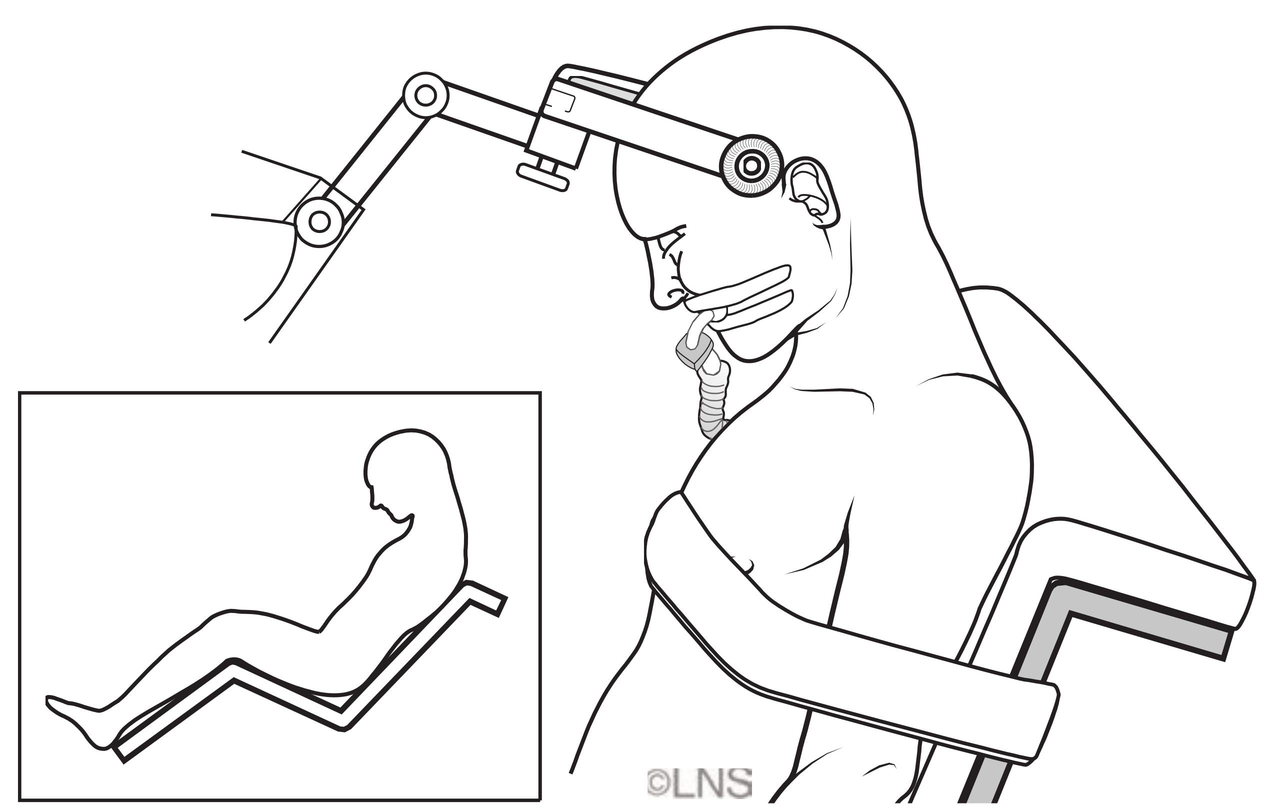


Fig. 1.48 The sitting position. The authors never use this position.

1.4 Skin Flap Design and Elevation

The scalp is typically richly vascularized, with the STA mainly providing the anterior and middle portion of the scalp and the OA mainly supplying the posterior scalp. The frontal scalp is also fed by supraorbital and supratrochlear arteries. For patients who need the STA or OA for a bypass procedure, the flap should be broad-based so that the other vessels will provide the blood supply after the bypass donor is taken. For patients who have had previous surgeries and in whom one or more scalp arteries may have been compromised, a reconstructive plastic surgeon should be consulted and should be involved in planning the skin incision. The STA courses over the zygomatic root in front of the tragus and a preauricular incision less than 0.5 cm from the tragus typically avoids the STA; careful dissection around this area should be performed to spare the STA. If there is a concern, the vessel's course should be marked with a Doppler probe; careful layered dissection will avoid damage to it. The OA exits the skull behind the mastoid along the digastric groove. Any incision near that region should aim to dissect out and mobilize the OA instead of sacrificing the artery. The length and width of the skin flap should also be carefully designed. Ideally, the maximal length of a skin flap should not be longer than twice the distance of the width to ensure sufficient blood supply to the skin flap.

For a skin flap behind the ear or around the suboccipital region, one may encounter the great auricular nerve or the greater occipital nerve. If possible, the nerve can be transected sharply and marked, and it can be anastomosed at procedure's end.

The incision should be behind the hairline if possible. We typically size the incision so that the underlying craniotomy lies ~ 2 cm from the skin incision. Thus, if there is a postoperative skin infection, the infection does not go through the craniotomy edge to involve the epidural or subdural space.