

**Pediatric Section
American Association of
Neurological Surgeons**

22nd Annual Meeting

**San Antonio, Texas
December 7 - 10, 1993**

American Association of
Neurological Surgeons

**Pediatric Section
22nd Annual Meeting**

**Plaza San Antonio
San Antonio, Texas
December 7 - 10, 1993**

The Joint Committee on Education of the American Association of Neurological Surgeons (AANS) and the Congress of Neurological Surgeons (CNS) is accredited by the Accreditation Council for Continuing Medical Education to sponsor continuing medical education for Physicians.

The Joint Committee on Education of the American Association of Neurological Surgeons (AANS) and the Congress of Neurological Surgeons (CNS) designates this continuing medical education activity for 25.00 neurosurgical credit hours in Category 1 toward the Continuing Education Award in Neurosurgery and the Physician's Recognition Award of the American Medical Association.

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Paolo Raimondi Lecturers

- | | |
|------------------------------|----------------------------|
| 1978 — E. Bruce Hendrick | 1986 — William F. Meacham |
| 1979 — Paul C. Bucy | 1987 — Dale Johnson |
| 1980 — Floyd Gilles | 1988 — Joseph J. Volpe |
| 1981 — Panel Discussion | 1989 — Martin Eichelberger |
| 1982 — Panel Discussion | 1990 — George R. Leopold |
| 1983 — Derek Harwood-Nash | 1991 — Judah Folkman |
| 1984 — Anthony E. Gallo, Jr. | 1992 — Olof Flodmark |
| 1985 — Frank Nulsen | 1993 — Maurice Albin |

Kenneth Shulman Award Recipients

- 1983 — Kim Manwaring: Neonatal Post-Hemorrhagic Ventriculomegaly: Management with Pulsed Lumbar Cisternostomy
- 1984 — Arno Fried: A Laboratory Model of Shunt Dependent Hydrocephalus
- 1985 — Anne-Christine Duhaime: The Shaken Baby Syndrome
- 1986 — Robert E. Breeze: CSF Formation in Acute Ventriculitis
- 1987 — Marc R. DelBigio: Shunt-Induced Reversal of Periventricular Pathology in Experimental Hydrocephalus
- 1988 — Scott Falci: Rear Seat-Lap Belts. Are They Really "Safe" for Children?
- 1989 — James M. Herman: Tethered Cord as a Cause of Scoliosis in Children with a Myelomeningocele
- 1990 — Christopher D. Heffner: Basilar Pons Attracts Its Cortical Innervation by Chemotropic Induction of Collateral Branch Formation
- 1991 — P. David Adelson: Reorganization of the Cortical-Tectal Pathway Following Neonatal Cerebral Hemispherectomy in Cats
- 1992 — David Frim: Effects of Biologically Delivered Neurotrophins in Animal Models of Neural Degeneration

Hydrocephalus Foundation Award Recipients

- 1989 — Eric Altschuler: Management of Persistent Ventriculomegaly
Due to Altered Brain Compliance
- 1990 — S.D. Michowiz: High Energy Phosphate Metabolism in
Neonatal Hydrocephalus
- 1991 — Neshor G. Asner: Venous Sinus Occlusion and
Ventriculomegaly in Craniectomized Rabbits
- 1992 — Marcia DaSilva: Reversal of High Energy Phosphate
Metabolism Changes in Experimental Hydrocephalus
After CSF Shunting

Pediatric Section Chairmen

- | | |
|------------------------------|-----------------------------|
| 1972-73 — Robert L. McLaurin | 1979-81 — Fred J. Epstein |
| 1973-74 — M. Peter Sayers | 1981-83 — Joan L. Venes |
| 1974-75 — Frank Anderson | 1983-85 — Harold J. Hoffman |
| 1975-76 — Kenneth Shulman | 1985-87 — William R. Cheek |
| 1976-77 — E. Bruce Hendrick | 1987-89 — David G. McLone |
| 1977-78 — Frank Nulsen | 1989-91 — Donald H. Reigel |
| 1978-79 — Luis Schut | 1991-93 — R. Michael Scott |
| 1993-95 — Arthur Marlin | |

Annual Winter Meeting Sites

- | | |
|--------------------|----------------------------------|
| 1972 Cincinnati | 1984 Salt Lake City |
| 1973 Columbus | 1985 Houston |
| 1974 Los Angeles | 1986 Pittsburgh |
| 1975 Philadelphia | 1987 Chicago |
| 1976 Toronto | 1988 Scottsdale |
| 1977 Cleveland | 1989 Washington, D.C. |
| 1978 Philadelphia | 1990 San Diego &
Pebble Beach |
| 1979 New York | 1991 Boston |
| 1980 New York | 1992 Vancouver, B.C. |
| 1981 Dallas | 1993 San Antonio, TX |
| 1982 San Francisco | 1994 St. Louis, MO |
| 1983 Toronto | |

Acknowledgments

The Section on Pediatric Neurological Surgery of the American Association of Neurological Surgeons gratefully recognizes the support of the following exhibitors for the 1993 Pediatric Annual Meeting.

Acra-Cut, Inc. - Acton, MA
BFW - Lexington, KY
Bremer Medical, Inc. - Jacksonville, FL
Camino Laboratories - San Diego, CA
Carl Zeiss, Inc. - Thornwood, NY
Codman & Shurtleff, Inc. - Randolph, MA
Cook, Inc. - Bloomington, IN
Cordis Corporation - Miami Lakes, FL
Elekta Instruments, Inc - Tucker, GA
Howmedica - Rutherford, NJ
Hydrocephalus Foundation - San Francisco, CA
Journal of Pediatric Neurosurgery - New York, NY
Laserscope - San Jose, CA
Leibinger LP - Dallas, TX
Moeller Microsurgical - Waldwick, NJ
Mosby, Churchill, Waverly, Inc. - San Antonio, TX
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Phoenix Biomedical Corp. - Bridgeport, PA
PMT Corporation - Chanhassen, MN
PS Medical - Goleta, CA
Radionics, Inc. - Burlington, MA
TiMesh, Inc. - Las Vegas, NV
Wild Microscopes, Division of Leica, Inc. -Rockleigh, NJ

**Officers of the Pediatric Section
of the
American Association of
Neurological Surgeons**

- Chairman:** Arthur Marlin
- Secretary-Treasurer:** Harold L. ReKate (1994)
- Executive Council:** R. Michael Scott (immediate past chairman, 1993)
Dennis Johnson (1994)
John P. Laurent (1995)
J. Gordon McComb (1994)
Bruce B. Storrs (1995)
- Membership Committee:** Walker Robinson, Chairman
Jerry Oakes
Richard Coulon
- Rules and Regulations:** Leslie Sutton, Chairman (1994)

Ad hoc Committees

- Committee on Utilization of Treasury Surplus:**
Ken Winston, Chairman
William Bell
Bruce Storrs
Timothy Mapstone
- Committee for Continuing Education (SANS V):**
Joseph Piatt
Corey Raffel
Michael Turner
John Waldman
Ken Winston

**Program of the
Pediatric Section
22nd Annual Meeting**

TUESDAY, DECEMBER 7, 1993

4:30 pm - 8:00 pm

Registration, Foyer

6:30 pm - 8:00 pm

Welcoming Reception, Foyer/Hidalgo C

WEDNESDAY, DECEMBER 8, 1993

6:30 am - 5:00 pm

Registration, Foyer

7:00 am - 8:15 am

BREAKFAST SEMINARS —Conference Center

Arachnoid Cysts:	Richard Coulon, MD
Update Myelomeningocele:	David McLone, MD
Vein of Galen Malformations:	Parker Mickle, MD
Selective Posterior Rhizotomy:	Bruce Storrs, MD:

7:45 am - 8:30 am

Continental Breakfast and Exhibits, Fountain/Hidalgo C

8:30 am - 8:45 am

Opening Remarks — Arthur E. Marlin, MD
Welcome — Mayor Nelson Wolff
Hidalgo A & B

SCIENTIFIC SESSION I —Hidalgo A & B

Moderators: John P. Laurent, MD, Paul Steinbok, MD

8:45 am - 9:00 am

1. "Americans With Disabilities Act: Impact Upon Therapeutic Decisions and Research." Clark Watts, MD, JD, Austin TX

9:00 am - 9:15 am

- *2. "The Currarino Triad: Clinical Presentations, Imaging, Genetics and Therapy." Robin M. Bowman, MD, Thomas G. Luerssen, MD, L.R. Scherer, MD, E.C. Klatte, MD, David D. Weaver, MD, Indianapolis, IN

9:15 am - 9:30 am

3. "Embryogenesis, Associated Malformations and Surgical Management of Myelocystoceles." Michael D. Partington, MD, Mark S. Dias, MD, Charles F. Harvey, MD, David G. McLone, MD, PhD, Chicago, IL

9:30 am - 9:45 am

4. "Symptomatic Hydromyelia Following Operation for Spinal Lipoma." Paul H. Chapman, MD, David M. Frim, MD, Boston, MA

9:45 am - 10:00 am

- *5. "Latex Sensitivity in the Myelodysplastic Population: Review and Recommendations." Sarah J. Gaskill, MD, Joanne Mackey, RN, BSN, Gordon Worley, MD, Herbert Fuchs, MD, Durham, NC

10:00 am - 10:30 am

COFFEE BREAK AND EXHIBITS — Fountain/Hidalgo C

10:30 am - 11:00 am

PAOLO RAIMONDI LECTURE — Maurice Albin, MD

SCIENTIFIC SESSION II — Hidalgo A & B

Moderators: Terrence Myles, MD, Glenn Morrison, MD

*indicates that the paper is eligible for a resident award and is primarily the work of the resident who is presenting the paper, as designated on the abstract submission form.

11:00 am - 11:15 am

6. "The Impact of Simultaneous Meningomyelocele Repair and Shunting of the Development of Symptomatic Chiari Type II Malformation." Todd Nida, MD, Mahmoud G. Nagib, MD, Stephen J. Haines, MD, Stephen Marker, MD, Minneapolis, MN

11:15 am - 11:30 am

7. "Chiari I Malformation and Acute Spinal Cord Infarction: A Report of 3 Cases." Frederick F. Marciano, MD, PhD, Harold L. Rekate, MD, Stanley D. Johnsen, MD, Phoenix, AZ

11:30 am - 11:45 am

8. "Pediatric Chiari Malformations: Long-Term Follow-Up of Surgical Treatment." Michael G. Muhonen, MD, John G. Piper, MD, Paul Sawin, MD, Arnold H. Menezes, MD, Iowa City, IA

11:45 am - 12:00 pm

9. "Surgical Management of Anterior Skull Base Lesions of Embryologic Origin in Children." Y. Hahn, A. Hotaling, B. Bauer, R. Pensler, Maywood, IL

12:00 pm - 12:15 pm

- *10. "Surgical Management of the Cloverleaf Skull Deformity." Daniel K. Resnick, MD, Ian F. Pollack, MD, A. Leland Albright, MD, Pittsburgh, PA

12:15 pm - 12:30 pm

11. "Methylmethacrylate Cranioplasty in Children: A Ten Year Experience." Steven J. Schneider, MD, Burt Greenberg, MD, Alan D. Rosenthal, MD, New Hyde Park, NY

12:30 pm - 1:30 pm

LUNCH AND EXHIBITS — Cavalier/ CC, C & D, Hidalgo C

SCIENTIFIC SESSION III — Hidalgo A & B

Moderators: Yoon Sun Hahn, MD, Peter Carmel, MD

1:45 pm - 2:00 pm

- *12. "Differential Language Localization in Bilingual Children." Michael Schneck, MD, Paul M. Kanev, MD, Kenneth Liebman, MD, Jack I. Jallo, MD, Philadelphia, PA

2:00 pm - 2:15 pm

13. "Vagal Nerve Stimulation for Intractable Pediatric Epilepsies." Gregory W. Hornig, MD, Jerome V. Murphy, Gloria Schallert, Melissa Baldus, Kansas City, MO

2:15 pm - 2:30 pm

14. "The Prevalence of Epilepsy Among Patients Treated for Hydrocephalus: An Actuarial Study." Joseph H. Piatt, Jr., MD, Michael A. Horgan, MD, Christina V. Carlson, Portland, OR

2:30 pm - 2:45 pm

15. "The Incidence of Postoperative Epilepsy in Children Following Subfrontal Craniotomy for Tumor." Mitchel S. Berger, MD, Earl C. Wang, MD, J.R. Geyer, MD, Seattle, WA

2:45 pm - 3:00 pm

16. "Seizure Control Following Extra-Temporal Resections in Children." Paul M. Kanev, MD, Jack I. Jallo, MD, Michael Schneck, MD, Christopher Getch, MD, Philadelphia, PA

3:00 pm - 3:15 pm

17. "The Use of Subdural Electrodes for Mapping Seizure Foci in Children." Derek Bruce, MD, Hugh O'Donnell, MD, Richard North, MD, Dallas, TX

3:15 pm - 3:45 pm

COFFEE BREAK AND EXHIBITS — Fountain/Hidalgo C

SCIENTIFIC SESSION IV — Hidalgo A & B

Moderators: Ann Marie Flannery, MD, Henry Bartkowski, MD

3:45 pm - 4:00 pm

- *18. "Crush Injuries to the Head in Children." Gary Correnti, MD, Ann-Christine Duhaime, MD, Philadelphia, PA

4:00 pm - 4:15 pm

19. "Dextromethorphan is Protective in Experimental Subdural Hematoma." Ann-Christine Duhaime, MD, Laura M. Gennarelli, MD, Doug T. Ross, PhD, Philadelphia, PA

4:15 pm - 4:30 pm

20. "Subarachnoid Hemorrhage and Post-Traumatic Hydrocephalus in Severe Pediatric Head Injury." Joseph C. Watson, MD, JoAnn M. Tillett, RN, John D. Ward, MD, FCCM, Richmond, VA

4:30 pm - 4:45 pm

- *21. "Late Outcome of Children With Inflicted Head Injuries in Infancy." C.W. Christian, MD, A.C. Duhaime, MD, T. Seidl, MSW, E. Moss, PhD, Philadelphia, PA

4:45 pm - 5:00 pm

22. "Growing Skull Fractures: Classification and Management." Naim-Ur-Rahman, MD, Zain Al Abedeen B. Jamjoom, MD, Abdel Hakim B. Jamjoom, MD, Waleed R. Murshid, MD, Riyadh, Saudi Arabia

5:00 pm

BUSINESS MEETING — Hidalgo A & B

THURSDAY, DECEMBER 9, 1993

7:00 am - 8:00 am

BREAKFAST SEMINARS — Conference Center

Risk Management:	Robert McLaurin, MD, Clem Lyons, JD
Spinal Cord Tumors:	Fred Epstein, MD
The Tethered Spinal Cord:	Donald Reigel, MD
Craniopharyngiomas:	Robin Humphreys, MD

7:30 am - 5:30 pm

Registration, Foyer

7:45 am - 8:30 am

CONTINENTAL BREAKFAST AND EXHIBITS — Fountain/Hidalgo C

SCIENTIFIC SESSION V — Hidalgo A & B

Moderators: Thomas G. Luerksen, MD, Derek A. Bruce, MD

8:30 am - 8:45 am

23. "Comparison of the Different Mathematical Pressure-Volume Models of the CSF Compartment." James M. Drake, MD, G. Tenti, PhD, S. Sivalsganathan, PhD, Toronto, Ontario

8:45 am - 9:00 am

24. "Limitations of the Ventriculo-Cisternal Perfusion Technique." J. Gordon McComb, MD, Berislav V. Zlokovic, MD, PhD, Los Angeles, CA

9:00 am - 9:15 am

- *25. A Volumetric Approach to Slit-Ventricle Syndrome." John A. Jane, MD, R.S. Polin, MD, L. Walker, RN, A.S. Polin, BA, R. Rao, BS, A.G. Chenelle, MD, J. Goble, PhD, Charlottesville, VA

9:15 am - 9:30 am

26. "Cortical Mantle Stress, Strain, and Creep – Results of Finite-Element Analysis of the Enlarged Ventricular System." Samuel R. Neff, MD, Ravi Subramaniam, MD, Camden, NJ

9:30 am - 9:45 am

- *27. "Metabolic Demonstration of Retained CNS Function in the Rabbit Model of Infantile Hydrocephalus." Monica C. Wehby, MD, Charles E. Olmstead, PhD, Warwick J. Peacock, MD, David Hovda, PhD, Greg Olavarria, R.J. Gayek, DVM, Robin S. Fisher, PhD, Los Angeles, CA

9:45 am - 10:00 am

- *28. "Neuroendoscopy for the Treatment of Antenatal Hydrocephalus."
Kenneth W. Reichert, MD, Kerry Crone, MD, Mimi Nurre-Miller, RN,
Lori L. Barr, MD, Janice W. Allison, MD, Bernadette L. Koch, MD,
Cincinnati, OH

10:00 am - 10:30 am

COFFEE BREAK AND EXHIBITS — Fountain/Hidalgo C

SCIENTIFIC SESSION VI — Hidalgo A & B

Moderators: Dachling Fan, MD, Walker L. Robinson, MD

10:30 am - 11:00 am

SPECIAL LECTURE — Joan L. Venes, MD, "Surgical Technology
Assessment/Commitment or Indifference."

11:00 am - 11:15 am

29. "Hydrocephalus: Under Arrest or on Parole?" John A. Campbell, MD,
Jeffrey P. Blount, MD, Stephen J. Haines, MD, Minneapolis, MN

11:15 am - 11:30 am

- *30. "Negative Pressure Hydrocephalus." M. Vassilyadi, MD, J.P
Farmer, MD, J.L. Montes, MD, Montreal, Quebec

11:30 am - 11:45 am

- *31. "Management of the Shunted Patient with a Bladder Perforation."
James D. Callahan, MD, John E. Kalsbeck, MD, Richard C. Rink, MD,
Thomas G. Luerksen, MD, Indianapolis, IN

11:45 am - 12:00 pm

- *32. "Complications of Posterior Fossa Shunting in Double Compartment
Hydrocephalus." Diana Leahu, MA, MS, Mark Lee, MD, Rick
Abbott, MD, Jeff Wisoff, MD, Fred Epstein, MD, New York, NY

12:00 pm - 12:15 pm

- *33. "The Epidemiology of Cerebrospinal Fluid Shunting." Charles P.
Bondurant, MD, David F. Jimenez, MD, Columbia, MO

12:15 pm - 12:30 pm

- *34. "Propionibacterium Acnes Infection: A Treatable Cause of Chronic Headache in Shunted Patients." Jeffrey P. Blount, MD, John A. Campbell, MD, Stephen J. Haines, MD, Minneapolis, MN

12:30 pm - 12:45 pm

- *35. "Asymptomatic Ventriculo-Peritoneal Shunt Malfunction." Michael Lefkowitz, MD, Kevin L. Boyer, MD, Corey Raffel, MD, PhD, J. Gordon McComb, MD, Los Angeles, CA

12:45 pm - 1:00 pm

36. "Incidence of Asymptomatic Shunt Malfunctions in Pediatric Patients Undergoing Routine Yearly Head CT." Nancy K. Rollins, MD, Maureen Packard, MD, Kenneth Shapiro, MD, Derek Bruce, MD, Dallas, TX

FREE AFTERNOON

6:30 pm - 7:30 pm

RECEPTION — Hidalgo

7:30 pm - Midnight

ANNUAL BANQUET — Hidalgo

FRIDAY, DECEMBER 10, 1993

7:00 am - 8:15 am

BREAKFAST SEMINARS — Conference Center

Hydrocephalus:	Harold Rekate, MD Gordon McComb, MD: Luis Schut, MD Derek Bruce, MD
Craniosynostosis:	Michael Edwards, MD:
Spinal Lipoma:	Paul Chapman, MD: Peter Black, MD
Epilepsy Surgery:	Warwick Peacock, MD:

7:30 am - 5:30 pm

Registration, Foyer

7:45 am - 8:30 am

CONTINENTAL BREAKFAST AND EXHIBITS — Fountain/Hidalgo C

SCIENTIFIC SESSION VII — Hidalgo A & B

Moderators: Andrew D. Parent, MD, Jack E. McCallum, MD

8:30 am - 8:45 am

37. "Selective Dorsal Rhizotomy and Lower Extremity Orthopedic Procedures for Spasticity in Cerebral Palsy." Michael Chicoine, MD, T.S. Park, MD, Bruce A. Kaufman, MD, Madeleine Ortman, RN, St. Louis, MO

8:45 am - 9:00 am

38. "Continuous Epidural Morphine-Butorphanol Infusion Following Selective Dorsal Rhizotomy." Frederick A. Boop, MD, C. David Lawhorn, MD, Michael Schmitz, MD, Raeford E. Brown, Jr., MD, Little Rock, AR

9:00 am - 9:15 am

39. "Motion Laboratory Gait Analysis: Preoperative and Postoperative in Children Undergoing Selective Dorsal Rhizotomy." Mary E. Dunn, MD, St. Paul, MN

9:15 am - 9:30 am

40. "Reflex Variability in Selective Dorsal Rhizotomy." Steven J. Schiff, MD, PhD, Ira P. Weiss, PhD, Washington, DC

9:30 am - 9:45 am

41. "Relationship of Intraoperative Electrophysiologic Criteria to Outcome After Selective Functional Posterior Rhizotomy." Paul Steinbok, MD, Bengt Gustavsson, Ann Reiner, John Kestle, MD, D. Doug Cochrane, MD, Vancouver, BC

9:45 am - 10:00 am

42. "Physical and Functional Outcome Five Years After Rhizotomy." Rick Abbott, MD, Michael Handler, MD, New York, NY

10:00 am - 10:30 am

COFFEE BREAK AND EXHIBITS — Fountain/Hidalgo C

SCIENTIFIC SESSION VIII — Hidalgo A & B

Moderators: Hector E. James, MD, James T. Goodrich, MD

10:30 am - 10:45 am

43. "MRI Changes with Clinical Correlation in Children with Spastic Cerebral Palsy." Myles Koby, MD, Cynthia M. Morrison, MD, Benjamin CP Lee, MD, T.S. Park, MD, Bruce A. Kaufman, MD, St. Louis, MO

10:45 am - 11:00 am

44. "Subcortical Infarctions in Children." Frank C. Powell, BS, Kerry W. McCluney, MD, William C. Hanigan, MD, PhD, Peoria, IL

11:00 am - 11:15 am

45. "The Natural History of Pediatric Familial Cavemous Malformations." Mark G. Hamilton, MDCM, FRCS(C), Karl A. Greene, MD, PhD, Harold L. Rekate, MD, FACS, Joseph M. Zabramski, MD, Phoenix, AZ

11:15 am - 11:30 am

46. "Extra-Axial Cavemous Malformations in Neonates." W. Bruce Chemy, MD, Frederick F. Marciano, MD, PhD, S. David Moss, MD, Kim H. Manwaring, MD, Harold L. Rekate, MD, Phoenix, AZ

11:30 am - 11:45 am

47. "Computed Tomographic Scanning Within 24 Hours of Craniotomy for Tumor in Children." Bruce A. Kaufman, MD, Christopher Moran, MD, T.S. Park, MD, St. Louis, MO

11:45 am - 12:00 pm

48. "Timing and Mode of Imaging After Tumor Surgery: Issues of Reliability." Charles Ted, MD, William Morris, MD, Nancy Rollins, MD, Tacoma, WA

12:00 pm - 12:15 pm

49. "Severe Cervical Kyphotic Deformities in Patients with Plexiform Neurofibromas." Brad A. Ward, MD, Andrew D. Parent, MD, H. Louis Harkey, MD, Jackson, MS

12:15 pm - 12:30 pm

50. "Prognostic Significance of Type 1 Neurofibromatosis (von Recklinghausen Disease) in Pediatric Optic Gliomas." Anastasia V. Deliganis, BS, J. Russell Geyer, MD, Mitchel S. Berger, MD, Seattle, WA

12:30 pm - 1:30 pm

LUNCH AND EXHIBITS — Cavalier/C & D

SCIENTIFIC SESSION IX — Hidalgo A & B

Moderators: Dennis L. Johnson, MD, Alexa I. Canady, MD

1:45 pm - 2:00 pm

51. "Hypothalamic Hamartomas." Georges Haddad, MD, Yoon S. Hahn, MD, Ossama Al-Mefty, Little Rock, AR

2:00 pm - 2:15 pm

52. "Factors Affecting the Long-Term Outcome of Children with Low-Grade Gliomas of the Cerebral Hemispheres." Ian F. Pollack, MD, Diana Claasen, MD, Janine Janosky, PhD, A. Leland Albright, MD, Pittsburgh, PA

2:15 pm - 2:30 pm

53. "Intracranial Infantile Myofibromatosis." Michael J. Rutigliano, MD, Ian F. Pollack, MD, Dachling Pang, MD, FRCS(C), A. Leland Albright, MD, Pittsburgh, PA

2:30 pm - 2:45 pm

54. "Intrinsic Midbrain Tumors in Children: A Benign Subset of Brain Stem Tumors?" Karin M. Muraszko, MD, Patricia Robertson, MD, Robert Dauser, MD, Andrew Turrisi, MD, Ann Arbor, MI

2:45 pm - 3:00 pm

55. "Placement of Off/On Switch in Post-Tumoral and Tumoral Hydrocephalus." David J. Donahue, MD, Ray Fryear, BS, Robert A. Sanford, MD, Michael S. Muhlbauer, MD, Memphis, TN

3:00 pm - 3:30 pm

COFFEE BREAK AND EXHIBITS — Fountain/Hidalgo C

SCIENTIFIC SESSION X — Hidalgo A & B

Moderators: Joseph H. Piatt, MD, John R. Mawk, MD

3:30 pm - 3:45 pm

56. "Stereotactic Radiosurgery for Childhood Brain Tumors." Paul A. Grabb, MD, L. Dade Lunsford, MD, A. Leland Albright, MD, Douglas Kondziolka, MD, John C. Flickinger, MD, Pittsburgh, PA

3:45 pm - 4:00 pm

57. "Survival of Children with Medulloblastoma: With Special Reference to Surgical Resection, DNA Ploidy and Chemotherapy." Tadanori Tomita, MD, David G. McLone, MD, MaryAnne H. Marymont, MD, William N. Brand, MD, Lakshmi Das, MD, Lewis C. Strauss, MD, Chicago, IL

4:00 pm - 4:15 pm

- *58. "Neurotrophins and Growth in PNETS." Lawrence S. Chin, MD, Corey Raffel, MD, PhD, Los Angeles, CA

4:15 pm - 4:30 pm

- *59. "Permeability and Glial Reactivity in C6 Glioma Implanted into the Infant Rat Striatum." Edward F. Aulisi, MD, Jeff Rosenstein, PhD, Washington, DC

4:30 pm - 4:45 pm

- *60. "P53 Mutations and Familial Cancer." Mark M. Souweidane, MD, Angel Pellicer, MD, PhD, Jeff Allen, MD, Fred Epstein, MD, Srinath Samudrala, MD, New York, NY

4:45 pm - 5:00 pm

61. "Expressions of TIMP-1, TIMP-2, and TYPE IV Collagenase Transcripts in Pediatric Tumors: Correlation with Tumor Grade." James T. Rutka, MD, PhD, FRCSC, Sherri Lynn Smith, Kouzou Fukuyama, Kazuhito Matsuzawa, Matthew Muller, Peter Dirks, Toronto, Ontario

5:00 pm

Closing remarks and adjournment

Poster Session

Reception Foyer

1. "SIDS Prevention Plagiocephaly." J.A. Winfield, MD, PhD, Syracuse, NY
2. "CINE MR Imaging in Retethered Spinal Cord." J. Wasenko, MD, J. Scheraga, MD, L. Hochhauser, MD, J.A. Winfield, MD, PhD, Syracuse, NY
3. "Cerebral Echinococcosis in Children." Azedine Medhkour, MD, Adel M. Medhkour, MD, New York, NY
4. "Poor Operative Results in Craniosynostosis Repair." Paul Francel, MD, PhD, John Jane, MD, PhD, St. Louis, MO
5. "Enhanced Evaluation in Management of Growing Skull Fracture With the Utilization of Magnetic Resonance Imaging." Andrew D. Parent, MD, Frank A. Raila, MD, Jonathan D. Fratkin, MD, Jackson, MS
6. "Floor Plate Establishes the Basic Organization of the Developing Spinal Cord." G.S. Sohal, PhD, Augusta, GA
7. "Stereotactic Radiosurgery for Pediatric Brain Tumors." Walter A. Hall, MD, Paul W. Sperduto, MD, John Gibbons, PhD, Minneapolis, MN
8. "Treatment of Pediatric Moyamoya." Warwick Peacock, MD, Andrew E. Sloan, MD, Los Angeles, CA
9. "Low-Grade Supratentorial Astrocytomas: Boston Children's Hospital Experience from 1974 to 1990." M.G. Luciano, MD, PhD, P. McL. Black, MD, PhD, R.M. Scott, MD, L.C. Goumnerova, MD, J.R. Madsen, MD, N.J. Tarbell, MD, P. Barnes, MD, W. Kupsky, MD, Boston, MA

Scientific Abstracts

1. Americans With Disabilities Act: Impact Upon Therapeutic Decisions and Research

Clark Watts, MD, JD (Austin, TX)

The Americans with Disabilities Act, federal legislation, was initially passed upon the urging of three special interest groups: the hearing impaired, the wheelchair bound, and the HIV positive individual. Phased into place over the past two and a half years, its main thrust is to prevent discrimination against individuals with disabilities in the workplace and in public facilities. While primarily directed at employment practices, it may be used to address a number of decisions made in the practice of medicine, and carries with it penalties of sanction and money damage awards. It has been used against a dentist and a neurosurgeon for refusing to treat HIV positive individuals. While it has not been used to question discriminatory therapeutic decisions, examination of a case brought under Section 504 of the Rehabilitation Act of 1973, a progenitor law, provides useful insight. In this case a team randomized infants with meningomyelocele into aggressive versus supportive treatment groups. The plaintiffs contended that this random assignment amounted to discrimination against the infants on the basis of their disabilities. The court held, in essence, that a discriminatory therapeutic decision based upon sound *medical principles* would be valid. It is important that pediatric neurosurgeons understand this law in order to define, for themselves, what sound medical principles exist for the basis of therapeutic decision making and research.

2. The Currarino Triad: Clinical Presentations, Imaging, Genetics and Therapy

Robin Bowman, MD, Thomas Luerssen, MD, L. Scherer, MD, E. Klatte, MD, David Weaver, MD (Indianapolis, IN)

The Currarino triad is a developmental syndrome consisting of anorectal abnormalities, sacral dysgenesis and a presacral mass. The presacral lesion may be an anterior meningocele, a teratoma, an enteric cyst, or any combination of these lesions. We have recently cared for a family with at least 4 new patients with this syndrome: a mother and 3 daughters. The family was discovered when the eldest daughter (at age 2 years) presented with constipation and clinical evidence of occult spinal dysraphism. The initial magnetic resonance imaging (MRI) studies of the eldest 2 daughters and the mother (performed with standard lumbosacral spinal MRI parameters) missed the extremely caudal malformations characteristic of this triad, although the tethered cords (present in 2 of the 4 patients) were readily detected.

The embryology, genetics, clinical presentations, imaging, and management of these malformations will be reviewed. MRI is the diagnostic procedure of choice, but the images must include the entire pelvis in order to detect this extremely caudal complex of anomalies.

3. Embryogenesis, Associated Malformations, and Surgical Management of Myelocystoceles

Michael Partington, MD, Mark Dias, MD, Charles Harvey, MD, David McLone, MD, PhD (Chicago, IL)

Twenty-one patients with terminal myelocystoceles underwent 24 operations from 1982 to 1993. Followup averaged 2.6 years, and ranged from 1 month to 8.1 years. All lesions contained some element of a spinal lipoma, and myelocystoceles represented 10.6% of the spinal lipomas treated at our institution during the same time interval. Cloacal extrophy was present in 13 patients (62%), and included an associated omphalocele in 5 patients; 1 additional patient had an imperforate anus without extrophy. Seven patients (33%) had associated Chiari I malformations, and 2 patients (9.5%) had Chiari II malformations. Hydrocephalus was present in 4 patients (19%); all had a myelocystocele which extended above L3. Hydromyelia was present in 4 patients (19%).

In all patients, the myelocystocele was repaired and no patient was neurologically worse following the initial repair. Of the 16 patients who exhibited neurologic deficits preoperatively, 10 patients (62.5%) were improved following surgery. Three patients had delayed neurologic deterioration from retethering and were re-explored; of these patients, 2 were weaker in one leg following the second operation (1 worsened following a combined untethering and spinal instrumentation). Other operative morbidity for the entire series included cerebrospinal (CSF) leakage in 5 patients (20.8%), pseudomeningoceles in 2 patients (8.3%), and wound infections in 2 patients (8.3%).

Our results from this relatively large series confirm the frequent association of myelocystoceles with other anomalies of caudal origin. We postulate that hindbrain anomalies occur only in association with the more cranially located myelocystoceles, and relate this to the recently proposed unified theory of embryogenesis for Chiari malformations (McLone and Knepper, 1989). The rate of retethering is similar to that for other types of spinal lipomas. We advocate an aggressive approach for all patients with skin-covered spinal masses, including magnetic resonance imaging for diagnosis and early surgical repair.

4. **Symptomatic Hydromyelia Following Operation for Spinal Lipoma**

Paul H. Chapman, MD, David M. Frim, MD (Boston, MA)

Magnetic resonance imaging (MRI) often shows a minor degree of central canal dilatation in association with lumbosacral spinal lipomas. This typically occurs within the distal spinal cord adjacent to the lipoma and is an incidental finding, unrelated to the patient's symptomatology. We report 3 children in whom symptomatic hydromyelia occurred *de novo* following operation for retethering of a previously treated lipoma. No patient had a Chiari malformation. In 2 cases, preoperative MRIs showed no evidence of a pre-existing syrinx, and, in the third, there was nothing to suggest a syrinx at the time of initial surgery. Neurologic deficits appeared abruptly within several months of operation in 2, and insidiously after 12-18 months in the other. The syrinx involved the distal spinal cord adjacent to the site of the lipoma. Treatment consisted of syringostomy which arrested the progression of deficits but did not reverse them. The details of each case will be presented and the possible mechanism of this unusual but important problem discussed.

5. Latex Sensitivity in the Myelodysplastic Population: Review and Recommendations

Sarah Gaskill, MD, Joanne Mackey, RN, BSN, Gordon Worley, MD, Herbert Fuchs, MD (Durham, NC)

In 1991 the Centers for Disease Control issued a warning that allergic reactions to latex in patients with myelodysplasia had reached alarming levels. These reactions were reported to occur at a rate of 18% to 40%. Reactions varied in severity from mild urticaria to life-threatening anaphylaxis. It is thought that individuals with myelodysplasia are at increased risk to develop latex allergies because the complexity of their congenital disorder leads to early and extensive exposure to latex. Frequent surgical procedures, intermittent catheterizations, bowel regimens, and frequent hospitalizations lead to significant latex exposure. Presumably this extensive exposure history is the etiology of the sensitivity.

In response to this concern we have incorporated a latex sensitivity screening program into our spina bifida clinic. We have found that 38 patients out of 199 (19%) have demonstrated latex positivity. Of these, 9 (4.5%) have developed anaphylactic reactions, many of these severe and life-threatening.

This paper will review the history and mechanism of latex allergies, review guidelines for a latex screening program, and review recommendations for the management of the latex sensitive individual.

6. The Impact of Simultaneous Meningomyelocele Repair and Shunting of the Development of Symptomatic Chiari Type II Malformation

Todd Nida, MD, Mahmoud Nagib, MD, Stephen Haines, MD,
Stephen Marker, MD (Minneapolis, MN)

Although controversy still lingers regarding the etiology for lower cranial nerve dysfunction in children with Chiari II malformations and meningomyeloceles, early decompression of the impact at hind brain has been proposed to halt the relentless clinical deterioration. Despite such aggressive surgical approach, a substantial number of patients fail to improve. Assuming that the lower cranial nerve dysfunction is related to the chronic compressive effect over the brain stem, would a simultaneous meningomyelocele repair and shunting procedure have an impact on the future development of symptomatic Chiari Type II malformation?

Seventy-one infants with meningomyeloceles were surgically treated over a period of 9 years; 37 were shunted simultaneously; 28 children were shunted at a second procedure and 6 were not shunted at all. These groups were similar for gestational age, birth weight, Apgar scores and occipitofrontal circumference. A total of 7 children required a decompressive cervical laminectomy for a symptomatic Chiari Type II malformation at a mean age of 12 months. Although there was a trend suggesting that delaying the shunt increased the likelihood of future decompression, this was not statistically significant.

The timing of shunt insertion did not have an effect on wound breakdown, shunt infection, shunt revision, or duration of the initial hospitalization.

We conclude that, while the insertion of a shunt at the time of a meningomyelocele repair eliminates some of the cost that would be incurred with a delayed second procedure, the timing of shunt insertion does not seem to influence the later development of a symptomatic Chiari Type II malformation.

7. Chiari I Malformation and Acute Spinal Cord Infarction: A Report of 3 Cases

Frederick Marciano, MD, PhD, Harold Rekate, MD, Stanley Johnsen, MD (Phoenix, AZ)

We report 3 children, ages 14-18 months, with acute spinal cord infarction and Chiari I malformation. All 3 children presented with acute weakness. Guillain-Barre syndrome was suspected and all had elevated spinal fluid protein. No prodromal symptoms consistent with an infectious etiology were present. Two had quadriplegia while 1 had paralysis of both arms with preservation of leg movement. Cervical magnetic resonance (MR) imaging revealed enlargement of the spinal cord over multiple segments. In 2, spinal cord tumor was considered the probable diagnosis. All 3 had a Chiari I malformation. Surgical biopsy and attempted removal in 2 revealed no histologic evidence of tumor, although at the time of surgery, infarcted cord was seen. A third did not have biopsy. One patient died of respiratory incompetence. Two survived with prominent bilateral upper extremity paralysis. Repeat MR imaging revealed a decrease in the size of the cervical cord in 1 and atrophy in the other patient with the more protracted course. None of the patients had evidence for trauma or cervical spine instability. Interestingly, 2 of the children were Navajo Indians and came from the same village in Northern Arizona.

The association of acute spinal cord infarction with Chiari I malformation in children has not been reported previously. Indeed, acute idiopathic spinal cord infarction in previously well children is rare and has been little reported or understood. The relationship of this rare infarction to the Chiari I malformation is speculative. Our experience suggests that those encountering similar patients should consider conservative management.

8. Pediatric Chiari Malformations: Long-Term Followup of Surgical Treatment

Michael Muhonen, MD, John Piper, MD, Paul Sawin, MD, Arnold Menezes, MD (Iowa City, IA)

Forty-one pediatric patients with Chiari malformations (without myelodysplasia) were treated surgically at The University of Iowa Hospitals and Clinics between 1975 and 1993. Age ranged from 2-20 years at presentation (mean 10.9 years). Symptoms ranged in duration from 2-114 months (mean 20 months).

Ventriculo-peritoneal shunts were placed in 4 patients with hydrocephalus. Sixteen of the earliest patients underwent posterior fossa decompression consisting of posterior fossa craniectomy, cervical laminectomy, fourth ventricle-subarachnoid shunt, occlusion of the central canal at the obex, and duraplasty. Fifteen of the later patients had a similar procedure, without occlusion of the central canal. Eight patients underwent transoral decompression of the cervical medullary junction, and 11 required dorsal occipital cervical fusion for instability. Syringosubarachnoid shunts were placed in 4 patients.

Followup ranged from 4-237 months (mean 74 months). Neurologically, 12 patients were normal, and 29 were improved. Of those who received posterior fossa decompression with occlusion of the central canal, 3 were normal and 13 were improved; without occlusion of the central canal, 7 were normal, and 8 were improved. Magnetic resonance imaging demonstrated resolution of syringomyelia. With respect to scoliosis, 9 had complete resolution, 10 improved, and 2 progressed.

Posterior fossa decompression is an effective treatment for Chiari malformations. Occlusion of the central canal does not appear to augment the standard posterior decompression. The restoration of normal cerebrospinal fluid dynamics at the craniovertebral junction is critical in the treatment of this condition.

9. **Surgical Management of Anterior Skull Base Lesions of Embryologic Origin in Children**

Y. Hahn, MD, A. Hotaling, MD, B. Bauer, MD, R. Pensler, MD
(Maywood, IL)

Midline anterior skull base lesions of embryologic origin in children include frontonasal or ethmoidal encephalocele, nasal glioma, and nasal dermal sinus cysts. Nasal dermal sinus cysts (NDSC) are rare congenital lesions (1.1% of all cysts; 3.7% to 12.6% of dermal cysts of the head/neck) of embryologic origin that occasionally extend intracranially. An enlarged foramen cecum and a bifid crista galli have been reported as radiographic evidence of an intracranial extension. Diagnostic and treatment problems persist, however, because of the insensitivity even of refined computed tomography and coil imaging techniques. Over the past 10 years, we have treated 33 children with NDSC (12 boys, 21 girls). Ages ranged from 1 month to 14 years (33.5 +/- 22 months). Eleven children with classic radiographic stigmata of the enlarged foramen cecum and bifid crista galli underwent combined intracranial/extracranial surgery; 7 of these had intradural extension (6 interdural dermoids, 1 frontal lobe abscess). In the remaining 4 children, the fibrous end of the cyst was attached to the dura with no intradural extension. Of the 33 children, 16 (48.5%) had purely superficial cysts with no deep extension. Ten (30.3%) had a blind end in the depth of the midline nose or at the level of the foramen cecum but not intradurally. Seven (21.2%) had intracranial intradural extensions with a dermoid. The foramen cecum was enlarged in the 17 children with intracranial or near-intracranial extensions; a bifid crista galli was found in 14 patients. There was no surgical morbidity or mortality and no recurrence. The radiographic stigmata of an enlarged foramen cecum and a bifid crista galli did not confirm intracranial and/or intradural extension, and regular coil and CT images can fail to visualize intracranial involvement. Therefore, imaging should focus on the midline anterior skull base with a very thin cut (1.5 mm). One-stage intracranial and extracranial surgery can be performed without complications; external and/or midline rhinoplasties are good alternatives. Details of the data will be discussed.

10. Surgical Management of the Cloverleaf Skull Deformity

Daniel Resnick, MD, Ian Pollack, MD, A. Leland Albright, MD
(Pittsburgh, PA)

The cloverleaf skull deformity, or kleeblattschadel, is a rare malformation caused by synostosis of multiple cranial sutures. This anomaly has been reported to carry a dismal prognosis in terms of both neurologic outcome as well as cosmetic appearance if treatment is delayed. Due to the paucity of data concerning the results of early operative intervention, it remains uncertain whether aggressive craniofacial decompressive/reconstructive procedures are consistently effective in ameliorating the effects of the malformation on both neurologic development and cosmetic appearance.

This paper reports the treatment and outcome of 7 children with the cloverleaf skull malformation treated at our institution between 1981 and 1993. All children underwent initial decompressive craniectomy with the removal of at least 50% of the cranial vault for relief of high intracranial pressure in early infancy. Subsequent reconstructions, intended to normalize the cosmetic appearance, were performed later in childhood. Followup ranges from 3 months to 9 years, with a mean of 47 months. Long-term results are reported with regard to neurologic outcome as well as normalization of skull shape in terms of both the cephalic indices and general cosmetic appearance. Overall, 4 of 7 children have had a good outcome with a normal neurologic status or mild developmental delay and an acceptable cosmetic result. One child is severely neurologically impaired following a sagittal sinus thrombosis suffered during a later reconstructive procedure. Two children have died, both due to complications resulting from later surgical revision. Conclusions drawn from this review include: (1) The cloverleaf skull malformation does not in itself portend a poor outcome; (2) early and aggressive decompressive procedures are necessary to ameliorate the effects of high ICP on the neurologic development of these children; (3) multiple procedures are often indicated in order to achieve a good result; and (4) operative morbidity and mortality rise with repeated surgery.

11. Methylmethacrylate Cranioplasty in Children: A 10-Year Experience

Steven Schneider, MD, Burt Greenberg, MD, Alan Rosenthal, MD
(New Hyde Park, NY)

Various cranioplasty techniques continue to evolve. To evaluate the efficacy of the standard method of wire mesh and methylmethacrylate cranioplasty (MMC) in childhood, a retrospective study of 50 patients between 10-18 years of age over a 10-year period was performed. Thirty-two procedures were performed for post-traumatic skull defects and 18 for nontraumatic causes.

The immediate results were satisfactory in all cases. During the first 2 years there were no complications reported; however, during the next 8 years, 17 (34%) complications occurred. These included 12 infections and/or wound breakdowns, 3 dislodgements, and 2 breakages. Influencing factors included postoperative radiotherapy in 6 patients, the size of the defect in 5 patients (greater than 36 cm), and the presence of prior infection in 6 patients.

A population at risk for complications following MMC in childhood is identified and the authors currently recommend avoidance of MMC in these patients. Our data is presented and discussed.

12. Differential Language Localization in Bilingual Children

Michael Schneck, MD, Paul Kanev, MD, Kenneth Liebman, MD,
Jack Jallo, MD (Philadelphia, PA)

Language representation within the dominant temporal lobe is quite variable. Differential aphasias in primary and secondary languages have occurred following cerebral infarction and separate cortical sites for naming have been localized during awake craniotomies in adults. We have studied differential language localization with subdural electrode grids in 2 bilingual children preparing for epilepsy surgery. Each patient suffered partial complex seizures, refractory to multiple anticonvulsants. English was a secondary language acquired 4 years after normal language acquisition in an Armenian child and 6 years after a second patient learned Spanish. Each right-handed male child was 8 years old. MRI revealed left mesial temporal lobe tumors and telemetric EEG confirmed widespread lateral and mesial temporal interictal foci. An 8x8-cm subdural electrode array was positioned over the lateral cerebral hemisphere through a wide craniotomy exposure. Cortical stimulation beginning on the second postoperative day localized primary naming within the posterior temporal operculum, 7.0 and 7.5 cm along the superior gyrus. English function was 2.0 cm from the temporal tip in the Armenian child and 2.5 cm in the Hispanic child. Fluency in each language was preserved after tumor resection with 6.5 cm lateral and mesial temporal lobectomy sparing the entire superior temporal gyrus. We conclude that differential language sites in bilingual children may reside within anterior temporal cortex generally considered functionally "safe." We advocate cortical stimulation of language function in bilingual children prior to dominant temporal lobe surgery.

13. Vagal Nerve Stimulation for Intractable Pediatric Epilepsies

Gregory Homig, MD, Jerome Murphy, Gloria Schallert, Melissa Baldus (Kansas City, MO)

Vagal nerve stimulation prevents experimental seizures in animals. In an adult series, about half the patients have had at least a 50% reduction in seizure frequency following activation of the surgical implanted stimulator. Permanent complications have not been observed. Our first five children with the implanted left vagal nerve stimulator have all demonstrated significant and persistent benefit.

Patient #1, 15 years old, was receiving phenobarbital and carbamazepine (CBZ), and was having daily absence seizures and a prolonged complex partial seizure with secondary generalizations every several months. Since activation of her vagal nerve pacemaker she has had no further seizures, save immediately following withdrawal of phenobarbital. Concurrently grades and self-image have improved dramatically. The tone of her voice drops during the 30 seconds of stimulation, but she is able to continue talking. Patient #2, 9 years old, was receiving vigabatrin, divalproex sodium, CBZ, and methsuximide. Generalized tonic-clonic (GTC) seizures were occurring several times a week with secondary injury. Felbamate, nitrazepam (NTZ), and a corpus callostomy were not helpful. Three months after pacemaker activation her seizures are less than 1 per week. Magnetic activation at the onset of a seizure aborts them. Dosages of antiepileptic drugs have remained unchanged. Patient #3, 5 years old, had GTC seizures, 1 to 20 per month, lasting 5-10 minutes despite phenytoin and NTZ. After 2 months of stimulation, seizure frequency is reduced to 3 a month. These are immediately aborted by magnetic activation at the onset of a seizure. Concurrently NTZ has been eliminated. The child is now alert, active, and is daytime toilet trained. Patient #4, 11 years old, had 2 to 3 GTC seizures weekly. She is taking valproic acid (VPA) and lorazepam. Seizures are now aborted with magnetic activation. Patient #5, 9 years old, was receiving phenytoin (PHT) and VPA. GTC seizures were occurring 6 to 10 times per day, lasting 2-4 minutes. His antiepileptic regimen now includes PHT, carbamazepine, and primidone. Three months postsurgery he is seizure-free. Functionally, he continues to have right-sided weakness. Observed side effects have been transient; change in voice and coughing during the stimulation. Vagal nerve stimulation appears to be a well-tolerated and effective device in the control of otherwise intractable seizures.

The surgical technique will be discussed, and the experimental basis of this therapy will be reviewed. This is the first study exclusively involving pediatric patients.

14. The Prevalence of Epilepsy among Patients Treated for Hydrocephalus: An Actuarial Study

Joseph Platt, Jr, MD, Michael Horgan, MD, Christina Carlson
(Portland, OR)

Four hundred and sixty-four patients underwent insertion or revision of cerebrospinal fluid shunts at Oregon Health Sciences University between 1976 and 1989. Hospital records were reviewed retrospectively to determine the prevalence of epilepsy in this population and to identify risk factors for its development. Epilepsy was defined as seizures that received chronic treatment with antiepileptic drugs. Actuarial statistical techniques were used.

The prevalence of epilepsy among patients undergoing initial shunt insertion was 13%. By 10 years after initial shunt insertion, the estimated prevalence of epilepsy rose to 33%. The age of the patient at initial shunt insertion had no detectable effect on the risk of development of epilepsy. The effect of burr hole site was not significant, but there was a trend suggesting lower risk with parietal sites as compared to frontal sites ($p = 0.1640$). This trend favoring parietal sites seemed to be based mostly on the outcomes of patients shunted as neonates ($p = 0.1071$); no trend favoring parietal sites was apparent in patients shunted later in life. Interestingly, the number of shunt operations performed during followup at our institution had no effect on the risk of development of epilepsy. The etiology of the hydrocephalus was a strong determinant of the risk of epilepsy, but most of the statistical effect of etiology was already manifest at the time of initial shunt insertion.

Epilepsy is common among patients with hydrocephalus, but shunt surgery seems to play a relatively minor role in the development of epilepsy in this patient population.

15. The Incidence of Postoperative Epilepsy in Children Following Subfrontal Craniotomy for Tumor

Mitchel Berger, MD, Earl Wang, MD, and J. Geyer, MD (Seattle, WA)

Thirty-one children who underwent 36 subfrontal craniotomies were retrospectively studied in postoperative time epochs, i.e., 0-7 days, 1 week to 1 month, 1-6 months, 6 months to 1 year, 1-2 years, 2-3 years, to determine the incidence of postoperative epilepsy and the effectiveness of antiepileptic drugs (AEDs) for seizure prophylaxis. The percent of patients with postoperative seizures within each time epoch remained roughly constant, i.e., less than 7%, except for 12% in the 1-6- month time period.

Postoperative seizures were not more likely to occur during any given time period in any statistically significant way. Patients not on AEDs were combined with patients who had subtherapeutic drug levels (Group A) and compared to children with therapeutic levels (Group B) which showed no significant differences in seizure activity in each time epoch. Patients on AEDs were as likely to have postoperative seizures as those not on AEDs. However, up to 50% of patients did not have serum AED levels documented postoperatively during the first week and from day 8-30.

Therefore, as we collect more data on children with AED levels done during the first postoperative month, we will continue to recommend AEDs during this time period, but a careful analysis of our data does not warrant long-term, i.e., greater than 1 postoperative month, prophylactic therapy in children following a subfrontal craniotomy. The incidence of postoperative epilepsy for this pediatric population was also assessed in terms of preoperative seizure history, subfrontal tumor site, pathology, complications and extent of resection, and will also be discussed.

16. Seizure Control Following Extra-temporal Resections in Children

Paul Kanev, MD, Jack Jallo, MD, Michael Schneck, MD, Christopher Getch, MD (Philadelphia, PA)

Children with intractable epilepsy are being considered as candidates for epilepsy surgery with increasing frequency. Long-term seizure control in patients with extratemporal seizure foci is possible. We have completed a retrospective review of our experience with children with intractable epilepsy not related to tumors. Twelve children with extratemporal foci underwent surgery during the last 2 years. There were 8 males and 4 females; average patient age was 8½ years. Seizures were generalized in 8 patients and complex partial in 4 children; the average duration of seizures was 3 years. Preoperative studies included MRI, scalp and video-telemetric EEG, WADA, and neuropsychologic testing. Extratemporal ictal and/or interictal seizure foci were localized in candidates for focal resections. Surgical procedures performed included 9 frontal and 3 parietal resections. Each resection was guided by ECoG and motor mapping. Following resections within accessory motor cortex 3 children experienced transient contralateral motor dyspraxia. Ten patients remain seizure-free on followup averaging 13 months; seizure severity and frequency is diminished in 2 out of 12 patients. Seizure control was not influenced by age or IQ. Anticonvulsant therapy was withdrawn in 5 children with a mean interval off medication of 6 months. We conclude that aggressive resection of extratemporal foci in children with chronic epilepsy can effect seizure control. Surgical morbidity was minimal and school performance and social integration was improved in all children. After failure of anticonvulsant therapy in children with chronic epilepsy, we advocate early consideration for surgery.

17. The Use of Subdural Electrodes for Mapping Seizure Foci in Children

Derek Bruce, MD, Hugh O'Donnell, MD, Richard North, MD (Dallas, TX)

In adults, identification of seizure foci amenable to surgical resection can usually be made from the scalp EEG monitoring (60%) often supplemented by depth electrodes; a minority (< 20%) require subdural strips or grids. In children, lateralizing and locating seizure foci is more difficult. At least 50% of the cases involve extratemporal epilepsy and require electrode coverage too large and often too superficial for the use of depth electrodes. This communication reports strategies for the best coverage of the brain using the minimum number of subdural strips or grids and the complications encountered.

From 1990-1993, a total of 33 children (22 boys and 11 girls) with a mean age of 11.5 years (ages ranging from 1-18 years) underwent placement of subdural electrodes for long-term electrocorticographic monitoring. Eighteen had burr hole placement of either bilateral temporal, frontal, or parietal strips or some combination thereof. Fifteen had craniotomy and insertion of subdural grids with or without subdural strips (up to 120 electrodes). Definitive seizure focus was identified and resected in 13 (72%) of the first group and in 14 (94%) of the second group. The hair was not shaved. All patients were maintained on IV antibiotics during the monitoring period. There were no early infections, but 1 child returned 2 months after surgery with a low-grade pseudomonas infection of the craniotomy site for infection rate of 3%. Large areas of the brain can be safely covered using subdural strips or grids with minimal morbidity. In properly selected patients, the confirmation and identification of a resectable focus is 88%.

18. Crush Injuries to the Head in Children

Gary Correnti, MD, Ann-Christine Duhaime, MD (Philadelphia, PA)

While the majority of head injuries in children and adults involve accelerating loading conditions, some patients suffer inertial loading. This occurs when forces are applied slowly to the head, and produces a much different pattern of injuries. Crush injuries are usually described in the context of industrial accidents, but in our experience they are not rare in children. We report a recent series of six serious crush injuries in young children and offer suggestions regarding evaluation and treatment of this often complex entity.

Patient ages ranged from 10 months to 6 years. In 3 cases the child's head was run over by a motor vehicle backing up in a driveway or parking lot. In another 3 patients inertial loading occurred when the child climbed or pulled on a heavy object which then fell over with the child, landing on the head.

One child died shortly after arrival to the hospital with massive brain injuries. The others showed varying degrees of soft-tissue injuries to the face and scalp, with coma scores ranging from 8 to 15. CT and MRI showed multiple and often extensive comminuted basilar and calvarial fractures, subarachnoid and parenchymal hemorrhage. There was 1 cervical spine injury but, surprisingly, no vascular injuries. One child had pituitary transection, 3 had cranial nerve palsies, and another developed a delayed CSF leak at 18 months. All children made good to moderate neurologic recoveries.

In spite of their alarming initial appearance, children who survive the acute period of a crush injury to the head have a good long-term outlook. Management requires a team approach and careful anticipation of early and late complications.

19. **Dextromethorphan Is Protective in Experimental Subdural Hematoma**

Ann-Christine Duhaime, MD, Laura Gennarelli, Doug Ross, PhD
(Philadelphia, PA)

While many agents are currently under investigation as neuroprotective agents designed to interrupt cascades of deleterious events after insult to the brain, few agents are approved or tested in children. This results from safety issues in the developing brain and liability issues faced by the pharmaceutical industry. Dextromethorphan, a commonly used antitussive which is also a potent noncompetitive NMDA receptor antagonist, is a generically available drug which has a long safety record in pediatric patients. It has been shown to be protective in various stroke models in animals. We report our recent experience with this agent in acute experimental subdural hematoma.

Twenty Long-Evans rats were anesthetized with halothane via endotracheal tube. Acute subdural hematoma was produced using a "cranial window" model, in which .25 cc of autologous blood is injected through a frontal burr hole and its distribution observed through a large parietal craniotomy. This model typically produces a large but thin subdural hematoma with an underlying zone of infarction. Experimental animals (n = 11) received 10 mg/kg dextromethorphan bid for 3 days; control animals (n = 9) were treated identically but no drug was given. Animals were sacrificed at 72 hours after injury and the volume of histologic lesions were analyzed and compared between groups.

Control animals had a mean lesion size of 135.3 mm³, while treated animals averaged 68.8 mm³ (p = 0.038). Dextromethorphan is a safe, well-tolerated neuroprotective agent which is effective after brain injury. Phase II trials of high-dose dextromethorphan assessing metabolism, toxicity, and pharmacokinetics in severely head-injured children are currently in progress.

20. Subarachnoid Hemorrhage and Post-Traumatic Hydrocephalus in Severe Pediatric Head Injury

Joseph Watson, MD, JoAnn Tillett, RN, John Ward, MD, FCCM
(Richmond, VA)

Traumatic subarachnoid hemorrhage (SAH) was the most common radiographic abnormality in severe pediatric head injured patients (GCS \leq 8) who developed post-traumatic hydrocephalus (PTH). Subarachnoid hemorrhage was seen on the admission computed tomography (CT scan) in 7 of the 8 patients with post-traumatic hydrocephalus requiring a permanent cerebrospinal fluid shunting procedure. The diagnosis of PTH was made on the basis of ventriculomegaly with evidence of increased intracranial pressure on CT scan of the head and/or an absorption defect study. Data from the Medical College of Virginia's Head Injury data base were reviewed for pediatric patients (age \leq 17 years) with severe head injury from 1985 until the present. CT scans of 87 patients were reviewed revealing SAH in 34% (N = 30). Eight (9%) subsequently developed PTH requiring a shunt. Seven of the 8 PTH patients belong to the SAH group. Other abnormalities including subdural hematoma, epidural hematoma, and cerebral contusions were not found with a significantly higher frequency in the PTH group when compared to the patient population. Seven out of 30 patients (25%) with SAH developed PTH. The incidence of PTH in those children with SAH was significantly higher than those without ($P > 0.005$). Subarachnoid hemorrhage preceding hydrocephalus is well known in the context of aneurysmal SAH, but the importance of SAH in pediatric head trauma and subsequent post-traumatic hydrocephalus has not been well described. There is a clear correlation in our patient population between the finding of SAH on presentation in severe pediatric head injury and the development of PTH.

21. Late Outcome of Children with Inflicted Head Injuries in Infancy

C. Christian, MD, A. Duhaime, MD, T Seidl, MSW, E. Moss, PhD
(Philadelphia, PA)

Nonaccidental injuries account for nearly one quarter of all head injury admissions in children under 2 years of age, and child abuse is the most frequent cause of traumatic mortality in this age group. Outcome in survivors of early inflicted injury has been poorly studied. We report an average 9-year followup of children with the "shaking-impact syndrome" and relate outcome to acute clinical presentation and radiographic findings.

The study group included 35 surviving patients drawn from a previously reported series describing the acute injuries in 48 children who were admitted to our institution between 1978 and 1984, along with 10 subsequent patients. All children were 2 years or younger at the time of injury, and all had unexplained subdural or subarachnoid hemorrhages and supporting evidence of nonaccidental injury. Neurologic status at presentation ranged from irritability and lethargy to coma. To assess long-term outcome, a questionnaire was designed regarding disabilities, functional status, school placement and performance, and behavior.

To date, 13 children have been assessed, who now range from 5 to 15 years of age. One severely disabled child died 6 years after injury, 6 children remain severely disabled, 1 is moderately disabled, and 5 have a good outcome. Of the latter, all attend regular school, although 3 require some tutoring. Acute seizures and level of consciousness were incompletely correlated with outcome; the best predictor was need for intubation, since no child who required intubation in the acute period had better than severe disability. Implications for management of these injuries will be discussed.

22. Growing Skull Fractures: Classification and Management

Naim-Ur-Rahman, MD, Zain Al Abedeen B Jamjoom, Abdel Hakim B. Jamjoom, Waleed R. Murshid, MD (Saudi Arabia)

Nine patients with growing skull fractures treated between 1983 and 1993 are described. These growing fractures constituted 2% of all the cases of skull fractures seen during the period (a total of 429 cases). Based on etiopathogenesis, computed tomography (CT) scan appearances, operative findings, and management strategies required; 4 main types of growing skull fractures were recognized: in type I (n = 2) a tense subdural collection, in type II (n = 3) a leptomenigeal cyst, in type III (n = 3) damaged and gliotic brain, and in type IV (n = 2) a porencephalic cyst, extended through the skull defect into the subgaleal space. A combination of type II and type IV coexisted in 1 patient. Initial head injury and neurologic deficit was judged to be mild to moderate in all the 9 cases. Continued growth of skull fractures correlated closely to the increasing neurologic deficit in 7 cases. In 2 patients, natural arrest of fracture growth at 5 and 7 months after trauma was accompanied by arrest in progress of neurologic deficit. Available surgical options are discussed and general guidelines for the management are given. The classification of the growing skull fracture suggested here was found to be helpful in planning treatment. Thus, type I fractures required subduroperitoneal and type IV, a ventriculoperitoneal shunt as initial/definitive treatment. Durocranioplasty was the correct treatment for type II and III fractures.

23. Comparison of The Different Mathematical Pressure-Volume Models of the Cerebrospinal Fluid Compartment

James Drake, MD, G. Tenti, PhD, S. Sivalsganathan, PhD,
(Toronto, Ontario)

The past 2 decades have witnessed the development of numerous mathematical models designed to characterize the pressure and volume dynamics of the central nervous system compartment. These models have been used to study the behavior of this compartment under such pathologic conditions as hydrocephalus, head injury, and brain edema.

Review of most previous models reveals that they are particular cases of a single basic differential equation describing the evolution in time of the cerebrospinal fluid (CSF) pressure. First models proposed that the brain compliance was constant, $C = C_0$. Subsequent models have proposed that the brain compliance is non-linear, $C = 1/kP$; $C = 1/(k_1P+k_2)$; $C = ae^{-bP}$, etc. A model addressing brain tissue mechanics using finite element analysis has recently been proposed although the major assumptions concerning brain elasticity and boundary conditions have not been verified.

To compare the various mathematical models, we simulated the effects on CSF pressure of bolus injection, bolus withdrawal, constant infusion, and constant withdrawal (including siphoning) using linear and nonlinear models. The simulation was performed on an ALR 486 computer using SCoP simulation software. Linear models differed from nonlinear models only in the rate at which they approached equilibrium pressures, which were equivalent.

Recent nonlinear models have offered little advance over early linear models and neither have given any information about the behavior of the brain itself. Simplified models of brain tissue mechanics, which can be experimentally verified, should be the next step in this research area.

24. Limitations of the Ventriculocisternal Perfusion Technique

J. Gordon McComb, MD, Berislav Zlokovic, MD, PhD
(Los Angeles, CA)

Much experimental work has focused on the mechanisms of cerebrospinal fluid (CSF) secretion in animals using the ventriculocisternal perfusion technique whereby CSF formation is estimated at steady state by measuring the concentration changes of a nondiffusible reference marker (i.e., one which moves solely by bulk flow) in a known volume of CSF being introduced into the ventricular system. Although this technique has proven very valuable it has its limitations.

In many experimental settings the change in CSF formation is relatively small. In the worse case scenario, counting errors of 1%, 2% and 5% in all variables could produce CSF formation estimates that are in error by 15%, 30%, and 75% respectively.

Admixture of newly secreted CSF with the artificial infusate, especially if only one ventricle is perfused, can lead to error.

Loss of the reference marker, especially in situations where the blood-brain interface is disrupted, in the order of 1%, 10%, 20%, 50% can produce overestimates of CSF secretion by 1%, 13%, 29%, and 117% respectively.

As CSF formation *in vivo* involves such factors as choroidal arterial blood flow, cellular permeability, alterations in blood-CSF-brain interface, the ability of a substance tested to reach the appropriate receptor sites, and the intracellular processes to an unknown extent, the ventriculocisternal perfusion technique has a limited ability to define processes occurring at the cellular level.

25. **A Volumetric Approach to Slit-Ventricle Syndrome**

John Jane, MD, PhD, R. Polin, MD, L. Walker, RN, A. Polin, BA, R. Rao, BS, A. Chenelle, MD, J. Goble, PhD (Charlottesville, VA)

The so-called "slit-ventricle syndrome" remains an uncommon but potentially devastating sequela of shunted hydrocephalus. Symptoms of severe headache, nausea, and vomiting can be dangerously attributed to shunt-independent causes. Traditional management of these patients has involved upgrading of valves, addition of antisiphon devices, and in extreme cases subtemporal decompression.

We have sought to develop a rational approach in the management of these children who present with symptoms of increased intracranial pressure (ICP) despite apparently functional shunts. Preoperative volumetric analysis including brain volume and ventricle-to-brain ratio are compared to normal controls. Preoperative ICP is also measured. Among patients with ICP spiking elevations and small brain volumes, valve upgrades are performed. ICP elevation associated with high brain volume and low ventricle-to-brain ratio are treated with osteoplastic decompressive craniotomy with lyodura duraplasty and loose reapproximation of the bone flap with suture.

Five of the latter cases were identified in children ages 15-74 months. Success as determined by normal postoperative ICP and resolution of clinical symptoms was obtained in all 5. Followup in these patients ranging from 2-32 months reveals no shunt or ICP related problems. These preliminary trials demonstrate a potentially beneficial use of volumetrics and ICP monitoring in the management of slit-ventricle syndrome.

26. Cortical Mantle Stress, Strain, and Creep: Results of Finite-Element Analysis of the Enlarged Ventricular System

Samuel Neff, MD, Ravi Subramaniam (Camden, NJ)

The cortical mantle changes shape and thickness both in acute and chronic hydrocephalus. The stress in the brain that results from dilation of the ventricles has already been calculated for the static case. We use an advanced finite-element computer model with an elastic skull, a viscous fluid, and a nonlinear creep material for the brain to predict the effects of acute and chronic hydrocephalus. The calculation incorporates the interaction between the fluid and structural elements accurately. This report addresses the effects of ventriculomegaly on the sensitivity of the brain to increased pressure.

Using x-ray computed tomographic data from hydrocephalic patients, we simulate the effects of increased ventricular pressure, both in the acute and chronic case. The model allows the stresses and strains to be calculated for a static load, and for deformation ("creep") to be calculated for chronic loads.

We determine the areas of high and low stress, the relationship between cortical mantle thickness and pressure-induced stress, and the relative dilating efficacy of increased pressure at different starting ventricular sizes. We also calculate the regions of greatest creep—those areas where tissue will be subject to the greatest distortion. The results are displayed graphically on a workstation in a variety of formats.

The results show that finite-element techniques have advanced sufficiently to be useful in understanding complicated physical models of the brain. The correlation of calculated creep values and neurologic deficits will be discussed.

27. Metabolic Demonstration of Retained Central Nervous System Function in the Rabbit Model of Infantile Hydrocephalus

Monica Wehby, MD, Charles Olmstead, PhD, Warwick Peacock, MD, David Hovda, PhD, Greg Olavarria, R. Gayek, DVM, Robin Fisher, PhD (Los Angeles, CA)

Rabbits with kaolin-induced hydrocephalus have few overt neurologic or behavioral deficits even when there is profound ventriculomegaly. We have been interested in a metabolic index of functional sparing in chronic untreated animals and in those recovering function after ventriculoperitoneal (VP) shunting. Rabbits were made hydrocephalic at 2-5 days of age by an injection of 100 μ l of kaolin into the *cisterna magna*. Control (N = 7), untreated hydrocephalic (N = 8), and shunted (N = 4) animals were sacrificed at survival periods between 60-120 days. Awake animals received 200 μ Ci of [¹⁴C]-2-deoxy-D-glucose. Coronal frozen sections (20 μ) were processed for quantitative 2DG autoradiography, cytochrome oxidase (CO) histochemistry, and cresyl violet histology.

Both glucose utilization and oxidative metabolic capacity were significantly higher in the chronic untreated hydrocephalics than in normal controls. There was a direct relationship between the CO density and the degree of hydrocephalus in the untreated animals. Interestingly, the highest CO values were seen in animals with functioning VP shunts.

The 2DG and CO results provided clear differentiation between structures in both the normal and hydrocephalic animals. Glucose utilization was highest in somatosensory, auditory, and visual cortex, the medial geniculate bodies and the inferior colliculus in both the control and hydrocephalic animals. Oxidative metabolism was more variable between animals with the control being highest in the olfactory and frontal cortices, while the somatosensory cortex, striatum and the geniculates stood out in the hydrocephalic. These data indicate that there is considerable functional activity in the compressed cortical mantle of the chronic hydrocephalic rabbit and those with functioning VP shunts.

28. Neuroendoscopy for the Treatment of Antenatal Hydrocephalus

Kenneth Reichert, MD, Kerry Crone, MD, Mimi Nurre-Miller, RN, Lori Barr, MD, Janice Allison, MD, Bernadette Koch, MD (Cincinnati, OH)

The incidence of congenital hydrocephalus is estimated to be 0.5 to 1.5 per 1,000 live births. Experimental animal data demonstrates that when progressive hydrocephalus is arrested by treatment, fetal brain tissue resumes normal maturation and cytoarchitecture. Initial *in utero* management of congenital hydrocephalus produced a high mortality and morbidity rate with a high incidence of shunt malfunction, slit ventricles, and loculated ventricles. Our initial results of laser-assisted neuroendoscopy in the management of hydrocephalus prove effectiveness in reducing shunt malfunction and associated morbidity. These two factors limited the effectiveness of *in utero* fetal shunting. Ten 90- to 100-day-old fetal lambs underwent 2% sterile Kaolin injection into the cisterna magna in a technique described by Edwards. Six fetuses developed hydrocephalus documented by ultrasound with average preoperative lateral ventricular width of 16.5 mm, cortical mantle 5.8 mm, and hemispheric width 54.5 mm. Five of the 6 animals underwent endoscopic placement of a ventriculoamniotic shunt. The sixth animal was used as a control. *In utero* postshunting ultrasonic assessment showed an average reduction of the lateral ventricular width 8.3 mm and an increase in cortical mantle 3.4 mm with all fetuses surviving the procedure. No shunts dislodged from the cranium and no shunts showed evidence of malfunction during the average life of 20.5 days (range 14 to 31 days). Fetuses were born at 133 to 142 days gestation (mean 138.5 days). The control fetus was delivered by C-section on day 142. The animal was unable to be resuscitated. One animal developed an abscess in her incision requiring incision and debridement. No other complications were encountered. This preliminary study documents the ability to maintain patency of endoscopically placed ventriculoamniotic shunts with reduction in ventricular size and minimal morbidity. Further research in tocolytic and endoscopic techniques will be needed to apply this technology to human fetuses.

29. Hydrocephalus: Under Arrest or on Parole?

John Campbell, MD, Jeffrey Blount, MD, Stephen Haines, MD
(Minneapolis, MN)

Background/Objective: Some children with hydrocephalus may reach an equilibrium in which they no longer require a functioning shunt. In such circumstances a diagnosis of "arrested hydrocephalus" may be made. We examined the characteristics of such patients with the goal of defining diagnostic criteria, demographic characteristics, and the long-term prognosis.

Methods: Using the Minnesota Shunt Database, a subset of pediatric patients who had a period of at least four years without a shunt revision was selected. Characteristics of the study group, such as hydrocephalus etiology, lifespan of shunts, occurrence of malfunction and infection, and incidence and presentation of acute shunt failure were examined.

Results: Forty-six subjects out of 435 patients included in the Minnesota Shunt Database were selected. Patients in this subset underwent 58 revisions after a revision-free period of at least 4 years. Of these 58 revisions, 23 (40%) were performed after 4 to 6 years of adequate shunt function, 10 (17%) after 6 to 8 years, and 25 (43%) after more than 8 years. Of the 46 patients, 5 were diagnosed during followup with "arrested hydrocephalus" and all eventually required further revisions. Of the 58 revisions, 22 (38%) were done urgently, 5 (9%) emergently, and the remainder electively.

Conclusions: Given the high incidence of acute shunt failure in those with presumed arrested hydrocephalus, the concept of shunt independence is a potentially hazardous one. Such a diagnosis requires careful assessment of shunt function and ventricular compliance, as well as fastidious followup.

30. Negative Pressure Hydrocephalus

M. Vassilyadi, MD, J. Farmer, MD, J. Montes, MD (Montreal, Quebec)

Deregulation of pressures across the craniovertebral junction, from spinal arachnoid cysto-pleural shunting, in children with Arnold Chiari malformation and ventriculo-peritoneal (VP) shunted hydrocephalus, may result in ventricular dilatation despite negative intracranial pressure. Two cases are presented to illustrate this phenomenon of "negative pressure hydrocephalus": Both patients received cysto-pleural shunts to treat their arachnoid cysts. Both demonstrated signs of herniation postoperatively despite functioning VP shunts, and both recovered after the cysto-pleural shunts were revised to increase the resistance in the system. Intraventricular pressure recordings in the first patient were between 0 and -5 mm Hg. The second patient was symptomatic only when sitting up.

We believe that some communication existed between the arachnoid cyst and the subarachnoid space in both cases, and the negative pleural pressure led to foraminal herniation. This negative pressure ventriculomegally remained as long as the opening pressure of the VP shunt valve was higher than the intracranial pressure. Paradoxically, the ventricular size decreased when the intracranial pressure was allowed to normalize after the resistance was increased in the spinal shunts. In conclusion, the brain stem symptoms were not due to the ventricular dilatation, rather they were caused by the foraminal herniation from the negative pressure transmitted across the craniovertebral junction, and the ventricles dilated secondarily.

31. Management of the Shunted Patient with a Bladder Perforation

James Callahan, MD, John Kalsbeck, MD, Richard Rink, MD,
Thomas Luerssen, MD (Indianapolis, IN)

Enterocystoplasty is a well accepted and popular method of bladder augmentation in children with dysfunctional urinary tract systems. In most series a high percentage of the children undergoing bladder augmentation are myelodysplastic. The majority of these patients have a cerebrospinal fluid shunt. An increasingly evident complication of bladder augmentation is perforation.

Our institution has a large series of children who have undergone bladder augmentation. There have been 28 bladder perforations in the postoperative period. We are presenting a series of 22 cases of bladder perforation in 19 children with ventriculoperitoneal shunts. There was no mortality in our series. Seventy-one percent of the cases had positive cultures from the distal shunt at presentation. Fifty-seven percent of the patients had positive CSF cultures. Perforation of the augmented bladder is a highly morbid complication, especially in the child with an existing ventriculoperitoneal shunt. The clinical presentation, management strategy, and long-term sequelae will be discussed.

32. Complications of Posterior Fossa Shunting in Double Compartment Hydrocephalus

Diana Leahu, MA, MS, Mark Lee, MD, Rick Abbott, MD, Jeff Wisoff, MD, Fred Epstein, MD (New York, NY)

Double compartment hydrocephalus, or entrapment of the fourth ventricle, is a well-recognized sequel of supratentorial shunting. Signs and symptoms related to the fourth ventricular dilatation include headache, ataxia, coma, cranial nerve palsies, and vomiting. The treatment of this condition is controversial. Most authors have advocated placement of a catheter into the cyst-like fourth ventricle with either a second shunt system, or a splice into an existing shunt system. Over the past 3 years, we have placed posterior fossa shunts in 11 patients with double compartment hydrocephalus. Remarkably, 7 of these patients have had serious complications related to catheter placement in the fourth ventricle. The patients have all developed new cranial nerve dysfunction caused by direct injury to the floor of the fourth ventricle.

As a result of this experience, we have altered our surgical technique. We now place the fourth ventricle catheter from a more lateral trajectory, and aim toward the foramen of Luschka. In this way, the catheter does not come in contact with the floor of the fourth ventricle either during cannulation or after decompression of the fourth ventricle. By using this technique, we hope to avoid our previous complications.

It is our intent to present these patients in detail in order to illustrate the complications of posterior fossa shunts, and make recommendations regarding a safer surgical technique.

33. The Epidemiology of Cerebrospinal Fluid Shunting

Charles Bondurant, MD, David Jimenez, MD (Columbia, MO)

The epidemiology of cerebrospinal fluid (CSF) shunting in the United States is not well known; however, with recent national surveys, the prevalence, incidence, and cost of these procedures can be estimated. The 1988 United States National Health Interview Survey produced prevalence data. The 1988, 1990, and 1991 National Hospital Discharge Surveys produced incidence data for nongovernment hospitals. Federal hospital data banks produced data for government health care; and cost data were figured by the Health Insurance Association of America. The estimated prevalence of CSF shunts in the United States is greater than 125,000, though this is likely an underestimate of the true value. There are approximately 70,000 discharges each year with the diagnosis of hydrocephalus. These visits support nearly 40,000 shunt-related procedures, 36,000 of which involve either placement or replacement of a shunt. CSF shunting procedures account for almost 100 million dollars of national health care expenditures each year. Unfortunately, nearly half of these dollars are spent on revision. The rates and costs of CSF shunting underscore the need for continued improvement in both materials and techniques. Methods, values, and errors will be presented.

34. **Propionibacterium Acnes Infection: A Treatable Cause of Chronic Headache in Shunted Patients**

Jeffrey Blount, MD, John Campbell, MD, Stephen Haines, MD
(Minneapolis, MN)

Background/Objective: Chronic recurring headache is a significant problem for a subset of patients with cerebrospinal fluid shunts. We identify a group of shunted patients with chronic headache syndrome and hypothesize that *Propionibacterium* shunt infection may be a significant contributory cause of chronic headaches in shunted patients.

Methods: The medical records of 435 patients who underwent shunt placement or revision at the University of Minnesota Hospitals between July 1982 and July 1992 were retrospectively reviewed.

Results: Seven of 26 patients (27%) who had chronic recurring headache were later found to have shunt infections with *Propionibacterium acnes*. Eighteen patients in the entire series were diagnosed with *P. acnes* shunt infection. These patients underwent a total of 111 procedures, 14 of which represented manipulations of functioning shunts due to chronic headache. A recurring clinical picture involved multiple evaluations, admissions, and interventions for chronic headache/shunt intolerance and the subsequent diagnosis of *P. acnes* shunt infection. Not uncommonly the late results of cultures obtained early in the evaluation revealed *P. acnes*. In several cases early positive cultures that were considered contaminants predated periods of prolonged headache that was resolved by shunt revision and antibiotic therapy.

Conclusion/Recommendations: There is a significantly increased (chi-square = 30.3, $p < .001$) incidence of *P. acnes* shunt infections in patients with chronic intermittent headache. Clinicians should consider *P. acnes* as a potential etiology in shunted patients with chronic headache and should include anaerobic cultures and prolonged observation of all CSF samples from such patients.

35. Asymptomatic Ventriculo-Peritoneal Shunt Malfunction

Michael Lefkowitz, MD, Kevin Boyer, MD, Corey Raffel, MD, PhD, J Gordon McComb, MD (Los Angeles, CA)

The current standard of practice is to obtain followup imaging studies at intervals to determine ventricular size in patients with shunted hydrocephalus even in the absence of any evidence of shunt malfunction. The present study was undertaken to determine the incidence of apparent asymptomatic progressive hydrocephalus in shunted patients to determine if such periodic imaging is justified.

The charts of patients who had one or more shunt revisions at the Children's Hospital in Los Angeles between 1988-1992 were reviewed.

Two hundred and fifteen patients underwent a total of 345 shunt revisions in the time period. Based solely on a significant increase in ventricular size on routine followup imaging, 21 of these patients (10%) underwent a revision of their shunt even though they appeared to be asymptomatic beforehand. The age, sex, and number of shunt revisions for the asymptomatic group was comparable to those symptomatic patients. Although not statistically significant, the asymptomatic patients were more likely to have myelodysplasia as the etiology of their hydrocephalus compared to the group as a whole. Postoperative imaging studies showed reduction in ventricular size. Some families reported improvement in mental or motor function in their child following shunt revision.

It is concluded that patients shunted for hydrocephalus need interval imaging assessment of ventricular size even if seemingly asymptomatic.

36. Incidence of Asymptomatic Shunt Malfunction in Pediatric Patients Undergoing Routine Yearly Head CT

Nancy Rollins, MD, Maureen Packard, MD, Kenneth Shapiro, MD,
Derek Bruce, MD (Dallas, TX)

Purpose: The use of yearly screening cranial computed tomography (CT) to identify patients with asymptomatic shunt malfunction is routine in some centers. We analyzed the frequency of asymptomatic shunt malfunction.

Materials and Methods: Over 12 months, 423 pediatric patients with chronic shunted hydrocephalus were seen for routine yearly visits in Neurosurgery Clinic; all underwent screening CT. The medical records of patients in whom CT showed any interval increase in ventricle size were reviewed to determine if the patients had clinical evidence of early shunt malfunction and whether the CT findings affected patient management.

Results: Of 423 head CT, 403 (95%) were unchanged from previous CT of 1 year earlier or showed some interval decrease in ventricle size. Twenty (5%) had increased ventricles; however, there were no patients with gross changes in ventricle size. Twelve out of 20 had no clinical evidence of shunt malfunction. One out of 12 had elective shunt revision; CT had shown moderate ventriculomegaly unchanged over the previous 14 months. Eight out of 12 were re-evaluated in 3 weeks; none required shunt revision. Three out of 12 were instructed to return to the clinic in 1 year; 1 presented 3 months later with symptomatic shunt malfunction. Eight out of 20 patients with increased ventricle size had clinical evidence suggesting shunt malfunction; 3 underwent shunt revision. The remaining 5 were re-evaluated at 3 weeks; none had shunt malfunction. The cost of 423 CT scans was \$253,800. There were no shunt revisions done on the basis of CT findings alone.

Conclusions: Ventricle size may fluctuate and subtle changes on screening CT may be misinterpreted as early shunt malfunction. Lack of correlation between clinical findings and subtle changes on CT indicates that routine screening head CT is not cost-efficient.

37. Selective Dorsal Rhizotomy and Lower Extremity Orthopedic Procedures for Spasticity in Cerebral Palsy

Michael Chicoine, MD, T. S. Park, MD, Bruce A. Kaufman, MD,
Madeleine Ortman, RN (St. Louis, MO)

The cases of 220 children who underwent selective dorsal rhizotomy between 1987 and 1991 for spasticity associated with cerebral palsy were reviewed to determine what effect the procedure had upon the need for further orthopedic operations, i.e. muscle and tendon releases or lengthenings, and osteotomies for orthopedic deformities. Patient age at the time of rhizotomy ranged from 2-19.3 years (mean - 5.5 years). The impairments were characterized as spastic quadriplegia in 31%, spastic diplegia in 67%, and spastic hemiplegia in 2%. The followup period ranged from 15-70 months (mean - 40 months). No control group has ever been established to determine the baseline rate at which this population requires orthopedic intervention. Therefore, the children who underwent rhizotomies between 2-4 years (Group I) were compared against the children who underwent rhizotomies after the age of 4 (Group II). Comparing the postrhizotomy orthopedic procedure rate (15%) of Group I to the prerrhizotomy orthopedic procedure rate (34%) of Group II reveals a considerable decrease in the rate of operations over a comparable age span. Realizing the limitations of these comparisons, this data suggests that selective dorsal rhizotomy limits the number of operations needed for the contractures and subsequent bony deformities that typically accompany the spasticity in cerebral palsy.

38. Continuous Epidural Morphine-Butorphanol Infusion Following Selective Dorsal Rhizotomy

Frederick Boop, MD, C. David Lawhorn, MD, Michael Schmitz, MD, Raeford Brown, Jr., MD (Little Rock, AR)

Postoperative analgesia in children is complicated by the fact that 20% to 50% of those receiving narcotics experience side effects of sedation, nausea, vomiting, pruritis, urinary retention, or respiratory depression. These side effects are mediated by Mu_2 receptors, whereas analgesia is mediated by kappa receptors. The Mu_2 receptors are blocked by synthetic narcotic agonist-antagonists. Given this, we initiated a prospective, randomized controlled trial of epidural analgesia in children undergoing selective dorsal rhizotomy, giving boluses of epidural morphine to one group and morphine/butorphanol (Stadol) to the second group. An 80% reduction in side effects was achieved in group 2 compared to group 1. Nonetheless, side effects were noted during peak levels of morphine/butorphanol and some children required supplemental analgesics during tough periods. This led to a subsequent trial utilizing a continuous epidural infusion. Patients received a bolus of 50-60 ug/kg morphine plus 15-25 ug/kg butorphanol during wound closure followed by 5 ug/kg/hr morphine plus 1.2 ug/kg/hr butorphanol.

Results: Blood pressure, pulse, and respiratory rate remained within 10% of normal for all patients. No episodes of O_2 desaturation occurred. Excellent pain control was maintained (parent satisfaction > 95%). No patient experienced nausea, vomiting, pruritis, or respiratory depression, nor did any patient require supplemental pain medication.

The continuous infusion of epidural morphine/butorphanol produces effective pain control without sedation and with minimal side effects. The extension of this technique to children undergoing other spine procedures (tethered cord release, spinal fusion, etc.) has proven equally gratifying.

39. Motion Laboratory Gait Analysis: Preoperative and Postoperative in Children Undergoing Selective Dorsal Rhizotomy

Mary Dunn, MD (St. Paul, MN)

Selective dorsal rhizotomy has been performed on 103 patients at Gillette Crippled Children's Hospital and Shriner's Crippled Children's Hospital. All children underwent a multidisciplinary team evaluation. Each child also underwent a full physical therapy evaluation as well as motion laboratory analysis if the child was ambulatory. We present here the data collected from our motion laboratory as collected on 27 patients both prerhizotomy and one-year postoperatively. Linear data, oxygen cost, and kinematic data were collected for all children.

Kinematic information obtained on these children indicates all children improved with regard to their ambulatory pattern. This will be discussed in more detail. Linear measurements and specifically, velocity, cadence and stride length were similarly improved in most patients. Oxygen cost during ambulation led to some very interesting findings. It appears, preliminarily, that those children with significant orthopaedic deformity prior to undergoing selective dorsal rhizotomy, as well as those children with significant underlying inability to isolate movement, fared much worse in terms of energy expenditure during ambulation than those children with selective control and minimal orthopaedic deformities. This will be discussed in greater detail.

Preliminarily, this information has led to correction of significant femoral anteversion 5-6 weeks prior to selective dorsal rhizotomy so as to smooth the rehabilitation process and facilitate an early return to more normal energy expenditure during ambulation. It also appears that residual orthopaedic deformities and underlying control issues need to be addressed preoperatively in predicting outcome.

40. Reflex Variability in Selective Dorsal Rhizotomy

Steven Schiff, MD, PhD, Ira Weiss, PhD (Washington, DC)

We have explored the hypothesis that selective dorsal rhizotomy is a random partial rhizotomy. The variability of reflex responses during selective dorsal rhizotomy was studied in 8 children between the ages of 3-7 years. For a given dorsal root or rootlet, electrical reflex threshold and response varied considerably when observed over several minutes. To better understand the origins of this variability, we demonstrate the complex nonlinear effects of variable pressure on the dorsal roots during stimulation, show a reduction in variability using an electrode clamp, demonstrate the continual influence of intrinsic spinal cord activity fluctuation on both reflex threshold determination and reflex output, describe the depressive effects of dissection on reflex output, and identify the phenomenon of spatial facilitation in roots being studied for selective section. These phenomena substantially weaken the validity of the intraoperative selection method used during this surgery, and suggest that the "selective" aspect of modern selective dorsal rhizotomy may often reduce to a "random partial" rhizotomy.

41. Relationship of Intraoperative Electrophysiologic Criteria To Outcome After Selective Functional Posterior Rhizotomy

Paul Steinbok, MD, Bengt Gustavsson, MD, Ann Reiner, MD, John Kestle, MD, D. Doug Cochrane, MD (Vancouver, BC)

Introduction: In our institution the criteria used in selective functional posterior rhizotomy (SFPR) evolved in three distinct phases. In phase 1 the electrophysiologic criteria of abnormality included low threshold to single stimulus, sustained response to 50 Hz stimulation, and spread outside the segmental level being stimulated. In phase 2 the electrophysiologic criteria were unchanged, but less of L3/L4 were cut. In phase 3, less of L3/L4 were cut as in phase 2, but based on the results of posterior root stimulation in nonspastic controls, the only electrophysiologic criterion used was spread contralaterally and suprasegmentally. The present study examined the relationship between the electrophysiologic criteria and outcome.

Method: Seventy-seven consecutive children with SFPR and a minimum followup of 1 year were reviewed, comprising 25, 19, and 32 in phases 1, 2, and 3, respectively. Outcome parameters included quantitative assessments of lower limb spasticity and range of movement, and qualitative assessments of lower limb function.

Results: In phase 3, 50% of the roots were saved, compared to 35% and 36%, respectively, in phases 1 and 2 ($p < .01$). In all 3 phases there was a significant decrease in lower limb spasticity and increase in range of movement, with the decrease in spasticity least in phase 3. There was no correlation between the percentage of roots cut and reduction of spasticity. Over 90% of children in each phase improved with respect to lower limb function, but improvement in the level of ambulation occurred in 60%, 58%, and 42% in phase 1, 2, and 3, respectively.

42. Physical and Functional Outcome 5 Years After Rhizotomy

Rick Abbott, MD, Michael Handler, MD (New York, NY)

The efficacy of selective dorsal rhizotomy for the treatment of ambulatory spastic diplegics and nonambulator spastic quadriplegics has long been established. Its use in the treatment of nonwalking spastic diplegics remains unproven. Twenty children who underwent selective dorsal rhizotomy in 1986 or 1987 were examined 6, 12, and 60 months after their operation and the results of these examinations were compared to their preoperative exam. Six of these children walked before the operation, 7 only crawled, and 7 were nonambulatory. All children in the walking and crawling groups could repeatedly rise out of a squat to a standing position preoperatively. Significantly disabling spasticity was present preoperatively for all three groups in the hip adductors, hamstrings, and plantar flexors. This was eliminated in all muscles and there was no significant return experienced. Each child's ability to assume and maintain a set of seated and standing positions was scored as was their appearance in these positions at each of their examinations preoperatively and postoperatively. Only the appearance scores for the walkers changed while the nonambulators had no significant changes. The crawlers, however, experienced significant changes in all scores and their scores rose to nearly those of the walkers except for the appearance scores for the standing positions. These changes are reflected in the fact that all the crawlers are now walking, with 1 not requiring any assistive device, 2 requiring only loftstrand crutches, and the rest rollators. While rhizotomies have been emphasized in treating ambulators, these results strongly support the use of the procedure for more severely involved diplegics.

43. **MRI Changes with Clinical Correlation in Children with Spastic Cerebral Palsy**

Myles Koby, MD, Cynthia Morrison, MD, Benjamin Lee, MD, T. Park, MD, Bruce Kaufman, MD (St. Louis, MO)

Introduction: There is limited information regarding the extent of magnetic resonance imaging (MRI) changes related to the severity of spastic cerebral palsy. We evaluated the MRI changes and correlated these findings with the clinical severity of spastic weakness and perinatal factors in children with spastic cerebral palsy.

Clinical Material: In 205 patients with spastic cerebral palsy who underwent selective dorsal rhizotomy, MRI was performed with spin echo, inversion recovery, and 3D T1 (MPRAGE) techniques. White matter signal changes, ventricular dilation, and cortical atrophy were graded. Corpus callosum, motor and sensory projection tracts in the cerebrum, and brain stem changes were also examined. The MRI changes were correlated with the severity of motor impairment, perinatal difficulties, gestational age, and birth weight.

Results: Periventricular white matter abnormal signal were present in 88% of patients. The lateral ventricles were dilated in 86%. There was no clear correlation between severity of motor impairment and white matter changes or ventricular dilatation. Sulcal enlargement with associated atrophy was present in 28%. The corpus callosum was atrophic in 83%. Increased T2 signal was present in the internal capsule in 19% and thalami in 27%. The sulcal, corpus callosal, capsular, and thalamic changes were indicative of relatively severe motor impairment. Perinatal difficulties were encountered in 53% of patients; birth asphyxia in only 2% of patients. Eighty-eight percent of infants were less than 37 weeks gestation at birth, of whom 25% were below 28 weeks; 10% were 37 or more weeks. Seventy-one percent of infants were between 1-2.5 kg, 13% were below 1 kg, and 16% were over 2.5 kg at birth.

Conclusions: The data suggest that sulcal enlargement, corpus callosal atrophy, and abnormal signal of projection tracts, rather than periventricular leukomalacia, are closely related to the severity of spastic weakness.

44. Subcortical Infarctions in Children

Frank Powell, BS, Kerry McCluney, MD, William Hanigan, MD, PhD
(Peoria, IL)

Subcortical infarction is uncommon in the pediatric population. This report describes the presentation and followup in 5 patients and reviews 51 cases with radiographic documentation.

Data were abstracted from medical records of patients hospitalized from 1988 to the present. Followup information was obtained from telephone or physician interview.

In this series, patients' ages ranged from 3 months to 12 years; 3 children were male. Four patients presented with hemiplegia; 1 with multiple seizures. Three patients showed mixed infarctions on computed tomography (CT) or magnetic resonance imaging (MRI) while 2 demonstrated capsular infarcts. Angiography in 1 patient was not diagnostic. Three children showed hypercoagulability with protein C deficiencies; 1 child had received chemotherapy for ALL. The remaining child demonstrated a cardiomyopathy. Mean followup was 13 months. Four children were neurologically normal; a moderate hemiparesis remained in 1 patient.

Twenty-six of 51 reported cases were male with a median age of 6 years (range 9 weeks to 17 years). Forty-six (91%) presented with hemiplegia; 5 patients demonstrated hemidystonia. Twenty (41%) demonstrated mixed infarctions, while 17 showed isolated capsular involvement. Six infarctions localized to the basal ganglia. Angiography was performed in 21 patients and diagnostic in 4. Twenty-two cases were associated with trauma or viral infection. Coagulopathies or cardiac conditions were demonstrated in 10; an etiology was not described in one-quarter of the patients. Followup greater than 5 months in 26 children showed clinical resolution in 11; severe deficits remained in 3.

In summary, acute hemiplegia or hemidystonia in children with MRI or CT evidence of subcortical infarction requires thorough medical evaluation. Diagnostic vascular examination may be deferred until trauma, infection, coagulopathies, or cardiac conditions are excluded. Fifteen of 30 cases showed complete clinical resolution; severe deficits remained in 3 patients.

45. **The Natural History of Pediatric Familial Cavernous Malformations**

Mark Hamilton, MDCM, FRCS(C), Karl Greene, MD, PhD, Harold Rekate, MD, Joseph Zabramski, MD (Phoenix, AZ)

Cavernous malformations are congenital vascular abnormalities which affect about 0.5% of the population and occur in either a sporadic form or a familial form that is characterized by multiple lesions with an autosomal dominant mode of inheritance. We report 17 pediatric patients with familial cavernous malformations, of which 15 are members of 6 families that are being prospectively followed as part of an ongoing study with clinical and magnetic resonance (MR) examinations. There were 8 boys and 9 girls with a mean age of 12.8 ± 3.1 years (range 8-17 years). The clinical presentation was seizures in 1 patient (5.9%), neurologic deficit (diplopia; brain-stem symptoms) in 2 patients (11.8%), and headache in 4 patients (23.5%). The remaining patients were identified during screening for a familial cavernous malformation protocol. The mean number of lesions per patient was 4.4 ± 2.5 (range 1-11). Three patients (17.6%) underwent surgical removal of 1 (n = 2) or 2 (n = 1) cavernous malformations at the time of presentation. The mean duration of followup has been 40.2 ± 12.7 months. Seizures have developed in 2 patients (11.8%), hemorrhage in 2 patients (11.8%), increase in cavernous malformation size in 2 patients (11.8%), and 6 patients (35.3%) developed new lesions.

The results of this review demonstrate that the familial form of cavernous malformations is a dynamic disease in the pediatric patient. Serial MR imaging revealed changes in the number, size, and imaging characteristics consistent with acute or resolving hemorrhage, and we describe for the first time the *de novo* development of new lesions. These findings suggest that patients with familial cavernous malformations require careful long-term followup. MR imaging should be repeated for any significant change in neurologic symptoms. Surgery should be considered, but restricted, for those lesions that produce repetitive or progressive symptoms. The prophylactic resection of asymptomatic lesions does not appear to be warranted, except for large surgically accessible lesions or when evidence of significant hemorrhage has occurred.

46. Extra-Axial Cavemous Malformations in Neonates

W. Bruce Chemy, MD, Frederick Marciano, MD, PhD, S. David Moss, MD, Kim Manwaring, MD, Harold Rekate, MD (Phoenix, AZ)

Cavemous malformations identified prenatally or in the newborn period are rare. For all age groups, both intra-axial and extra-axial malformations have been reported; however, extra-axial lesions are quite uncommon. Neonatal extra-axial cavemous malformations are extremely rare. Four neonates with extra-axial cavemous malformations are described; 2 were pathologically confirmed; 2 torcular lesions were not biopsied, but their radiographic appearance and intraoperative findings were highly suggestive of the diagnosis; 3 were identified in utero and 1 child was referred because of a prominent occipital bony protuberance since birth. All 4 patients were neurologically asymptomatic. No other congenital anomalies were present. A consumptive coagulopathy existed in 1 patient and was presumed to be related to a blood clot surrounding 1 of the torcular malformations. All patients underwent operative exploration. One torcular malformation was completely excised. The tentorial malformation was excised except for that portion adherent to the transverse and sigmoid sinuses. Excessive blood loss occurred during exploration of 2 torcular hemangiomas, but no mortality or permanent morbidity was encountered. The details of this experience and a summary from the literature will be discussed.

47. Computed Tomographic Scanning Within 24 Hours of Craniotomy for Tumor in Children

Bruce Kaufman, MD, Christopher Moran, MD, T. Park, MD
(St. Louis, MO)

The use of computed tomographic (CT) scans to define residual tumor after craniotomy has been limited by artifactual enhancement occurring as early as 72 hours postoperatively. Earlier scanning has been suggested to allow better identification of residual tumor. We retrospectively reviewed nonenhanced and enhanced CT scans obtained within 24 hours of surgery on 18 patients, 72% with gross total resections, assessing the ability to distinguish tumor from artifact or hemorrhage, and defining the extent of enhancement in the tumor resection bed, along the incision through brain tissue, and in noncontiguous sites.

Patients with gross total resections had postoperative enhancement at the tumor resection site in 31% of these immediate studies. Small amounts of hemorrhage in the resection bed severely impaired the ability to identify residual tumor or enhancement. Of 5 incompletely resected lesions, tumor was not identifiable in 2 cases, and contrast enhancement was seen in only 1 case. Two cases had enhancement along the brain incisions, but none had enhancement in noncontiguous regions of the brain.

The lowest reported incidence of artifactual enhancement in a tumor resection bed occurs with CT scanning within 24 hours of craniotomy. Although this method should reliably define the gross extent of tumor resection, its utility for identifying small amounts of residual disease is severely limited by the high rate of operative bed enhancement and the inability to distinguish tumor from small amounts of hemorrhage. These results should be compared with early postoperative magnetic resonance imaging to define the best imaging approach for defining significant residual disease.

48. Timing and Mode of Imaging After Tumor Surgery: Issues of Reliability

Charles Teo, MD, William Morris, MD, Nancy Rollins, MD (Tacoma, WA)

The timing and reliability of postoperative imaging in pediatric low-grade tumors are important since amount of tumor removal is a major factor in determining survival statistics. Also, decisions about reoperation depend on postoperative radiographs. To address these questions we performed a retrospective study of 46 patients followed a minimum of 12 months after gross total removal of low-grade tumors who did not receive adjuvant therapy.

Records of 326 children with primary brain tumors seen at Children's Medical Center and Humana Medical City (Dallas) were reviewed. Of these, 46 fulfilled all criteria for inclusion, most important, low-grade tumor, absence of postoperative radiation or chemotherapy, and availability of serial CTs and/or MRIs beginning within 7 days of surgery.

We will discuss the significance of abnormalities seen on immediate postoperative scans by evaluating their subsequent progress on later radiographs, and, in some cases, correlating tissue diagnosis from reoperation. The role of MRI in the immediate post-operative period will be addressed, since 20% of "suspicious" MRI findings resolved with time, indicating MRI's high sensitivity and low specificity.

Some Conclusions and Recommendations: (1) Small flecks seen on immediate scans do not reliably reflect residual tumor; (2) MRI with Gd is essential since T2 changes are common, whereas most enhancing nodules are residual tumor; (3) in the event residual tumor is seen, regrowth is slow and can be monitored with serial scans, reoperation being reserved for selected patients.

49. Severe Cervical Kyphotic Deformities in Patients with Plexiform Neurofibromas

Brad A. Ward, MD, Andrew D. Parent, MD, H. Louis Harkey, MD
(Jackson, MS)

Primary kyphoscoliotic deformities of the cervical spine associated with plexiform neurofibromas are quite unusual. Of 5 patients with cervical plexiform neurofibromas followed at our institution, 3 are in the pediatric age group and 4 have developed severe kyphotic deformities ($> 60^\circ$). These patients have been evaluated radiographically with plain x-rays, magnetic resonance imaging, and computed tomography with 3-D reconstruction. One patient with a progressive swan neck deformity but no evidence of myelopathy was treated with reduction and posterior arthrodesis. Two other patients presented with signs of cervical myelopathy and spastic quadriplegia. These patients were treated with anterior decompression, anterior reconstruction, and posterior stabilization. Postoperatively, all 3 patients have regained full strength although some long tract signs remained in the 2 myelopathic patients.

The bony changes observed in this population severely distort the normal anatomy and cause deformity, pain, and neurologic deficit. These bony changes are due to an altered vascularity to the bone, direct invasion by neurofibroma cells, mechanical pressure and weight of tumor, and in some cases, primary dysplasia of the bone. Managing these deformities is problematic and highly challenging even to the accomplished spine surgeon. We present these patients and the details of their operative management emphasizing the decompressive and reconstructive challenges posed by severe cervical deformities associated with plexiform neurofibroma.

50. Prognostic Significance of Type I Neurofibromatosis (von Recklinghausen Disease) in Pediatric Optic Gliomas

Anastasia Deliganis, BS, J. Russell Geyer, MD, Mitchel Berger, MD
(Seattle, WA)

Although the association between optic glioma and neurofibromatosis is well recognized, few studies have systematically compared the outcome of optic gliomas in patients with and without neurofibromatosis. In the present study, 30 cases of optic glioma seen between 1964 and 1990 were studied retrospectively. Thirteen of these patients (43%) met the NIH criteria for Type 1 neurofibromatosis. The medical records of all patients were examined and letters of inquiry were sent to every living patient to ascertain current health status. Death certificates were obtained to determine cause of death. Patients with optic glioma and neurofibromatosis were compared to patients with optic glioma without neurofibromatosis with respect to survival, time to tumor progression, tumor location, and long-term outcome. Followup averaged 7.6 years (10.8 years for patients with NF, 5.8 years for patients without NF). Five- and 10-year survival rates for patients with NF were 100% and 80%, respectively; for those without NF: 80% and 80%. Fourteen patients had tumor progression (4 with NF, 10 without NF). A difference was seen in the average time to tumor progression between the 2 groups (with NF, 9.81 years, without NF, 3.01 years ($p < 0.01$)). A significant difference in distribution of location of tumor between the NF and non-NF group was also noted (Fisher's Exact Test $p = 0.0084$). We conclude that optic gliomas in patients with neurofibromatosis do have different characteristics than those in patients without neurofibromatosis and that for first relapse, the presence of neurofibromatosis is a significant favorable factor.

51. Hypothalamic Hamartomas

Georges Haddad, MD, Yoon Hahn, MD, Ossama Al-Mefty, MD
(Little Rock, AR)

Hypothalamic hamartomas are rare central nervous system tumors. Whereas their exact pathology is still a matter of discussion (hamartoma versus ganglioglioma), their presenting features are well studied. Most patients with hypothalamic hamartomas present with precocious puberty and/or gelastic seizures. We report on 4 cases of hypothalamic hamartomas (3 boys, 1 girl). All had precocious puberty and seizures. The pathophysiology of precocious puberty will be reviewed, as will the diagnostic modalities of help in studying these tumors. The different medical and surgical treatments will be discussed, and an algorithm for treating these patients will be presented.

52. Factors Affecting the Long-Term Outcome of Children with Low-Grade Gliomas of the Cerebral Hemispheres

Ian Pollack, MD, Diana Claasen, MD, Janine Janosky, PhD,
A. Leland Albright, MD (Pittsburgh, PA)

Low-grade gliomas constitute the largest group of cerebral hemispheric tumors in the pediatric population. Although complete tumor resection is generally the goal in the management of these lesions, this can prove difficult to achieve because tumor margins may blend imperceptibly into the surrounding brain. Moreover, even in cases in which a radiographically complete resection has been obtained, it is not uncommon to find microscopic evidence of neoplastic cells infiltrating to the resection margin. This raises several important issues regarding the long-term behavior of the residual gross or microscopic tumor and the role of adjuvant therapy in the management of these lesions. To address these issues, we reviewed our experience in 72 children with low-grade cerebral hemispheric gliomas who were treated at our institution between 1956 and 1991, and examined in univariate and multivariate analyses the clinical, radiographic, pathologic, and treatment-related factors that correlated with outcome. Only 7 patients in the series have died, 2 from perioperative complications and 5 from progressive disease; malignant degeneration of the original tumor was confirmed histopathologically in only 1 of these patients. Overall actuarial survivals for the group at 5, 10, and 20 years were 93%, 91%, and 88%, respectively; progression-free survivals were 89%, 87%, and 78%, respectively. The factor that correlated most closely with outcome was extent of resection. None of the 22 patients who underwent complete tumor resection (3 of whom received radiation therapy) have had tumor recurrence, in comparison to 13 of 48 patients who underwent subtotal excisions and survived past the perioperative period ($P < 0.001$). The use of postoperative radiotherapy following subtotal resection decreased the incidence of subsequent disease progression: 6 of 35 patients (17%) who received postoperative radiotherapy after subtotal excision developed progressive disease in comparison to 7 of 13 patients (54%) who did not receive postoperative radiotherapy ($P < 0.05$). However, the 5 patients who died of disease progression had each received postoperative radiotherapy ($P < 0.05$). The impact of other factors on the duration and quality of survival will be discussed.

We conclude that children with low-grade gliomas of the cerebral hemispheres have an excellent overall prognosis. Complete resection provides the best opportunity for long-term survival. However, even with subtotal excision, long-term recurrence-free survival is common. Although the use of postoperative radiotherapy following subtotal tumor excision increases the likelihood of long-term progression-free survival, overall survival is not improved significantly.

53. Intracranial Infantile Myofibromatosis

Michael Rutigliano, MD, Ian Pollack, MD, Dachling Pang, MD, FRCS(C), A. Leland Albright, MD (Pittsburgh, PA)

Infantile myofibromatosis is a neoplastic disorder of infancy and early childhood characterized by mesenchymal tumors of the skin, subcutaneous tissues, skeletal muscle, bone, and visceral organs. Although these tumors are considered to be the most common fibrous neoplasm of infancy, central nervous system involvement is reportedly rare. During the last 7 years, we treated 3 children with intracranial myofibromas, who presented at 6 weeks, 7 months, and 3¾ years of age, respectively. Each child had a large calvarial mass which demonstrated progressive growth and produced significant brain compression. The developmental history and neurologic examination of each patient was normal. Radiographically, these tumors were isodense to brain on computed tomography (CT) scan, enhanced strongly with intravenous contrast, and showed smoothly marginated bone erosion without surrounding sclerosis. On magnetic resonance imaging (MRI) the tumors were hypointense on T1-weighted images with dense enhancement following the administration of intravenous contrast, and hyperintense on T2-weighted images. One patient underwent angiography which demonstrated blood supply from the occipital and posterior middle meningeal arteries and a profound tumor blush. Embolization of the occipital artery supply with 250 µm polyvinyl alcohol (PVA) particles was performed, largely eliminating the angiographic tumor blush. At operation, the tumors, with the exception of the tumor that was embolized, were highly vascular and appeared to arise from within the leaves of the dura, eroding through the overlying bone, but not violating the galeal or arachnoidal layers. Two of the lesions were adherent to major dural venous sinuses. Both of these lesions were completely resected in continuity with the involved dura, and have shown no signs of recurrence, 6 years and 9 months postoperatively. However, in 1 other patient in whom the involved dura was not resected at the initial procedure the tumor rapidly recurred. A complete excision of tumor and involved dura was then performed and the patient is now recurrence-free, 4.5 years after the second surgical resection. All patients tolerated resection well, but 2 have required cranioplasty for persistent calvarial defects. A review of the literature suggests that the natural history of these tumors outside the CNS is often characterized by a period of initial rapid growth, subsequent stabilization, and, in many cases, eventual spontaneous regression. Radical resection, therefore, is reserved for those tumors that pose an immediate threat due to their location or massive size and those that show obvious progression. Preoperative embolization appears to be a useful technique to decrease tumor blood supply and reduce intraoperative blood loss.

54. Intrinsic Midbrain Tumors in Children: A Benign Subset of Brain Stem Tumors?

Karin Muraszko, MD, Patricia Robertson, MD, Robert Dauser, MD,
Andrew Turrisi, MD (Ann Arbor, MI)

Controversy exists regarding the prognosis and optimal management of various brain stem lesions. We have reviewed the presentation, radiographic findings, and course of 15 patients who presented over the last 9 years, with radiographically documented intrinsic tectal and peritectal lesions, excluding tumors with pineal epicenters. Ten patients were male and 5 were female with a median age of 9 years at the time of presentation (range 3.5-16 years). Hydrocephalus, requiring a shunt, was present at diagnosis in 12 patients whose initial signs and symptoms included headache/lethargy (6); decrease in school performance (5); decreased motor coordination/ataxia (6); ocular motility abnormalities (1); and tremor (2). All these symptoms resolved after shunting. Of the 3 patients without hydrocephalus, 1 presented with seizures, 1 with transient ocular motility disturbance during an episode of hemolytic uremic syndrome, and 1 with ptosis of unknown etiology.

Radiographically these lesions could be divided into 4 groups based on magnetic resonance imaging (MRI) findings: (1) Lesions whose epicenter was at the junction of the tectum and pineal gland, but clearly separate from the pineal gland, at the posterior aspect of the third ventricle (7/15). Four were contrast enhancing with gadolinium. (2) Lesions that exclusively involved the tectum or quadrigeminal plate, causing thickening of the plate (6/15). One was contrast enhancing. (3) Lesions involving the midbrain tegmentum but not involving the tectum or quadrigeminal plate (1/15) and without contrast enhancement. (4) Lesions of the periaqueductal region, without mass effect or contrast enhancement (1/15). Histopathologic diagnosis was confirmed in 3 of the larger tumors (2 in group 1, 1 in group 3). All were low-grade gliomas that were subsequently treated with focal radiation therapy. The remainder of the patients were followed without other therapy. Mean followup for all patients was 3 years and all but 1 of our patients have remained stable, clinically and radiographically, during the period of observation.

We conclude that there is a subset of brain-stem lesions, located within the peritectal and tectal region, which have a relatively benign course. These patients often present with hydrocephalus, usually after infancy. Such patients often remain stable for considerable periods of time and can be followed with regular MRI evaluation. Change in the size of such lesions should prompt either surgical resection or biopsy of these lesions. Radiation was effective in significantly shrinking large tumors in this region. These lesions represent a distinct subgroup that can be identified by their MRI appearance and have a good prognosis.

55. Placement of Off/On Switch in Post-Tumoral and Tumoral Hydrocephalus

David Donahue, MD, Ray Fryear, BS, Robert Sanford, MD, Michael Muhlbauer, MD (Memphis, TN)

Children with central nervous system (CNS) neoplasms often develop hydrocephalus associated with their brain tumor. We routinely employ ventriculostomy and controlled cerebrospinal fluid (CSF) drainage perioperatively. In spite of gross total resection of tumors, a number of children eventually require permanent CSF diversion. Seeking to avoid chronic shunt dependence, we placed an off/on switch in-line with a ventriculoperitoneal shunt in 9 children with gross total resection of their posterior fossa tumors who had failed temporary CSF drainage. At varying intervals after proving absence of intracranial tumor on computed tomography (CT) or magnetic resonance imaging (MRI), we closed the off/on switches at outpatient followup. Only 1 of the children tolerated closure of the off/on switch. One child was hospitalized several times because of accidental closure of his off/on switch. Because of the low yield of children independent of their VP shunt, we no longer place off/on switches in those who fail perioperative ventriculostomy management.

56. Stereotactic Radiosurgery for Childhood Brain Tumors

Paul Grabb, MD, L. Dade Lunsford, MD, A. Leland Albright, MD,
Douglas Kondziolka, MD, John Flinckinger, MD (Pittsburgh, PA)

We have evaluated the role of adjunctive stereotactic radiosurgery (SR) in a diverse series of 30 unresectable pediatric brain tumors in 28 children (age range 3-18 years; 18 boys, 10 girls). Histopathologic types included: astrocytoma (6), ependymoma (6), craniopharyngioma (5), malignant glioma (4), pituitary adenoma (3), primitive neuroectodermal tumor (2), meningioma (2), embryonal carcinoma (1), and pineocytoma (1). Histology was confirmed by either craniotomy (n = 25; most children had 2 or more prior attempts at resection) or stereotactic biopsy (n = 3). Radiosurgical doses were calculated based on tumor-volume location and prior radiation administration. Followup ranged from 3-65 months (mean 1.8 years).

Postoperative imaging revealed tumor control in 20 of 30 tumors (9 unchanged, 6 decreased in size, 5 disappeared). Ten tumors had delayed increase in size. Twenty-one children were alive with a median followup of 24 months. Tumor control was achieved in 6 of 6 children with astrocytomas, 2 of 2 with meningiomas, 2 of 3 with pituitary adenomas, 3 of 5 with craniopharyngiomas, 2 of 4 with malignant gliomas, and 2 of 6 with ependymomas. Four children developed long-term neurologic complications likely attributable to SR. Local tumor control was obtained in 81% of benign tumors, in comparison to 36% of malignant tumors ($P < 0.05$ by chi-square analysis). SR alone effectively controls most unresectable histologically benign neoplasms in children. SR should be combined with other current multimodality adjunctive therapies in order to improve outcomes in children with unresectable malignant brain tumors.

57. Survival of Children with Medulloblastoma: With Special Reference to Surgical Resection, DNA Ploidy, and Chemotherapy

Tadanori Tomita, MD, David McLone, MD, MaryAnne Marymont, MD, William Brand, MD, Lakshmi Das, MD, Lewis Strauss, MD (Chicago, IL)

During the period from 1978 through June, 1991, 83 infants and children with medulloblastoma were treated at our institution. Age at diagnosis ranged from 4 months to 16 years. All were investigated with computed tomography (CT), and 25 had magnetic resonance imaging (MRI) studies. Aggressive radical resection was done in all patients (except for 3 patients who already had a widespread cerebrospinal fluid [CSF] dissemination in the subarachnoid space). One patient died of upward herniation after precraniotomy shunt. Two others refused further therapy. Five patients received chemotherapy as a primary adjuvant therapy; all had tumor recurrence during chemotherapy and received subsequent radiation therapy (RT). All remaining 75 patients were treated with postoperative RT (11 of these also received adjuvant chemotherapy). In order to identify the factors influencing survival, the extent of surgical resection, the type of DNA ploidy, and the use of chemotherapy were correlated with survival of these 75 patients. Forty-three patients had a total resection which was confirmed by both surgical observation and postoperative neuroimaging studies, while 32 had an incomplete resection. Thirty-two (74%) with total resection are alive, while only 12 patients (38%) with incomplete resection are alive (7 of these survivors received adjuvant chemotherapy). Flow cytometric DNA analysis was done and correlated with patients survival. Among 45 patients who had postoperative RT, only 4 of 22 patients with diploid tumor are alive, while 18 of 22 with aneuploid tumor are alive. On the other hand, all 10 patients who received both RT and chemotherapy (5 with diploid tumor, 3 with aneuploid, and 2 with tetraploid tumor) are alive. In conclusion, patients with medulloblastoma with incomplete resection and/or diploid type are considered to be high-risk group, and adjuvant chemotherapy is recommended in this group.

58. Neurotrophins and Growth in PNETs

Lawrence Chin, MD, Corey Raffel, MD, PhD (Los Angeles, CA)

Neurotrophins are a family of growth factors comprised of nerve growth factor (NGF), brain-derived neurotrophic factor (BDNF), and neurotrophin-3 (NT-3). They bind to the trk family of receptors (trkA, trkB, trkC). Their functional importance has not been demonstrated in brain tumors. We examined 3 primitive neuroectodermal tumor cell lines (Daoy, PFSK, D283Med) and 8 fresh frozen surgical specimens for expression of the neurotrophins. Expression of BDNF was seen in all samples and NT-3 was seen in 2 of 3 cell lines and 5 of 8 tumors. No NGF expression was detected. A trkb expression was detected in 3 of 3 cell lines and 8 of 8 tumors. The trkA and trkC expressions were demonstrated in 1 of 3 cell lines only. K252a, a microbial alkaloid with trk family inhibition properties, was placed on cell lines and caused complete growth arrest at 400nM. However, 400nM K252a did not result in growth inhibition of NIH 3T3 cells in culture. To determine if the trk system operated independently of protein kinase C, H7 at 10^{-6} M was used. H7 is a protein kinase C antagonist with no effect on the trk receptors. H7 did not slow growth of the cell lines tested. In summary we find evidence for an autocrine loop involving the neurotrophins interacting with the trk receptors in PNETs. Therapy targeting this interaction may represent an exciting new treatment alternative for these tumors.

59. Permeability and Glial Reactivity in C6 Glioma Implanted Into The Infant Rat Striatum

Edward Aulisi, MD, Jeff Rosenstein, PhD (Washington, DC)

Multiple factors are important in determining the biologic behavior of primary brain tumors. Among these are the ability of circulating serum proteins to pass through the vessels of these tumors and the abundance of glial reactivity at the brain/tumor interface. The C6 glioma model in the adult rat has been reported to be one having a variable amount of tumor "leakiness" and an abundant amount of glial reactivity. Other investigators have grown C6 gliomas in adult rats using implanted volumes as large as 10 ul, but little is known about the growth of this tumor in the infant rat. In this study, we examined a series of C6 tumors in 1-week-old rats by evaluating immunocytochemical expression of serum albumin (SA), glucose transporter (GT) (a marker for impermeable cerebral vessels), GFAP, and GAP-43 (a marker for newly formed vessels). Stereotactically, pellets (approximately 20,000 cells in 0.2 ul PBS) of C6 glioma cells (gift of T. Moody) were implanted into the striatum of infant rats. Six to 14 days after implantation, small definable tumors were strongly positive for SA within the tumor, with some accumulation at the brain-tumor interface. Expression of GT was normal for cerebral vessels at the interface. GAP-43 was markedly positive at the periphery of the tumor. Of note, there was reduced glial reactivity at the periphery of the tumor, as evidenced by GFAP staining. This reactivity was markedly reduced from that seen in earlier experiments performed in adult rats. These results demonstrate: (1) A very small volume of C6 glioma implanted in the infant rat striatum can produce definable tumors. (2) The permeability of blood vessels within C6 glioma in the infant rat mimics that seen in the adult. (3) The glial reactivity of the infant rat is markedly reduced in comparison to the adult. The different biologic behavior of some pediatric brain tumors, compared to adult tumors, may be at least in part related to a difference in glial reactivity. The significance of these differences is the focus of future studies.

60. p53 Mutations and Familial Cancer

Mark Souweidane, MD, Angel Pellicer, MD, PhD, Jeff Allen, MD,
Fred Epstein, MD, Srinath Samudrala, MD (New York, NY)

Mutations in the p53 tumor suppressor gene have been well established in a variety of human tumors, including certain central nervous system (CNS) tumors. Additionally, germ line mutations have also been found, implicating these genetic alterations as a possible mode of tumor transmittance.

The attempt has been made to determine the incidence of p53 mutations in pediatric patients who might be predisposed to a neoplastic phenotype. Twenty-three pediatric patients, who harbor a CNS tumor and have at least 1 first-degree relative with a known cancer were included in this study. DNA was extracted from postoperative tumor specimens imbedded in paraffin and screened for mutations in the p53 gene. The analysis was performed by the polymerase chain reaction and single strand conformational polymorphism techniques. The coding regions of the p53 gene that were screened comprised the most highly conserved region of this gene, namely exons 5 through 9. Of the 22 patients, 11 were found to have changes with SSCP analysis in various coding regions (exons 5-8) of the p53 gene. In an effort to elucidate whether these p53 mutations are of the somatic versus the constitutional variety, the same analysis is currently being performed on DNA isolated from leukocytes.

The frequent finding of p53 mutations in brain tumor patients, who also have a family history of cancer, has been established in the present study. Recent findings showing inheritance of p53 mutations in familial cancer, in conjunction with these results, suggest a possible mode of predisposition for pediatric CNS tumors.

61. Expression of TIMP-1, TIMP-2, and Type IV Collagenase Transcripts in Pediatric Brain Tumors: Correlation with Tumor Grade

James Rutka, MD, PhD, FRCS(C), Sherri Lynn Smith, Kouzou Fukuyama, Kazuhito Matsuzawa, Matthew Muller, Peter Dirks, MD (Toronto, Ontario)

Human malignant astrocytomas are highly invasive neoplasms which infiltrate diffusely into regions of normal brain. In general, tumor cell invasion is a complex cellular process mediated in part by the elaboration of tumor-associated metalloproteases (MPs) and modulated by various protease inhibitors (TIMPs). We have recently shown that among astrocytoma cell lines, TIMP-1 and TIMP-2 transcript levels correlate inversely with in vitro tumor cell invasion (*Proc AACR* 34:70, 1993). In the present study, we sought to determine if a relationship exists between transcript levels of MPs and TIMPs and histopathologic tumor grade in a series of pediatric brain tumors. Northern and in situ hybridization analysis was performed on 20 pediatric brain tumors (5 low-grade astrocytomas, 5 high-grade astrocytomas, 5 PNETs, 2 ependymomas, 1 rhabdoid tumor, 1 meningioma, and 1 gliosarcoma) using cDNA probes for TIMP-1, TIMP-2, and the 72- and 92-kD type IV collagenases. While there was some variability of transcript expression within this group of tumors, in general, transcript levels for type IV collagenase were much higher in the high-grade or anaplastic tumors than in the low-grade tumors; by way of contrast, transcript levels for TIMPs 1 and 2 were higher in the low-grade, well-differentiated tumors than in the high-grade tumors. These data support the notion that high-grade pediatric brain tumors are invasive neoplasms in part because of higher expression of MPs than of TIMPs.

Scientific Posters

1. **SIDS Prevention Plagiocephaly**

J. A. Winfield, MD, PhD (Syracuse, NY)

Based on recommendations by the American Pediatric Society, parents are being counseled to "sleep their infants on their backs" to decrease the likelihood of Sudden Infant Death Syndrome (SIDS). During the last year this author has experienced a dramatic rise in the number of infants referred for evaluation of "lambdoidal suture synostosis." Clinical history has confirmed that many of these infants have been "encouraged" to sleep on their backs and parents observe an eventual left/right preference in the infant's sleeping position.

Evaluation of the infant to distinguish between lambdoidal/asterion synostosis, tight Sternocleidomastoid Muscle Syndrome, hemiparetic-associated, and sleeping-position-acquired plagiocephaly will be reviewed. SIDS prevention appears to be an increasing underlying etiology of plagiocephaly in infants referred for evaluation of a misshapen head and is identical to Idiopathic Infantile Scoliosis. Awareness of this entity is highlighted in order to prevent unnecessary surgical procedures and suggestions made in order to treat this problem.

2. CINE Magnetic Resonance Imaging (MRI) in Retethered Spinal Cord

J. Wasenko, MD, J. Scheraga, MD, L. Hochhauser, MD, J. A. Winfield, MD, PhD (Syracuse, NY)

Despite considerable efforts to establish radiologic criteria for spinal cord retethering in children with repaired meningomyeloceles, lipomas, and other dysraphic pathology, retethering has remained largely a clinical diagnosis. Using cardiac-gated two-dimensional phase contrast CINE (2DPC-CINE) MRI 14 infants/toddlers with dysraphic spines previously repaired were subsequently studied preoperatively and postoperatively to determine the thoracolumbar cerebrospinal fluid (CSF) flow dynamics at the time of clinical suspicion of retethering. Clinical signs included the development of back/leg pain, progressive scoliosis, change in lower extremity motor exam, including the development of a Trendelenburg sign, and a change in bladder function. In addition, 6 infants with tethering pathology were studied prior to any surgical repair.

The 2DPC-CINE MRI studies demonstrated consistent abnormal CSF flow patterns with reduced flow dorsal to the spinal cord. In those cases where a caudal syrinx was present, dorsal flow was present, but noted to be out of phase with CSF flow ventral to the spinal cord. This phase dissociation occurred overlying the syrinx location. Although all patients clinically improved following surgery, CSF flow dynamics did not always show improvement in flow. These studies raise the possibility of dorsal arachnoid adhesions, well rostral to the expected terminal cord tethering site as additional anatomical loci of adhesions and subsequent tethering. The possible mechanism of conus syrinx formation will be discussed in light of our observations on CSF flow dynamics and video images of representative cases presented.

3. Cerebral Echinococcosis in Children

Azedine Medhkour, MD, Adel Medhkour, MD (New York, NY)

Echinococcosis of the brain is prevalent in North Africa and represents 7% to 9% of the echinococcus infection in childhood. We report our experience with 12 patients aged between 3-16 years. The presenting symptoms in all patients were those of increased intracranial pressure, in particular visual disturbances. One patient was blind on admission and 2 patients presented with epileptic seizures. CT scans demonstrated large hemispheric mass lesions with significant shift of the midline structures. The treatment consists of neurosurgical extirpation of the cyst unruptured. The surgical technique employed was hydropulsion extrusion of the cyst as described by Dowling. Ten patients had an uncomplicated postoperative course, while 2 patients died during the postoperative period. One patient had an intraoperative cyst rupture, the second died of postsurgical complications. The morbidity and mortality of this parasitic infection remain high and preventive measures are mandatory to eradicate this infectious disease.

4. Poor Operative Results in Craniosynostosis Repair

Paul Francel MD, PhD, John Jane, MD, PhD (St. Louis, MO)

At the University of Virginia, we have developed an approach to all forms of craniosynostosis that emphasizes that the deformity observed is secondary to both a restricting sutural fusion abnormality and a compensatory deformation. Utilizing such a concept has led us to the development of a system of total cranial vault reconstructions to achieve excellent cosmetic repair of these deformities. Many techniques have been developed and have produced excellent results; however, not all attempts at cranial vault remodeling were successful. This report focuses on several of these cases in which either the final skull shape was certainly less than satisfactory or in which the actual cranial vault reconstruction resulted in a significant dilatorious effect on the patient. The total cranial vault reconstruction can immediately produce a pleasing skull shape, and at the end of the surgery it does alter the forces acting in an individual patient that result in the final skull morphology. However, total cranial vault reconstruction can actually create a new synostosis that is different from the previous abnormality or can result in cranial defects, unsightly prominences, or even intracranial hypertension. In our presentation we, therefore, critically evaluate an extremely powerful method of analysis and treatment for cranial synostosis but in particular highlight some potential risks that can occur with such major cranial vault reconstructions.

5. Enhanced Evaluation in Management of Growing Skull Fracture with the Utilization of Magnetic Resonance Imaging

Andrew Parent, MD, Frank Raila, MD, Jonathan Fratkin, MD
(Jackson, MS)

Skull fractures in infants produce the unique complication of a growing fracture. Although in the past, these were considered post-traumatic leptomeningeal cysts, modern imaging studies have conclusively demonstrated that in most cases the dural tear will result in underlying brain injury and porencephaly with secondary enlargement of the fracture. Radiologic studies that have been employed in the past included pneumoencephalography, isotope cisternography, and angiography and have been mostly replaced by computed tomography (CT) and magnetic resonance imaging (MRI). We have reviewed the radiologic findings seen in growing skull fractures and correlated them with surgical and pathologic findings in a series of 7 growing skull fractures evaluated by CT and MRI scan in the past 5 years. There were 4 males and 3 females. The patients' ages ranged from 4 months to 4 years. The growing skull fractures were recognized 2 weeks to 2½ years after trauma. The dural defects all were in excess of 10 cm in length and greater than 4 cm in width.

Our surgical technique stresses the preservation of the pericranium to be utilized in reconstructing the dural defect. The bone flap was removed in 1 piece at least 3 cm beyond the bone defect in all instances. Careful identification of the dural margins from the underlying gliotic brain required meticulous dissection, hemostasis with duraplasty with the pericranial graft. The bone defect was repaired with a split thickness calvarial cranioplasty. Only 2 of these patients subsequently required a ventricular shunting procedure. Seizures or neurologic deficits were related to the underlying cortical injury.

6. Floor Plate Establishes the Basic Organization of the Developing Spinal Cord

G. Sohal, PhD (Augusta, GA)

Shortly after the closure of the neural tube, functionally distinct groups of neurons begin to differentiate in specific locations in the spinal cord. The role of floor plate, a group of cells in the ventral midline of the neural tube, in establishment of the basic pattern of the spinal cord was examined in Japanese quail embryos. When Hensen's node was extirpated, the notochord and the floor plate did not develop, and the neural tube was totally disorganized. When the notochord was pushed to one side and the floor plate was cut in the midline, both sides of the spinal cord developed normally suggesting that continued presence of the notochord is not necessary for normal development. In another experiment, only 1 side of the neural tube was deprived of the floor plate. The side of the spinal cord with the intact floor plate differentiated normally, whereas the side lacking the floor plate did not. The ventral horn motor neurons did not develop. The dorsal horn neurons became motor neurons in that they sent their axons out of the CNS. When an additional floor plate was induced, by grafting a notochord, on the lateral side of the neural tube, the dorsal horn neurons behaved like motor neurons as they sent their axons out of the CNS. These results suggest that the floor plate establishes the basic plan of differentiation of cell types in the developing spinal cord. This work was supported by NIH grant HD 28601.

7. Stereotactic Radiosurgery for Pediatric Brain Tumors

Walter Hall, MD, Paul Sperduto, MD, John Gibbons, PhD
(Minneapolis, MN)

Objectives: To determine whether supratentorial and infratentorial pediatric brain tumors can be treated safely and effectively with stereotactic radiosurgery.

Methods: From March 1992 to June 1993, 7 children (ages: 4, 4, 7, 7, 7, 7, 17, 20 years) were treated with the Philips LINAC-based stereotactic radiosurgery system. Three lesions were supratentorial (glioblastoma multiforme [GBM], juvenile pilocytic astrocytoma [JPA], xanthoastrocytoma) and 4 were infratentorial (2 ependymomas, astrocytoma, brain-stem glioma). General anesthesia was necessary in 5 patients and 5 of 7 patients had prior external beam irradiation. Treatment volumes measured 8-71 cc and a single isocenter was used in 4 patients (28, 30, 30, 30 mm), 2 isocenters in 2 (18/30 and 16/24 mm) and 4 isocenters in 1 patient (all 30 mm). Doses administered ranged from 1000-3000 cGy and were delivered to the 50% to 90% isodose line with maximum doses between 1250-6000 cGy.

Results: Tumor progression with clinical worsening was seen in both patients with ependymomas. Both patients with ependymoma died 9 months after treatment and autopsy revealed tumor in both and radiation necrosis in 1. Tumor stabilization has been seen in 1 patient with a cerebellar astrocytoma for > 12 months. The GBM patient developed symptomatic swelling at 6 months requiring surgical resection of necrotic tissue without demonstrable tumor. The JPA patient worsened clinically at 6 months requiring tumor resection; no radiation effect was seen. The xanthoastrocytoma and brain-stem glioma patients are early in followup.

Conclusions: Radiosurgery for posterior fossa ependymomas has limited benefit which may be related to brain-stem tolerance dose restrictions. Well-differentiated astrocytomas may respond to radiosurgery by growth stabilization. General anesthesia is necessary and well tolerated in young children.

8. Treatment of Pediatric Moyamoya

Warwick Peacock, MD, Andrew Sloan, MD (Los Angeles, CA)

Pediatric moyamoya, which has been described primarily in patients of Japanese descent, is characterized by progressive stenosis and occlusion of the supraclinoid internal carotid arteries and their distal branches bilaterally, with the development of an extensive compensatory network of dilated collateral vessels at the base of the brain. The disease typically presents with repeated transient ischemic attacks (TIAs) or acute infarctions manifested by hemiplegia, paraplegia, aphasias, seizures, or mental retardation. Medical therapy has achieved limited success but surgical revascularization procedures have recently shown promise.

Direct revascularization procedures utilizing extracranial to intracranial (EC-IC) bypass grafts to proximally occluded vessels are technically difficult, but have been favored because they provide immediate revascularization to ischemic brain. However, pathologic specimens and Xenon 133-CT scanning at UCLA suggest that moyamoya is characterized by diffuse obstruction with isolated islands of ischemia, rather than focal obstruction characteristic of atherosclerotic disease. This model implies that indirect revascularization procedures would be more successful.

Here we present the UCLA series of 5 non-Japanese patients with pediatric moyamoya seen over a 7-year period. One patient was treated with Diltiazem only and showed marked improvement. One patient was treated with a series of 3 direct revascularization procedures and demonstrated only fair results. Three patients underwent indirect revascularization procedures with encephaloduroarteriosynangiosis (EDAS) with good to excellent results. These results suggest indirect revascularization as a first-line surgical therapy in patients with moyamoya refractory to medical treatment.

9. **Low-Grade Supratentorial Astrocytomas: Boston Children's Hospital Experience from 1974 to 1990**

M. Luciano, MD, PhD, P. Black, MD, PhD, R. Scott, MD, L. Goumnerova, MD, J. Madsen, MD, N. Tarbell, MD, P. Barnes, MD, W. Kupsky, MD (Boston, MA)

The treatment of low-grade supratentorial astrocytomas in children remains controversial. In order to develop a protocol for management at our institution, we reviewed 40 patients (23 males, 17 females) diagnosed with low-grade supratentorial astrocytomas at Boston Children's Hospital between 1974-1990. Low-grade astrocytomas were classified into 3 histologic types: diffuse astrocytoma (Ringertz 1, n = 19), those with some pilocytic features (n = 17), and true pilocytic astrocytomas (n = 4). The age range was from 6 months to 20 years (average 11 years) and the followup ranged from 1-15 years (average 6 years). The initial treatment was gross total resection (GTR, n = 10), subtotal resection (STR, n = 20), or biopsy (n = 10). While surgery was the only treatment in 19 cases, radiation treatment was given to 21 patients. Measurement of outcome was based on computed tomography (CT) and magnetic resonance imaging (MRI) and clinical report.

Tumors in younger patients (< 6 years) progressed more frequently (56%) than in older patients (> 6 years, 29%). The lowest frequency of progression was seen in patients where a GTR was achieved (10%), while progression was seen more frequently in patients who underwent a STR (40%) or biopsy (50%). Similarly, larger tumors (> 4 cm at presentation) progressed more frequently (54%) than smaller tumors (26%). Tumors involving midline structures progressed more frequently (41%) than tumors limited to the hemispheres (41%). These features were likely related to the resectability of the tumor. The presence of "pilocytic" features in tumors did not alter the frequency of progression (29%) when compared to diffuse astrocytomas (37%). This data and that in the literature was used to set up a treatment protocol for low-grade supratentorial astrocytomas.

American Association
of Neurological Surgeons

Pediatric Section

1993 Membership Roster

Abbasy, Munir H., MD
80 Congress Street
Springfield, MA 01104
413/781-5050
Active

Aibright, A. Leland, MD
Child Hosp Pittsburgh
3705 5th Ave/Neuro
Pittsburgh, PA 15213
412/647-5090
Active

Altenau, Lance, MD
501 Washington
Suite #700
San Diego, CA 92103
619/297-4481
Active

Amacher, A. Loren, MD
Geisenger Clinic
Dept of Neurosurgery
Danville, PA 17822
717/271-6437
Active

Amador, L. V., MD
1440 Veteran Ave, 336
Los Angeles, CA 90024
213/787-3369
Active

Anderson, Jim D., MD
Redwood City Offices
1150 Veterans Blvd
Redwood City, CA 94063
415/780-2287
Active

Andrews, Brian T., MD
2100 Webster Street
Suite #110
San Francisco, CA 94115
Active

Arkins, Thomas J., MD
Neurosurgical Associates
60 Temple Street
New Haven, CT 06510
203/789-2030
Active

Aronin, Patricia A., MD
Child Hosp of Michigan
3901 Beaubien, 2nd Flr
Detroit, MI 48201
Active

Arpin, Elaine J., MD
SW Florida Neuro Assoc
413 Del Prado Blvd, Ste #102
Cape Coral, FL 33990
813/772-5577
Active

Bailey, Walter L., MD
Doctors Professional Bldg
280 N Smith Ave, Ste 234
St Paul, MN 55102
612/227-7088
Active

Balis, Gene A., MD
3000 E Fletcher Ave.
Suite #340
Tampa, FL 33613-4645
813/977-3776
Active

Barrer, Steven J., MD
1584 Old York Road
Abington, PA 19001
215/657-8145
Active

Bartkowski, Henry M., MD
Neurological Associates
931 Chatham Lane
Columbus, OH 43221
614/457-4880
Active

Beatty, Robert M., MD
8919 Parallel Parkway
Suite #331
Kansas City, KS 66112
913/299-9507
Active

Bell, William O., MD
Bowman Gray School of Med
Medical Center Blvd
Winston-Salem, NC 27103
919/748-4047
Active

Benzel, Edward C., MD
Univ of New Mexico/Neuro
ACC-2nd Flr Div of Neuro
Albuquerque, NM 87131
505/272-3401
Active

Berger, Thomas S., MD
Mayfield Neurological Inst
506 Oak Street
Cincinnati, OH 45219
513/221-1100
Active

Black, Peter M., MD, PhD
Brigham Wn's & Child. Hosp.
300 Longwood Ave, Neuro
Boston, MA 02115
617/735-6008
Active

Boggs, John Scott, MD
1820 Barrs Street
Suite #104
Jacksonville, FL 32204
904/388-5391
Active

Bressler, Bruce C., MD
720 S Van Buren
Green Bay, WI 54301
414/465-1900
Active

Brown, Jeffrey Alan, MD
Medical College of Ohio
Dept of Neurosurgery
Toledo, OH 43699-0008
419/381-3547
Active

Bruce, Derek A., MD
1935 Motor St
Dallas, TX 75235-7794
214/640-6660
Active

Buchheit, William A., MD
Temple Univ Health Ctr
3401 N Broad Street
Philadelphia, PA 19140
215/221-4068
Active

Cahan, Leslie D., MD
1505 N Edgemont St
Neurosurgery, Room 4141
Los Angeles, CA 90027
213/667-4703
Active

Canady, Alexa Irene, MD
Children's Hospital of MI
3901 Beaubien
Detroit, MI 48201
313/833-4490
Active

Carmel, Peter W., MD
Neurological Institute
710 W 168th Street
New York, NY 10032
212/305-5208
Active

Chadduck, William M., MD
Children's National Med Ctr
111 Michigan Ave, NW
Washington, DC 20010
202/745-3020
Active

Chapman, Paul H., MD
Massachusetts Gen Hosp
Fruit Street
Boston, MA 02114
617/726-3887
Active

Cheek, William R., MD
Clinical Care Center, #950
6621 Fannin MC 3-3435
Houston, TX 77030
713/770-3950
Active

Choux, Maurice, MD
Hopital Des Enfants
De La Timone, Cedex 5
Marseille, 13385 France
Corresponding

Cogen, Philip Harry, MD PhD
Univ of Chicago/Neuro
5841 S Maryland, MC-3-26
Chicago, IL 60637
312/702-2123
Active

Cohen, Alan R., MD
New England Med Ctr/Neuro
750 Washington, Box #267
Boston, MA 02111
617/956-5860
Active

Coulon Jr, Richard A, MD
311 Midway Drive
River Ridge, LA 70123
504/834-7070
Active

Crone, Kerry R., MD
Children's Hosp Med Ctr
Elland & Bethesda Avenues
Cincinnati, OH 45229
513/559-4726
Active

Dagi, T. Forcht, MD
993 E Johnson Ferry Rd
Atlanta, GA 30342
404/256-2633
Active

Davidson, Robin I., MD
Univ of Mass Medical Ctr
55 Lake Avenue, N
Worcester, MA 01655
617/856-3079
Active

Davis, Dudley H., MD
Mayo Clinic/Neurosurgery
200 First Street, SW
Rochester, MN 55905
507/284-4871
Active

Di Rocco, Concezio, MD
Univ Cattolica/Neuro
Largo Gemelli 8
Rome, 00168 Italy
Corresponding

Dorsen, Michael, MD
2905 San Gabriel #310
Austin, TX 78705
512/474-8765
Active

Duncan, Charles Cecil, MD
Yale Univ Sch of Medicine
Neurosurgery Section
New Haven, CT 06511
203/785-2805
Active

Edwards, Michael S.B., MD
UCSF Div of Ped Neurosurgery
533 Parnassus Ave, U-126
San Francisco, CA 94143
415/476-1087
Active

Eisenberg, Howard M., MD
Div of Neurosurgery
22 S Greene St.
Room S10B11
Baltimore, MD 21201
409/761-1500
Active

Epstein, Mel H., MD
Brown Univ/Neuro
110 Lockwood Street
Providence, RI 02903
401/277-8701
Active

Erasmus, Mark D., MD
PO Box 470
Corrales, NM 87048
505/247-4253
Active

Fell, David A., MD
Neurological Surgery Inc
6767 S Yale
Tulsa, OK 74136-3302
918/492-7587
Active

Fischer, Edwin G., MD
110 Francis St
Suite #3B
Boston, MA 02215
617/732-9795
Active

Fannery, Ann Marie, MD
Medical College of Georgia
1120 15th St/Neuro
Augusta, GA 30912-4010
404/721-3071
Active

Foltz, Eldon L., MD
UCI Medical Center
PO Box 14091
Orange, CA 92613-4091
714/634-5775
Active

Freed, Michael H. MD
825 Washington St
Suite #100
Norwood, MA 02062
617/769-4640
Active

Fried, Arno H., MD
Brown University/
Rhode Island Hosp
110 Lockwood St #328
Providence, RI 02903
401/444-8716
Active

Gahn, Norman H., MD
100 Retreat Avenue
Suite #705
Hartford, CT 06106
203/278-0070
Active

Gainsburg, Duane B., MD
5600 Monroe Street
Suite #101-Bldg A
Sylvania, OH 43560
419/882-8401
Active

Galicich, Joseph H., MD
Memorial Hospital
1275 York Avenue
New York, NY 10021
212/988-1629
Active

Gallo Jr, Anthony E., MD
4855 SR 105-S
Grayland, WA 98547
206/268-0957
Active

Gamache Jr, Francis W., MD
New York Hospital/Neuro
525 E 68th Street
Room ST-627
New York, NY 10021
212/746-2388
Active

Godersky, John C., MD
2841 De Barr Road
Suite #34
Anchorage, AK 99508
907/258-6999
Active

Goodrich, James T., MD
Dept of Neurosurgery
Montefiore
111 E 210th Street
Bronx, NY 10467
212/920-4196
Active

Goumnerova, Liliana C., MD
Children's Hospital-Bader 3
300 Longwood Ave
Boston, MA 02115
617/735-6364
Active

Greene Jr, Clarence S., MD
2865 Atlantic Avenue
Suite #103
Long Beach, CA 90806
213/426-4121
Active

Guido, Laurance Jacobi, MD
2660 Main Street
Suite #302
Bridgeport, CT 06606
203/576-1778
Active

Gutierrez, Francisco A., MD
707 N. Fairbank Court
Suite #199
Chicago, IL 60611
312/726-6330
Active

Hahn, Joseph F., MD
Cleveland Clinic
9500 Euclid Avenue, S80
Cleveland, OH 44195
216/444-5753
Active

Hahn, Yoon Sun, MD
Loyola Univ/Ped Neurosurgery
2160 S First/Bldg 54/#261
Maywood, IL 60153
312/880-4373
Active

Haines, Stephen J., MD
Box #96 Mayo
420 Delaware St, SE
Minneapolis, MN 55455
612/624-6666
Active

Hammargren, Lonnie L., MD
3196 S Maryland Pkwy
Las Vegas, NV 89109
702/735-7272
Active

Hammock, Mary Kathryn, MD
8650 Sudley Road
Suite #200
Manassas, VA 22110
703/551-2225
Active

Handler, Michael H.
224 Jefferson Rd
Princeton, NJ 08540
Active

Hanigan, William C., MD
214 NE Glen Oak Avenue
Suite #500
Peoria, IL 61603
309/676-0766
Active

Harwood-Nash, Derek C., MD
Hosp for Sick Children
Neuro Radiologist
Toronto, ON M5G1X8 Canada
416/598-6025
Associate

Hawkins III, John C., MD
1871 Montgomery Place
Jacksonville, FL 32205
904/388-6516
Active

Heafner, Michael D., MD
1010 Edgehill Rd N
Charlotte, NC 28207
704/376-1605
Active

Heffez, Dan S., MD
Chicago Inst of Neuro
428 W Deming Place
Chicago, IL 60614
312/883-8585
Active

Hellbusch, Leslie C., MD
8905 Douglas Ct
Omaha, NE 68114
402/397-4124
Active

Hemmy, David C., MD
20611 Watertown Rd
Suite J
Waukesha, WI 53186
414/798-9897
Active

Hendee Jr, Robert W., MD
4710 Lookout Mtn Cove
Austin, TX 78731
512/480-9905
Active

Hendrick, E. Bruce, MD
63 Leggett Avenue
Etobicoke, ON M9P1X3 Canada
416/224-3507
Lifetime Active

Hoffman, Harold J., MD
Hosp for Sick Children
555 University Ave/#1504
Toronto, ON M5G1X8 Canada
416/598-1210
Active

Hollenberg, Robert D., MD
McMaster Univ Med Ctr
Dept of Surgery/Rm 4U4
Hamilton, ON L8N3Z5 Canada
416/521-2100
Active

Hudgins, Roger, MD
5455 Meridan Mark Road
Suite #540
Atlanta, GA 30342
404/255-6509
Active

Humphreys, Robin P., MD
Hosp for Sick Children
555 University Ave/# 1504
Toronto, ON M5G1X8 Canada
416/598-6427
Active

James, Hector E., MD
7930 Frost Street
Suite 304
San Diego, CA 92123
619/560-4791
Active

Jane, John A., MD
Univ of Virginia Med Sch
Dept of Neurosurgery
Box 212
Charlottesville, VA 22908
804/924-8101
Active

Johnson, Dennis L., MD
400 Roseland
Hummelstom, PA 17036
202/745-3020
Active

Johnson, John K., MD
Greenville Neuro Grp
27 Memorial Medical Dr
Greenville, SC 29605
803/295-3600
Active

Johnson, Martin, MD
2800 N Vancouver
Suite #106
Portland, OR 97227
503/287-2646
Active

Johnson, Mary M., MD
5555 Peachtree
Dunwoody, Suite #337
Atlanta, GA 30342
404/256-4510
Active

Joseph, Allen S., MD
7777 Hennessy Blvd
Suite #10000
Baton Rouge, LA 70808
504/766-4487
Active

Kalsbeck, John E., MD
Riley Childrens Hosp
702 Barnhill Rd
Indianapolis, IN 46202-5200
317/274-8910
Active

Kasoff, Samuel S., MD
New York Med Col/Neuro
Munger Pavillion/Rm #329
Valhalla, NY 10595
914/285-8392
Active

Kelly Jr., David L., MD
Bowman Gray Sch of Med
Medical Ctr Blvd/Neuro
Winston-Salem, NC 27157
919/716-4049
Active

Klein, David M., MD
Dept of Neurosurgery
219 Bryant Street
Buffalo, NY 14222
716/878-7386
Active

Knierim, David Stevens, MD
Dir Ped Neuros
Loma Linda University
Children's Hospital
Loma Linda, CA 92354
Active

Kosnik, Edward J., MD
Chatham Village Prof Bldg
931 Chatham Lane
Columbus, OH 43221
614/457-4880
Active

Kril, Merv, MD
158 Oakdale Street
Redwood City, CA 94062
619/294-9723
Active

Laurent, John P., MD
Clinical Care Ctr, MC3-3435
6621 Fannin
Houston, TX 77030
713/770-3950
Active

Laws, Edward R., MD
Univ of Virginia/Neuro
Box 212
Health Science Center
Charlottesville, VA 22908
804/924-2650
Active

Lipow, Kenneth I., MD
267 Grant Street
Bridgeport, CT 06610
203/384-3805
Active

Loeser, John D., MD
Pain Center
Univ of Washington RC95
Seattle, WA 98195
206/548-4429
Active

Loffman, Morris D., MD
15211 Vanowen Street
Suite #102
Van Nuys, CA 91405
818/782-5111
Active

Longo-Cordero, Rafael, MD
Calle Rochester 911
University Gardens
Rio Piedras, PR 00927
809/758-1836
Active

Louis, Kenneth M., MD
3000 E Fletcher Ave
Suite #340
Tampa, FL 33613-4645
813/977-3776
Active

Luerssen, Thomas G., MD
James Whitcomb Riley Hosp
One Childrens Square
Indianapolis, IN 46202
317/274-8852
Active

Magid, Gail A., MD
1661 Soquel Drive, F
Santa Cruz, CA 95065
408/476-8900
Active

Manwaring, Kim Herbert, MD
Phoenix Childrens Hosp
909 E Brill Street
Phoenix, AZ 85006
602/239-4880
Active

Mapstone, Timothy B., MD
University Hospital
2074 Abington Rd/Neuro
Cleveland, OH 44106
216/844-3004
Active

Marlin, Arthur E., MD
Methodist Plaza
4499 Medical Drive
Suite #397
San Antonio, TX 78229
512/615-1218
Active

Mawk, John R., MD
2222 NW Lovejoy Street
Suite #512
Portland, OR 97210-5103
503/725-1777
Active

McCallum, Jack E., MD
1522 Cooper Street
Fort Worth, TX 76104
817/336-1300
Active

McComb, J. Gordon, MD
1300 N Vermont Ave
Suite #906
Los Angeles, CA 90027
213/663-8128
Active

McLanahan, C. Scott, MD
Charlotte Neuros Assoc
1010 Edgehill Road N
Charlotte, NC 28207
704/376-1605
Active

McLaurin, Robert L., MD
250 William Howard Taft Rd
Ste #205
Cincinnati, OH 45219
513/221-0400
Lifetime Active

McLone, David Gordon, MD
Childrens Memorial Hospital
2300 Childrens Plaza, Box 28
Chicago, IL 60614
312/880-4373
Active

Meacham, William F., MD
Neuro Assoc/4230 Harding Rd
709 St. Thomas Med Plaza, E
Nashville, TN 37205
615/322-3343
Senior

Mealey Jr, John, MD
Indiana Univ Med Ctr
545 Barnhill, Emerson #139
Indianapolis, IN 46202
317/274-8549
Lifetime Active

Menezes, Arnold H., MD
Univ of Iowa Hospital
Dept of Neurosurgery
Iowa City, IA 52242
319/356-2768
Active

Meyer, Glenn A., MD
Medical College of Wisconsin
9200 W Wisconsin Avenue
Milwaukee, WI 53226
414/257-6465
Active

Michelsen, W. Jost, MD
Montefiore Med Ctr
111 E 210th St/Neuro
Bronx, NY 10467-2490
718/920-4196
Active

Mickle, J. Parker, MD
Univ of Florida Med Sch
Dept of Neurosurgery
Gainesville, FL 32610
904/392-4331
Active

Milhorat, Thomas H., MD
Box 1189
450 Clarkson Avenue
Brooklyn, NY 11203-2098
718/270-2111
Active

Miller, Clinton F., MD
330 Borthwick Ave
Suite 108
Portsmouth, NH 03801
603/433-4666
Active

Minella, Philip Arthur, MD
146 Wyoming Street
Dayton, OH 45409
513/228-5261
Active

Moiel, Richard H., MD
7400 Fannin St
1160 One Fannin Bldg
Houston, TX 77054
713/797-1160
Active

Montes, Jose L., MD
Montreal Childrens Hosp
2300 Tupper St Room C-811
Montreal, PQ H3H1P3 Canada
514/934-4301
Active

Montoya, German, MD
1801 Cook Avenue
Orlando, FL 32806
305/896-0463
Active

Morrison, Glenn, MD
3200 SW 60 Court
Suite #301
Miami, FL 33155
305/662-8386
Active

Moyes, Peter D., MD
Apt #303
2210 W 40th
Vancouver, BC V6M1W6
Canada
604/266-4881
Lifetime Active

Muhlbauer, Michael S., MD
930 Madison Ave
Suite #600
Memphis, TN 38103
901/522-7761
Active

Murtagh, Frederick, MD
Univ of Penn Hosp
3400 Spruce St
Philadelphia, PA 19104
215/662-3490
Lifetime Active

Myles, Terence, MD
1820 Richmond Rd, SW
Calgary, AB T2T5C7 Canada
403/229-7805
Active

Nadell, Joseph M., MD
Childrens Hospital
200 Henry Clay Ave
New Orleans, LA 70118
504/588-5564
Active

Nagib, Mahmoud G., MD
1106 Metro Medical Bldg
825 S Eighth Street
Minneapolis, MN 55404
612/332-1653
Active

Nagle, Richard C, MD
3000 Coley
Suite 101
Berkeley, CA 94705
415/843-0261
Active

Parent, Andrew D., MD
Univ of Miss Med Ctr
2500 N State Street
Jackson, MS 39216
601/984-5703
Active

Raffel, Corey, MD
1300 N Vermont Avenue
Suite #906
Los Angeles, CA 90027
213/663-8128
Active

Nijensohn, Daniel E., MD
340 Capitol Avenue
Bridgeport, CT 06606
203/336-3303
Active

Park, Tae Sung, MD
Washington Univ Med/Neuro
1 Children's Place Rm #1546
St. Louis, MO 63110
314/454-2810
Active

Raimondi, Anthony J., MD
Villa Monteleone
37020 Gargagnago
Verona, 37100 Italy
045/770-4974
Active

Nimel, Krishna, MD
10 Union St
Natick, MA 01760-4710
508/650-1022
Active

Penix, Jerry O., MD
607 Medical Tower
Norfolk, VA 23507
804/622-5325
Active

Ransohoff, Joseph, MD
915 Mooring Circle
Tampa, FL 33602
000/000-0000
Active

O'Brien, Mark Stephen, MD
1900 Century Boulevard
Suite #4
Atlanta, GA 30345
404/321-9234
Active

Piatt, Joseph H., MD
3181 SW Sam Jackson Park Rd
Div of Neurosurgery (L-472)
Portland, OR 97201-3098
503/494-8070
Active

Reigel, Donald H., MD
320 E North Avenue
7th Floor, South Tower
Pittsburgh, PA 15212
412/359-4765
Active

Oakes, W. Jerry, MD
Childrens Hosp of Alabama
Suite #400
Birmingham, AL 35233
919/684-5013
Active

Pittman, Hal Watson, MD
Barrow Neurological Inst
2910 N 3rd Ave
Phoenix, AZ 85013
602/285-3468
Active

Rekate, Harold Louis, MD
Barrow Neurological Inst
2910 N 3rd Ave
Phoenix, AZ 85013
602/285-3632
Active

Page, Lamy Keith, MD
1501 NW Ninth Ave
Miami, FL 33136
305/547-6946
Active

Portnoy, Harold D., MD
1431 Woodward Ave
Bloomfield Hills, MI 48302
313/334-2568
Active

Reynolds Jr, Arden F., MD
Magan Medical Clinic
420 West Rowland St
Covina, CA 91723
818/331-6411
Active

Pang, Dachling, MD
Univ. of California-Davis
2516 Stockton Blvd
Sacramento, CA 95817
916/734-3658
Active

Pudenz, Robert H., MD
574 Garfield Ave
So Pasadena, CA 91030
818/441-0530
Senior

Rhoton Jr, Albert L., MD
Univ of Florida/Neurosurgery
Box J-265/JHM Health Ctr
Gainesville, FL 32610-0265
904/392-4331
Active

Roberts, Theodore S., MD
University of Washington
RI-20, PC 102487
Seattle, WA 98195
206/526-2508
Active

Saunders, Richard, MD
Dartmouth-Hitchcock Med Ctr
1 Medical Center Drive
Hanover, NH 03756
603/646-5109
Active

Shapiro, Kenneth N., MD
1935 Motor Street
Dallas, TX 75235-7794
214/640-6660
Active

Robinson, Walker L., MD
Univ of Maryland Hosp
22 S Green St/Neurosurgery
Baltimore, MD 21201
301/328-5714
Active

Scarff, Timothy B., MD
33 SW Upper Riverdale Rd
Suite #25
Riverdale, GA 30274
404/997-0600
Active

Shillito Jr, John, MD
300 Longwood Ave
Dept of Neurosurgery
Boston, MA 02115
617/735-6012
Active

Rosenblum, Bruce R., MD
29 Route 34 North
Suite #103
Colts Neck, NJ 07722
908/462-4401
Active

Schut, Luis, MD
Child Hosp Of Philadelphia
34th & Civic Ctr Blvd
Philadelphia, PA 19104
215/596-9368
Active

Simmons, James C., MD
190 Grove Park Rd
Memphis, TN 38117
901/522-7700
Lifetime Active

Rosenthal, Alan, MD
Long Island Neurosurg Assoc
410 Lakeville Road
New Hyde Park, NY 10042
516/354-3401
Active

Scott, R. Michael, MD
Childrens Hosp-Bader 3
300 Longwood Ave/Neuro
Boston, MA 02115
617/735-6011
Active

Sklar, Frederick H., MD
1935 Motor Street
Dallas, TX 75235-7794
214/640-6660
Active

Rothman, Allen S., MD
1160 Fifth Avenue
Suite #106
New York, NY 10029
212/289-5451
Active

Seljeskog, Edward L., MD
Neuro & Spinal Surg Assoc
2805 5th St, S
Rapid City, SD 57701
605/341-2424
Active

Smith, Harold, MD
2011 Church St
Suite #800
Nashville, TN 37203
615/329-7840
Active

Sanford, Robert A., MD
Semmes-Murphy Clinic
920 Madison Ave/Suite #201
Memphis, TN 38103
901/522-7700
Active

Selker, Robert G., MD
Western PA Hospital
Division of Neurosurgery
4800 Friendship Avenue
Pittsburgh, PA 15224
412/578-4400
Active

St. Louis, Phillip G., MD
1801 Cook Ave
Orlando, FL 32806-2913
307/425-7470
Active

Sato, Osamu, MD
Dept of Neurosurgery
Bo Sei Dai Isehara
Kanagawa, 259-11 Japan
046/393-1121
Corresponding

Shallat, Ronald F., MD
3000 Colby Street
Suite #101
Berkeley, CA 94705
415/843-0261
Active

Stein, Sherman C., MD
Dept of Surgery
3 Cooper Plaza, Ste #411
Camden, NJ 08103
403/733-4153
Active

Steinbok, Paul, MD
B.C. Childrens Hospital
1 C 4480 Oak St
Vancouver, BC V6H3V4
Canada
Active

Storrs, Bruce B., MD
Medical Univ of SC
171 Ashley St/428-CSB
Charleston, SC 29425-2272
803/792-2422
Active

Stringer, Douglas L., MD
2011 Harrison Avenue
Panama City, FL 32405
904/769-3261
Active

Stringer, Merle Preston, MD
2011 Harrison Avenue
Panama City, FL 32405
904/769-3261
Active

Sukoff, Michael, MD
801 N Tustin
Suite #406
Santa Ana, CA 92705
714/834-1303
Active

Susen, Anthony F., MD
504 Remora Circle
Fripp Island, SC 29920
412/682-5900
Lifetime Active

Sutton, Leslie N., MD
Child Hosp of Philadelphia
34th & Civic Center Blvd
Philadelphia, PA 19104
215/387-6059
Active

Taekman, Michael S., MD
3000 Colby
Suite #101
Berkeley, CA 94705
510/843-0261
Active

Tew Jr, John M., MD
Mayfield Neuro Instit
506 Oak Street
Cincinnati, OH 45219
513/221-1100
Active

Tomita, Tadanori, MD
Childrens Memorial Hospital
2300 Childrens Plaza
Chicago, IL 60614
312/880-4373
Active

Turner, Michael S., MD
1801 N Senate Blvd
Suite #535
Indianapolis, IN 46202
317/926-5411
Active

Uscinski, Ronald H., MD
3301 Woodburn Rd, #209
Annandale, VA 22003
301/654-6688
Active

Venes, Joan, MD
6A1 President Point Dr
Annapolis, MD 24103
313/936-5016
Active

Ventureyra, Enrique C., MD
401 Smyth Road
Ottawa, ON K1H8L1 Canada
613/737-2316
Active

Vries, John Kenric, MD
University of Pittsburgh
217 Victoria Bldg
Pittsburgh, PA 15261
412/624-1650
Active

Wald, Steven L., MD
10 Grove Lane
Shelburne, VT 05482
802/656-4310
Active

Waldman, John B., MD
Albany Medical College
Div of Neurosurgery, A-61
Albany, NY 12208
Active

Walker, Marion L., MD
Primary Childrens Med Ctr
100 N Medical Dr
Salt Lake City, UT 84113-1100
801/521-1209
Active

Walsh, John Willson, MD
1701 Hermann Dr, #20G
Houston, TX 77004
713/793-6445
Active

Waltz, Thomas A., MD
Scripps Clinic
10666 N Torrey Pines
La Jolla, CA 92037
619/455-9100
Active

Ward, John D., MD
Virginia Commonwealth Univ
Neuro, MCV Station, Box 631
Richmond, VA 23298
804/786-9165
Active

Weiss, Martin H., MD
USC Medical Center
1200 N State St/Box 5046
Los Angeles, CA 90033
213/226-7421
Active

Yamada, Shokei, MD
Loma Linda Univ Sch of Med
Rm #2539, Neurosurgery
Loma Linda, CA 92350
714/824-4417
Active

Wernick, Shelley, MD
2350 W Villard Avenue
Room #101
Milwaukee, WI 53209
414/462-9697
Active

Zanetti, Paul Henry, MD
3006 S Alameda Street
Corpus Christi, TX 78404
512/883-1731
Active

White, Robert J., MD PhD
Metrohealth Med Ctr
2500 Metrohealth Dr.
Cleveland, OH 44109-1998
216/459-4383
Active

Zavala, L. Manuel, MD
Neurosurgery Office/SCVMC
751 S Bascom Avenue
San Jose, CA 95128
408/299-5762
Active

Willman, Philip J.A., MD
3006 S Alameda Street
Corpus Christi, TX 78404
512/883-1731
Active

Winfield, Jeffrey A., MD PHD
750 E Adams St
Syracuse, NY 13210
315/464-4470
Active

Winston, Ken R., MD
1950 Ogden
B467
Denver, CO 80218
Active

Woodward, Meredith V., MD
110 N. Valeria Street
Suite #401
Fresno, Ca 93701
209/264-6800
Active

