WELCOME TO MONTANA
Talent – Neurological Surgery

- **Thomas C. George, MD, PhD, FAAN**
  Neurological Surgery

- **Stefan Campbell, MD**
  Neurological Surgery

- **Joshua Krass, DO**
  Neurological Surgery

- **Robert Griffin, MS, PA-C**
  Neurological Surgery

- **Joshua Williford, PA-C**
  Neurological Surgery

- **Amy Tangedahl, PA-C**
  Neurological Surgery

- **Stephen Campbell, MD**
  Neurological Surgery

**Talent – Neurology**

- **Bret Lindsay, MD**
  Neurology

- **Marcus S. Wheeler, MD**
  Neurology

- **Kurt Lindsay, MD**
  Neurology

- **Donald Stone, MD**
  Neurology

- **Kristin Yandora, DO**
  Neurology

- **Paul Coats, NP**
  Neurology

- **Melanie Klawiter, MD**
  Neurology

**Talent – Neurology**

- **Kris Ippolito, MD**
  Neurology

- **Anita Warnick, MD**
  Neurology

- **Fred Krohn, MD**
  Neurology

- **Brenda Rankin, MD**
  Neurology

**Talent – Neurology**

- **Distinction:** Fellowship trained Cerebrovascular Neurologist, Neuromyelitis Optica Neurologist, Epilepsy Neurologist, Pediatric Neurologist, Headache Medicine, Neuroimaging
Talent – Physical Medicine & Rehabilitation (Physiatry)

Not Pictured:
Mark Weber MD, Medical Director
Austin Johnston DO
Justin Shobe PA-C (APP Fellow)

Distinctions: CARF (Certification for Rehabilitation Facilities) accreditation including stroke

Montana Center for Wellness and Pain Management

A comprehensive center offering interventional pain management, physical therapy, gentle movement classes, yoga, chiropractic, massage therapy, acupuncture, naturopathic medicine, addiction medicine, and medical pain management.

SUPPORT STAFF

Montana Center for Wellness & Pain Management
Consolidated Productivity
Neuroscience and Spine Institute

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Total Visits</td>
<td>28,010</td>
<td>30,001</td>
<td>37,943</td>
<td>46,458</td>
<td>60,458</td>
<td>6.0%</td>
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<tr>
<td>New Patient Visits</td>
<td>3,403</td>
<td>4,860</td>
<td>5,422</td>
<td>6,194</td>
<td>14.2%</td>
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<tr>
<td>Total Procedures</td>
<td>2,801</td>
<td>3,187</td>
<td>4,585</td>
<td>4,831</td>
<td>11.4%</td>
<td></td>
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<tr>
<td>Major Surgical Procedures</td>
<td>272</td>
<td>120</td>
<td>601</td>
<td>582</td>
<td>-3.0%</td>
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Neurosurgical Focused Care

Trauma/Critical Care

<table>
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<tr>
<th>Metric</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
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</thead>
<tbody>
<tr>
<td>Total trauma activations</td>
<td>241</td>
<td>239</td>
<td>296</td>
</tr>
<tr>
<td>Direct Neurological Surgery trauma admits</td>
<td>52</td>
<td>76</td>
<td>71</td>
</tr>
<tr>
<td>Neurological Surgery trauma consults</td>
<td>75</td>
<td>48</td>
<td>78</td>
</tr>
<tr>
<td>Total (in percent)*</td>
<td>53</td>
<td>52</td>
<td>50</td>
</tr>
</tbody>
</table>

* Does not include new activations, new traumatic neurological injuries (e.g., subdural hematoma, stroke, intracranial hemorrhage, hydrocephalus).

A Rising Tide Lifts All Boats: KRH in Evolution

- Women and children
- Cardiovascular
- Family medicine
- Musculoskeletal
- Surgery
- Urology
- Emergency Medicine, Trauma, Transport
- Wellness and prevention

Synergies
WHY BOOT CAMP FOR ADVANCED PRACTICE PROVIDERS?

The future of neurosurgical care is intimately tied to the integration of physician ADVANCED PRACTICE PROVIDERS into neurological surgery.

Evolving Roles and spectrum of care of Midlevel Advanced Practice Providers

- Integral role in deliver of healthcare in rural and semirural areas mainly in delivery of primary care
- Expanding penetration into subspecialty care as rural and semirural areas acquire subspecialists
- Changes in resident work hours have enhanced their roles in academic practices
- Changes in methodology of compensation (RVU Based) both in academic and non-academic practices has increased their value
- The economics of Population Health models will require significant increases in patient/provider ratios
- Less expensive providers to perform acutely appropriate care (average PA-C treats 70 patients/week).
Physician Assistant Fun Facts

- 95,583 certified PA-Cs
- Certification comes through the National Commission on Certification of Physicians Assistants (1975)
- 43,500 PA-C in 2003 grew 219% by 2013
- 76.5% office based private practice or hospital setting
- Average number of patients seen per week 70

Educational Process of Physician Assistance

- Four year college degree
- Two year Physician Assistant program many conferring the equivalent of a masters degree
- One year of Classroom education similar to medical school
- One year of Clinical rotations: Core plus Electives
- NO DEDICATED TRAINING IN SUBSPECIALTIES DURING PA SCHOOL

Roles of Physician Assistants in Neurosurgical Practice

- Independent Clinics*/Independent Billing
- Assist in Clinic
- Assist in Operating Room
- Round in Hospital
- First Call On call: Phone, Floor, icu, ER
- In Clinic procedures: injections, shunt adjustments, dbs adjustments, pain pump refills
- In hospital procedures: icp, evd, lp, lumbar drain, drain removals
- Independent DEA
- Screening Clinics: ie Spine
So why the boot camp course

- Neurological surgery needs APPs as part of the care teams of the future. We are trying to recruit you.
- Proof of concept of the boot camp course with Neurosurgery PGY-1 and PGY-2 as effected educational venue for durable transfer of skills.
- Proof of concept in previous 3 mid-level boot camp courses by the Neuroscience and Spine Institute, Kalispell, Montana
- Presentation at the Lende last year of the course in form of scientific paper
- University of Utah attends NS&SI 3rd annual course
- And Here we are.
- Concepts: this is a safe place to learn. You learn by making mistakes. Take advantage of the faculty and simulations
Subspecialty training for Advanced Practice Providers: The Initial Experience with a Neurosurgical Primary Technical skills Boot Camp for Physicians Assistants and Nurse Practitioners with Evolution into a Midlevel Fellowship Training Program

Tacey E P Griffin PA-C
TC Origitano MD PhD
Department of Neurological Surgery
Neuroscience and Spine Institute
Kalispell Regional Healthcare
Kalispell, Montana

Current Fellowship Programs
12 MONTH STRUCTURED CURRICULUM

50 Weekly Learning Modules

- Weekly Schedule.
- Weekly reading recommendations.
- Weekly Objectives.
- Weekly Assessment.

Modules increase in complexity as the program progresses.
FIRST NEUROSURGERY
EX-FELLOW
(CONGRATULATIONS !)
Jessica Christensen, MCMSc,
PA-C, ATC

Thank you for joining us at the end of the rainbow.
Checklist of Information Needed to Complete an Associate Membership Application:

- Education dates and institutions
- Primary hospital affiliation and start date, if affiliated with a hospital
- Current medical license number and dates in effect
- Copy of certification

Application is easy as 1-2-3

1. Login at MyAANS
2. Select “AANS Membership” from under the My Applications icon
3. Select “Create a new application” and follow the instructions

If you have questions, please contact Shahida Razvi at snr@aans.org or call her at 847/378-0539 or toll free 888/566-2267, extension 539.

Associate Membership
Advanced Practice Provider

AANS Members-Only Benefits for Associate Members:

- **Free** Category 1 CME through *Neurosurgical Focus*, 3.0 credits available per month (value: $50/CME credit)
- **Free** online educational sessions, some offering CME (value: $50/CME credit)
- **Free** CME tracking and online transcripts
- **Reduced registration rates** for AANS Annual Meeting as well as Advanced Practice Provider and Practice Management courses
- Searchable members-only online Directory
- AANS Online Career Center
- Exclusive offers, savings, and services through AANS partners
- Discount on AANS publications purchases

Requirements:

- Employment/residence in North America
- CV
- Sponsorship letters from three (3) AANS members (at least one letter must be from a neurosurgeon).
- Physician Assistant
  - certified by the National Commission on Certification of Physician Assistants (PA-C) - copy of certificate required
- Nurse who
  - specializes in the care of neurosurgical patients

Obligations:

- 2018 Membership Dues: $145
- Attendance at one out of five AANS Annual Scientific Meetings
Neurosurgery NP/PAs (Advanced Practice Providers)
Know Your Organizations

Presented by
Tracey Anderson, MSN, CNRN, FNP-BC, ACNP-BC
University of Colorado Health
UCHealth Medical Group – Brain & Spine

Financial Disclosures
Clinical Faculty/Speakers Bureau
Codman Neuro

Today’s Objectives

• Identify organizations supporting Neurosurgery APPs
• Discuss membership and volunteer opportunities
• Share future educational offerings
American Association of Neurologic Surgeons (AANS)
• Associate Membership available
  – Annual Dues currently $145
    • 3.0 free CME monthly through Neurosurgical Focus ($50/CME value)
    • Free online educational sessions
    • Free CME tracking & online transcripts
    • Reduced optional journal subscriptions
    • Reduced registration rate for meetings

www.aans.org

AANS Associate Membership Requirements
• Employment/residence in North America
• CV
• Sponsorship letter from 3 AANS members (at least one must be a neurosurgeon)
• PA – certified by NCCPA (PA-C)
• NP/RN – specializes in care of neurosurgical patients
• Must attend at least one out of 5 AANS Annual Scientific meetings

Upcoming AANS Education Events
• April 28 – May 2, 2018
  – AANS Annual Scientific Meeting, New Orleans, LA

• August 29-Sept 1, 2018
  – Advanced Practice Provider Course, Los Angeles, CA
Webinars NE

- Intro to Neuroimaging: Spine
- Intro to Neuroimaging: Cranial

www.aans.org/appwebinars

AANS Volunteer Opportunities

- Committee membership
  - Education & Practice Management
  - Membership
  - Scientific Planning Committee
  - Subspecialty Section Committees
  - Neuro Trauma & Critical Care, Peds, Pain, Spine & Peripheral Nerve, Stereotactic & Functional, Tumors
- Course Director
- Speaker
- Moderator

Council of State Neurosurgical Societies (CSNS)

The CSNS is a representative, deliberative and collaborative organization of delegate neurosurgeons in training and practice that exists to:

- Positively influence and affect the socioeconomic policy of organized Neurosurgery for the benefit of Neurosurgical patients and our profession,
- Serve as a resource for socioeconomic knowledge and education for our Neurosurgical colleagues, regulatory and health care officials as well as legislative representatives,
- Provide a conduit for new initiatives, concerns and issues to be brought to the AANS and CNS for response and action, and
- Provide an environment for developing future leaders in healthcare policy and advocacy for Neurosurgery.

www.csnsonline.org
Neurosurgery Executives’ Resource Value and Education Society (NERVES)

- NERVES was established with the purpose of helping neurosurgery practice managers and administrators network, combine resources, and learn from their colleagues about how to build stronger practices.
- NERVES is the first national neurosurgery practice manager and administrator society in the US. This organization is the result of an initiative by CSNS.

www.nervesadmin.com

Neurosurgery Certification

- Currently no specialty certification exists for NPs or PAs in neurosurgery
- Closest thing to neuro certification is CNRN which is a nursing certification and does not reflect role of APP
- Numbers desiring certification small
- Difficult to develop as you are dealing with two different licensing boards & multiple certification entities

Nurse Practitioner Certification (ANCC)

- Acute Care NP*
- Adult NP*
- Adult-Gerontology Acute Care NP
- Adult-Gerontology Primary Care NP
- Adult Psychiatric-Mental Health NP*
- Family NP
- Gerontological NP*
- Pediatric Primary Care NP
- Psychiatric-Mental Health NP
- School NP*

Specialty: Diabetes Management-Advanced* Emergency Medicine (cert by portfolio) *Retired Exam

www.nursecredentialing.org
Nurse Practitioner Certification (AANP)

- Adult Nurse Practitioner (retiring 12/2016)
- Family Nurse Practitioner
- Adult-Gerontology Primary Care NP
- Emergency Nurse Practitioner Specialty for Family Nurse Practitioners (launched 1/2017)

Physician Assistant Certification (NCCPA)

- Primary Certification (PA-C)
- Specialty Certificates of Added Qualifications (CAQS)
  - Cardiovascular and Thoracic Surgery
  - Emergency Medicine
  - Hospital Medicine
  - Nephrology
  - Orthopaedic Surgery
  - Pediatrics
  - Psychiatry

AANS Milestones Project

- Need recognized to differentiate levels of knowledge/experience
- No formal training available to use as criteria (mostly OTJ)
- Widely variable skill sets
- Somewhat variable scope of practice depending on clinical practice setting (community hospital vs teaching hospital)
Fellowships

- No credentialing organization
- Widely variable based on practice setting/host organization
- Limited spaces
- AANS looking at how they can support/facilitate

Questions??

tracey.anderson2@uchealth.org
Pelvic Evaluation in Thoracolumbar Corrective Spine Surgery

How and Why I do It
Making sense of the techniques
Gus Varnavas MD

Adult Scoliosis overview

• Prevalence 60% in the elderly
• Cosmetic and functional concerns
• Substantial Pain and disability
• 3 Dimensional problem

Adult Scoliosis Cont’d

• Historically focused on Coronal deformity
• Great Coronal Corrections BUT
• Pain and Dysfunction
• The COBB Angle not enough
Cobb Angle

Neglects Sagittal Balance

Consequences
Scoliosis correction pre and post

Spine Functions in 3 Dimensions and in Association
- Sagittal balance is Key
  - Glassman et al 2005
- Coronal balance
  - 50-60% improvement usually good enough
- Must respect pelvic anatomy and morphology
- Must view Multi-Dimensionally

“Cone of Economy”
Normal Sagittal Balance

Normal Coronal Balance

Coronal Plane Decompensation
Cobb Angle

Abnormal Sagittal Vertical Alignment
Spine and Pelvis act as a Continuum

Both are striving for Neutral Coronal and Sagittal balance

• Abnormal Anatomy, Position or Biomechanics of one affects the other

• Think Compensatory Mechanisms

Role of the Pelvis

• Critical in Spino-Pelvic Alignment

• Important Role in Sitting and Standing

• Relevant parameters
  pelvic obliquity
  Pelvic incidence
  Pelvic tilt
  Sacral slope

Pelvic Obliquity
Pelvic Obliquity

• Important consideration in Coronal corrections
• Can serve as an indicator of compensation
• May also signify the presence of other issues
  Leg length discrepancies
  Hip, Knee or acetabular issues

Pelvic Incidence

Pelvic Incidence (PI)

• Most important relationship to lumbar lordosis (LL)
• LL within +/-9 degree’s of PI
• Describes the fixed shape of the Sacrum
• Angle does not Change
Pelvic incidence Cont’d

• The baseline reference for lumbar lordosis to be introduced during Surgical Therapy

• Posteriorly by osteotomies

• Anteriorly by adding Correct interbody cage

• BOTH

LL and PI

Measurement Overview
Pre-op Major PI and LL discrepancy

Post Op Correction

Pelvic Tilt
Pelvic Tilt

- Position Dependent
- Reveals the body's attempt to realign and achieve Neutral Sagittal balance
- Retroversion (Pelvis pushed posteriorly)
- Knee Flexion
- Both compensatory mechanisms require energy
**Pelvic Tilt**

- Ideal PT >10 and < 20 degrees
- Retroversion increases so does PT
- <20 = normal per SRS
- 20-30= + or moderate
- >30 ++ severe deformity

---

**SVA and Pelvic Tilt**

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**T1 Pelvic Angle**

---
T1 Pelvic Angle

- Newer Measurement
- Takes in account the combined compensatory effects of increased Sagittal balance and Pelvic Retroversion

Bringing It Together

<table>
<thead>
<tr>
<th>Category</th>
<th>Normal</th>
<th>According to SIR/AHNS Classification</th>
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</thead>
<tbody>
<tr>
<td>Spinal vertical alignment</td>
<td>≤ 2.5 cm in asymptomatic adults</td>
<td>≤ 4 cm: non-pathologic; 4.5-6 cm: moderate deformity; &gt;6 cm: marked deformity</td>
</tr>
<tr>
<td>Pelvic incidence</td>
<td>Normally within 10° of bony landmarks</td>
<td>&lt;10°: non-pathologic; 10°-20°: moderate deformity; &gt;20°: marked deformity</td>
</tr>
<tr>
<td>Pelvic tilt</td>
<td>Normally between 10° and 30°</td>
<td>&lt;20°: non-pathologic; 20°-30°: moderate deformity; &gt;30°: marked deformity</td>
</tr>
<tr>
<td>T1 pelvic angle</td>
<td>Approximately 17°</td>
<td>Severely obtuse greater than 30°</td>
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</table>

How We Get There

Alignment Considerations

- Can we do it at Disc/Joint level
- Bone Resection Needed?
- BOTH?
Approach Overview

Approach Options

<table>
<thead>
<tr>
<th>Approach</th>
<th>L5/S1</th>
<th>L4</th>
<th>L3</th>
<th>L2</th>
<th>L1/L2</th>
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<td>+++</td>
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<tr>
<td>ALIF</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LLIF</td>
<td>-</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>OLF/AFP</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
</tbody>
</table>

- Fair options: ++, good options: ++++, excellent options: +++, poor options: -

How We Get There

- ALIF  Best Sagittal Balance
- Lateral XLIF  best for Coronal
- Posterior fixation, bone resections/decompressions
Sagittal Balance Restoration

Anterior lumbar interbody fusion (ALIF)

XLIF
Thank You

Gus K Varnavas MD FAANS, DABNS
CHOA Neurological Spine Service
EMERGENCY CRANIAL RADIOLOGY ASSESSMENT

Joshua Krass D.O., FACOS
Department of Neurological Surgery
Kalispell Regional Medical Center

Background
- Medical School – Des Moines University College of Osteopathic Medicine and Surgery, Des Moines, IA
- Osteopathic Internship – St. John Providence Hospital, Southfield, MI
- Neurological Surgery Residency – St. John Providence Hospital, Southfield, MI
- Fellowships:
  - Minimally Invasive Endoscopic Brain and Skull Base Research Fellowship, Weill Cornell Medical College, New York, NY
  - Skull Base and Cerebrovascular Surgery Fellowship, University of California Irvine, Irvine, CA

Case 1
- CC: fall from height
- HPI: 12 y/o male s/p fall from second story window, positive LOC briefly, returned to baseline prior to ER, CT negative
- Exam:
  - Initial - Alert and Awake, Oriented x 2, confused and combative, MAE symmetrically, PERRLA
  - Called urgently secondary to increased somnolence and weakness on the left side
Case 1

- Diagnosis: Epidural Hematoma
- Discussion:
  - Between the skull and the dura
  - Biconvex or lens shaped
  - More common in children and young adults. Uncommon in the elderly since the dura is very adherent to the skull.
  - Does not tend to cross suture lines
  - Over 90% are associated with a skull fracture. Classically due to laceration of the middle meningeal artery.
  - Initial concussion – "lucid interval" – deterioration
  - Treatment is usually emergent surgical evacuation

Case 2

- CC: motorcycle accident
- HPI: 21 y/o female passenger on motorcycle, no helmet; questionable LOC
- Exam: Alert and Awake, combative, MAE symmetrically, PERRLA, GCS = E2V3M5
- Diagnosis: Traumatic Contusion
- Discussion:
  - Coup or contra-coup contusion
  - Usually located over bony prominences
  - Hemorrhagic contusions can enlarge or "blossom"
  - Accompanied by significant edema, SIADH/Hyponatremia
  - High index of suspicion and close monitoring
Case 3

- CC: severe headache
- HPI: 70 y/o female called sister complaining of severe headache and visual disturbance. Subsequently became lethargic with slurred speech follow by loss of consciousness.
- PMHx: Htn, Obesity, 30 yr smoking
- Exam: Intubated and recently sedated, PERRLA, Pupils sluggishly 2mm, Positive corneal and gag response, extensor posturing

Case 3

- Diagnosis: Aneurysmal Subarachnoid
- Discussion:
  - Most common cause following trauma
  - May be associated with ruptured aneurysm or arteriovenous malformation
  - Consider benign perimesencephalic hemorrhage (depending on pattern and symptoms)
  - May warrant further diagnostic testing
    - CT-angiography
    - MRA-angiography
    - 4-vessel cerebral angiogram

<table>
<thead>
<tr>
<th>Grade</th>
<th>Clinical condition</th>
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<tbody>
<tr>
<td>0</td>
<td>Unruptured</td>
</tr>
<tr>
<td>I</td>
<td>Asymptomatic or minimal headache, nuchal rigidity</td>
</tr>
<tr>
<td>II</td>
<td>Moderate to severe headache, nuchal rigidity, no neurological deficit other than cranial nerve palsy</td>
</tr>
<tr>
<td>III</td>
<td>Drowsiness, confusion, mild focal deficit</td>
</tr>
<tr>
<td>IV</td>
<td>Stupor, moderate to severe hemiparesis, possible early decerebrate rigidity and vegetative disturbances</td>
</tr>
<tr>
<td>V</td>
<td>Deep coma, decerebrate rigidity, moribund appearance</td>
</tr>
</tbody>
</table>
### Case 3

- **Diagnosis:** Aneurysmal Subarachnoid Hemorrhage

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Radiographic Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACoA Aneurysm</td>
<td>Diffuse SAH</td>
</tr>
<tr>
<td>Perimesenchephalic</td>
<td>Diffuse SAH</td>
</tr>
</tbody>
</table>

*Modified from Chiras, et al.*

### Case 4

- **CC:** Severe headache
- **HPI:** 70 y/o female with acute onset of acute headache associated with facial droop and weakness of the left upper extremity. This progressed to hemiplegia and eventual loss of consciousness.
- **PMHx:** Htn, Obesity
- **Meds:** Pradaxa
- **Exam:** Intubated and sedated, right pupil 4mm and non-reactive, left pupil 2mm and non-reactive, positive corneal and gag, withdrawal to pain on the right, left hemiplegia
Case 4
• Diagnosis: Intracerebral Hemorrhage
• Discussion:
  • Causes
    • Uncontrolled hypertension
    • Coagulopathy --vs-- Anticoagulation
  • 50% Basal Ganglia
  • 15% Thalamus
  • 10-15% Pons

Case 4
• Diagnosis: Intracerebral Hemorrhage
• Discussion:
  • Causes
    • Amyloid angiopathy
      • Unknown cause, may be familial, amyloid deposit weakens vessel walls
    • Cavernous Angioma
    • Arteriovenous malformation/angioma
    • Aneurysmal
    • Hemorrhagic tumor (i.e. metastasis/GBM)

Case 5
• CC: headache
• HPI: 72 y/o active male with progressive headache and balance difficulty; progressing over the last several weeks after a slip and fall on ice without LOC, on Pradaxa for A. Fib; no nausea, vomiting, diarrhea, trauma, fevers chills, numbness, visual changes, confusion, speech problems
• Physical Exam: A&Ox3, FCx4 symmetrically, EOMI, PERRLA, +pronator drift left, left upper extremity 4/5
Case 5

- Diagnosis: Subacute Subdural Hematoma
- Discussion:
  - Consistency determines treatment
  - High recurrence rate for chronic component
  - Crescent shaped
  - Holohemispheric (i.e. crosses suture lines)
  - Consider risk of anticoagulation in future and fall risk
  - Long term follow-up indicated and monitoring of symptoms
  - Higher morbidity and mortality than EDH

Case 5

- Diagnosis: Acute Subdural Hematoma
Case 6

- **CC**: comatose
- **HPI**: 52 y/o s/p high speed MVA, unconscious at the scene, intubated, no sedation
- **Exam**: PERRLA, positive corneal and gag response, decorticate posturing
- **Treatment**: ICP monitor placed with initial reading 17mmHg

**Case 6**

- **Diagnosis**: Diffuse Axonal Injury
- **Discussion**:
  - High index of suspicion in patients with neurologic deficit out of proportion to CT images
  - MRI test of choice for identification

<table>
<thead>
<tr>
<th>Grade</th>
<th>Pathology</th>
<th>Duration of Coma</th>
<th>Causes of Death/Prognosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Sheared or torn axons</td>
<td>None</td>
<td>Prolonged Coma</td>
</tr>
<tr>
<td>II</td>
<td>Sheared or torn axons</td>
<td>None</td>
<td>Prolonged Coma</td>
</tr>
<tr>
<td>III</td>
<td>Sheared or torn axons</td>
<td>Prolonged Coma</td>
<td>Prolonged Coma</td>
</tr>
</tbody>
</table>

**QUESTIONS!**

Joshua Krass D.O., FACOS
Cell: (406)890-8752
E-Mail: jkrass@kmc.org
Neuroscience and Spine Institute
Kalispell Regional Healthcare
Complications of Spine Surgery
Ned Wilson M.D.

Anything Under the Sun
- In the course of human medicine, anything can and occasionally does happen
- We take enormous precautions, but complications still happen
- We can’t promise the outcome, but we can promise to do our best and be honest with our patients

Anything…
- Wrong operation
- Hemorrhage
- Infection
- Hematoma
- Injury to structures
- Fixation malposition or failure
- Positioning complications
- Medical problems
- Narcotic issues
When things go wrong
- The "ostrich reaction": find a hole to place your head
- Pain out of proportion is common first indication of a problem
- May be especially difficult to interpret in the chronic pain patient
- Don’t wait, investigate
- Discounting the patient’s complaint is the fastest way to make a bad situation worse
- Low threshold to image (x-ray, CT, MR), labs (CBC, ESR, CRP)
- Consultation, get an unbiased perspective.

Wrong site surgery
- Does the radiology report agree with the side and level
- Is there transition anatomy that confuses the level
- Should resolve and document any discrepancy during pre-op visit
- Write procedure, level, side, and initial
- Time out prior to incision
- X-ray confirmation
- Surprisingly easy to end up at the wrong level!

Hemorrhage
- Vessel laceration
  - Vertebral artery, cervical
  - Great vessels, and segmental artery, lumbar
- Coagulopathy
  - Stop anticoagulants (including aspirin, nsaids, herbals) well in advance of surgery
  - In complex patients, consult with internists
  - Draw coag labs in compromised patients
- Clotting adjuvants
  - Thrombin soaked gelfoam
  - Tranexamic acid (antifibrinolytic)
- Reduce intra-abdominal pressure
Hematoma

- Cervical prevertebral, airway compression
  - Rare, usually with long anterior exposure
  - Place drain in prevertebral space, and suture in place
  - If airway becomes compromised, open incision emergently
- Epidural hematoma, decompressive lami
  - Compresses neural element
  - Extremely painful*, may be axial pain only
  - May or may not have neuro deficit
  - More common in heavy, and heavily muscular pts
  - More common in medically compromised, coagulopathy

Hematoma, cont

- Epidural hematoma
  - MRI highly sensitive, maybe too sensitive?
  - Probably all lami pts have some degree of hematoma
  - Urgent evacuation
  - Sub-facial drain
  - Tranexamic acid
  - How much gelfoam to leave?

Infection

- Prevention
  - Prophylactic abx prior to incision (how long after?)
  - Irrigation *** (jet lavage in big cases)
  - Debride devitalized tissue
  - Drain
  - Vancomycin powder ?
  - Monofilament sub-q for discectomy
Infection cont.

- Presentation
  - 7-14 days post-op
  - +/− fever
  - Wound drainage*
    - Often serous, copious
    - May have little erythema
  - Discitis may have no wound abnormality
  - MR with gad
  - CBC, ESR, CRP
  - May need aspiration if discitis suspected

Infection cont.

- Treatment
  - Usually I&D, frequently multiple
  - Pack wd open v.s close over drains
  - Usually don’t remove hardware
  - Serial dressing changes until bed of granulation tissue forms (wound vac may be helpful)
  - Secondary closure 2-3 wks
  - Discitis can sometimes be treated with abx alone

Injury to adjacent structures

- Neural
  - Laceration (uncommon, irreversible)
  - Malpositioned hardware
  - Traction
    - Highly variable tolerance
    - Often transient
  - Evaluate with imaging, electrodiagnostic
Injury cont.
- Dural tear
  - Not uncommon, usually no permanent sequelae
  - Usually immediately apparent
  - Sometimes presents late (2-10 days) related to partial thickness tear at surgery
- Large subcutaneous fluid collection, or clear fluid leaking from wound
- Postural headache
- Primary closure, patching (duragen, surgicell), sealant (fibrin glue, duraseal polymer), keep flat 1-3 days,
- Dural drain at remote site for complicated cases

Injury cont.
- Visceral
  - Vascular
    - Great vessel, vertebral artery, segmental artery
    - Ureter
      - Abdominal and retroperitoneal approach
      - Sympathetic plexus (results in retrograde ejaculation)
  - Anterior L5-S1 approach

Fixation
- Malposition
  - Hardware placement technically demanding
  - Adjacent neural structures unforgiving
  - Experience, imaging, navigation
    - Helpful, not perfect
  - Final x-ray prior to closure
  - CT post-op if concerned
Fixation cont.
- Failure
  - All hardware will loosen or fatigue and break eventually
  - Race between fusion and failure
  - Bone failure
    - Loosening, halo or windshield wiper effect around screw
    - Fracture usually by cantilever, rarely by pull-out
    - Vertebral body failure, subsidence
  - Follow with x-ray, CT

Positioning
- Prone and lateral decubitus mostly pressure related
  - Peripheral nerve (median and ulnar n.)
  - Related to inadequate padding, direct pressure
  - Not uncommon
  - Usually transient
  - Worse in already compromised nerve
- Brachial plexopathy
  - Mostly in obese pts
  - Pressure on shoulder, axilla
  - Lateral decubitus requires axillary roll
  - Usually transient

Positioning cont.
- Facial skin necrosis
  - Large, big head
  - Good padding, close attention by anesthesiologist
  - Shift weight away from head, reverse trendelenburg
- Ischemic optic neuropathy
  - Inadequate perfusion of retina
  - Results in partial or total blindness
  - Direct pressure on globe
  - Venous outflow obstruction secondary to facial pressure
Positioning cont.
- Compartment syndrome
  - Anterior tibial compartment
  - Direct pressure in kneeling (Andrew’s frame) position
  - Severe pain in compartment
  - Painful passive motion of involve muscles
  - Test compartment pressure

Medical
- Cardiac
  - Perioperative MI
  - Occult coronary disease
  - Sedentary pt secondary to spine disease (spinal stenosis)
  - Pre-op stress test

Medical cont.
- DVT/PE
  - Low incidence in spine surgery
  - Pneumatic stockings
  - Limited ability to anticoagulate secondary to risk of epidural hematoma
  - High risk pts may need pre-op vena cava filter
Pain management

- Chronic narcotic use
  - Tolerance requires high dose post-op narcotic
  - Very difficult to evaluate
  - Often little margin between adequate pain relief and apnea
  - Better if narcotics can be reduced as much as possible for several weeks before surgery

Thank you
Management of Granulomas

Replace Medications with Preservative Free Normal Saline
Withdraw Catheter
Surgical Excision if Progressive Symptoms Exist

Implantable Pain Management Devices

Pearls

Questions

Spinal Cord Stimulation

Basics

Trials

Complications and adverse effects
Intrathecal Medication Withdrawal

- Quidos: Diagnosis and Treatment
- Same as IV or Oral
- Not Life Threatening

- NB: Life Threatening
- Immediate Admission
- IV Bolus
- Oral Bolus
- Emergency Supply

---

SCS Problems

- Problems include...
- Pain at site and/or another site

---

MRI Consideration

- Most Spinal Cord Stimulator Systems are NOT MRI Compatible
- Newer models since 2015 are usually MRI Compatible if leads are below the neck
- 1.5 Tesla Only
SPINAL EMERGENCIES
NEUROSURGICAL BOOTCAMP FOR THE MIDLEVEL PRACTITIONER
KALISPELL, MT
2017
JOSHD BURG, MD

SPINAL CORD INJURY STATISTICS
(NATIONAL SPINAL CORD INJURY DATABASE)

- Approximately 250,000 Americans have a spinal cord injury
- Approximately 11,000 new injuries occur annually.
- 82% are male
- 56% of injuries occurred to people under the ages of 16 and 32
- The average age of a spinal cord injured person is 31

SPINAL CORD INJURY: CAUSES

...
SPINAL CORD INJURIES: STATISTICS (2010-2013)

- Vehicular Accidents: 37%
- Violence: 14%
- Falls: 28%
- Sports Injuries: 9%
- Other: 11%

SPINAL EMERGENCIES - CASE #1

26 year old male presents to the ER dept after attempting to jump onto the sidewalk with his bike and taking a header.

Exam: NAD, LOC A & O 3
- Speech: Fluent and appropriate
- Motor: 3/5 Deltoids & Elbow/Wrist Flex/Ext, 4/5 throughout LE
- Sensory: Preservation of light touch
- Rectal tone and cremasteric: Intact
- No neck pain or discomfort, NAD

• INITIAL MANAGEMENT?
• WHEN TO IMAGE?
• WHAT IMAGING MODALITY?
SPINAL EMERGENCIES - WORK UP
PLAIN FILMS:
CAVEATS:
FLEXION/EXTENSION

READING LATERAL SPINE FILMS
• AIRSPACE
• MIST VISIBLE TO UPERM VERTEBRE OF T1
• ALIGNMENT
• TRANSLOCATION OF 2.5 MM IS SIGNIFICANT
• VERTERAL BODIES & FORAMEN
• PERIPHERAL VERTERAE
• UPPER CERVICAL SPINE
• ATLAS/VERTERAL INTERVAL (AX)
• SLOPE OF A SLOWLY INFERIOR

COMPUTERIZED TOMOGRAPHY (CT SCAN)
SPINAL EMERGENCIES: CASE #1

CENTRAL CORD SYNDROME

SPINAL EMERGENCIES: CASE #1 - TREATMENT

Steroid Protocol
- CONTRAINdicated
- Methylprednisolone
  - Loading 30mg/kg, wait 45 minutes
  - then 5.4mg/kg x 23 hours

Surgical Options
- ACDF
- CORPECTOMY
- LAMINOPLASTY
- POSTERIOR DECOMPRESSION WITH OR WITHOUT FUSION

SPINAL EMERGENCIES: CASE #1 - SURGICAL RESULT AND OUTCOME FOR CASE #1

ALMOST COMPLETE RECOVERY WITHIN 12 WEEKS POST-OP
SPINAL EMERGENCIES: CASE #1

QUESTIONS AND DISCUSSION

SPINAL EMERGENCIES: CASE #2

• 34 YO MALE PRESENTS TO THE ER WITH THE ONSET OF BACK PAIN AFTER LIFTING A 40 POUND BOX YESTERDAY. THIS MORNING HE NOTED PENILE AND SCROTAL NUMBNESS AS WELL AS URINARY RETENTION.

• EXAM - MOTOR: 5/5 THROUGHOUT EXCEPT LEFT DORSIFLEXION AND EHL WHICH ARE 4/5.

• SENSORY: DECREASED PINPRICK SENSATION IN L4, L5, S1 DERMATOMES ON THE LEFT. DECREASED SCROTAL AND PERIANAL PINPRICK SENSATION.

DECREASED RECTAL TONE AND POST VOID RESIDUAL OF 800MLS.

SPINAL EMERGENCIES: CASE #2

SAGITTAL T2

AXIAL T2
SPINAL EMERGENCIES: CASE #2
OUTCOME
• Full recovery at 18 months
• Questions??????????

SPINAL EMERGENCIES: CASE #3
• 16 year old female patient presents to the ER after rolling an ATV at 25MPH.
• No LOC
• C/O back pain
• Motor 5/5 in UE, 5/5 in both LPSOAS, 4/5 in both QS, no movement in ANTs, GASTROS bilaterally.
• Flicker of TOE movement in LF.
CASE 8 - A 717 YEAR OLD FEMALE WITH AN ACUTE SPINAL CORD INJURY

- Initial MRA, arterial imaging
- Initial MRA, venous imaging
- Initial MRA, sagittal view
- Initial MRA, coronal view
- CT head, axial, coronal, sagittal
- MRI head, axial, coronal, sagittal
- FEV 1, FVC, DLCO, 6MWT
- Serum inflammatory markers
- CT scan of chest, abdomen, pelvis
- Lumbar puncture
- CECT lumbar

TREATMENT PLAN

- Stabilized on high dose steroid protocol
- Taken emergently from ED to OR for surgical stabilization
  - Open fracture reduction C6-7
  - Anterior stabilization C6-7
  - Posterior stabilization C5-11

- Discharged to PT/OT
- Immobilized in bed
- Continued steroid protocol
- Pain management
- Pulmonary physical therapy
- Occupations therapy
- Physical therapy
- Discharged to long-term care
Cranial Imaging and Neoplasms

2017

Stephen S. Campbell, MD
Neuroscience and Spine Institute
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Overview

Imaging Modalities
Terminology
Important Findings
Common Diagnoses
Case Studies

X-ray

Electromagnetic radiation from source to detector
Dense materials absorb the radiation and cast a shadow
Shadows are bright

Skull X-rays
Shunt Series
Fluoroscopy
Real-time X-rays acquired digitally
Allows image-guided placement of needles, screws, etc.

CT scan
Computed Tomography
X-rays from a multitude of angles processed by computer into slices
Bones - white
Blood - white
Brain - gray
Soft tissue - gray
Air - black
CSF - black
Can be done with, or without, contrast

MRI
Hydrogen atoms release radio frequency energy when subjected to an external magnetic field
Sensors detect this energy
Different tissues have specific amount and distribution of H atoms
Computers process this data into slices
Can be done with, or without, contrast
T1 sequences show CSF as dark
T2 sequences show CSF as bright
Angiogram
Catheter placed in large artery and dye injected
Real-time X-rays shows flow of dye in vessels
Dye dissipates quickly and can show venous phase

Nuclear Scan
Safe radioactive tracer injected into vessel
Tracer is then circulated through bloodstream
Sensors detect radioactive decay

Terminology
Describing images to your attending
Location
  by lobe
  by structure

#Lesions
  solitary
  multiple
  too numerous to count

Enhancement
  Contrast extravasates from the blood vessels when the blood-brain-barrier is disrupted.
  Certain lesions enhance, while others do not.
Important findings

- midline shift
- edema
- mass effect
- atrophy
- herniation
- hydrocephalus

Midline Shift
Increased pressure on one side of the brain shifts the structures towards the opposite side. Measured from the line connecting the attachments of the anterior and posterior falx to the septum pellucide.
**Edema**

Cytotoxic edema is increased interstitial water due to CELL DEATH - increased osmotic pressure from cell lysis draws water into the area.

Vasogenic edema is increased interstitial water due to DYSFUNCTIONAL ENDOTHELIAL CELLS - water leaks from the vessels.

- Hypodensitvity on CT
- Hyperintense on MRI T2

**Mass Effect**

Tumors, hematomas, etc take up space.

The cranial vault is a finite space with a fixed volume.

Normal structures are compressed when a lesion occupies volume within the cranial vault.

**Atrophy**

Diffuse volume loss usually due to age, vasculopathy, or alcoholism.

Can show enlarged ventricles called hydrocephalus ex vacuo.
Herniation
brain shifts across a barrier
subfalcine
uncal
transtentorial
cerebellar

Hydrocephalus
communicating vs obstructive
enlarged ventricles
transependymal edema
dilation of temporal horns
rounded 3rd ventricle

Suggestions for presenting imaging to your attending

1) determine whether findings require immediate OR
   examples: EDH with pending herniation or SDH with midline shift and trapped ventricle
2) always examine patient
3) present imaging with standard terminology
   example: axial T1 MRI with contrast shows a 2cm right frontal ring enhancing lesion with local mass effect, mild edema, and no midline shift
4) know differential diagnosis; above example would be metastatic tumor, glioblastoma, cerebral abscess
5) know answers to follow-up questions. Is there a cancer history? Is there a source of infection?
6) end with "My plan is..."
Neoplasms

glioblastoma
anaplastic astrocytoma
pilocytic astrocytoma
pontine glioma
metastases
meningioma
lymphoma
oligodendroglioma
medulloblastoma
pituitary macroadenoma
acoustic neuroma
colloid cyst
epidermoid

Glioblastoma

most common primary brain tumor
common term for Astrocytoma, grade IV
usually enhances with contrast on MRI T1+C
can be multifocal, spread across corpus callosum, or spread via ependyma in ventricles
Anaplastic Astrocytoma

generally do not enhance
25% of all glial tumors
often transforms to GBM
roughly 2-3 year survival, but many long-term survivors

Pilocytic Astrocytoma

most common brain tumor in children
cystic lesion with enhancing mural nodule
well circumscribed, slow growing
20 year survival is 70%

Diffuse Intrinsic Pontine Glioma

diffusely infiltrating
pons, medulla, midbrain, cerebellum
difficult to biopsy
1, 2, 5 year survival 30%, 10%, 1%
Oligodendroglioma
- from oligodendrocytes which are support cells
- often cause seizures
- can show calcification on CT
- does not enhance on MRI T1+C

Metastatic Tumor
- neoplasm which spread from another site in the body
- lung, breast, melanoma are most common
- classically, ring enhancing on MRI T1+C at gray-white junction

Meningioma
- most common benign brain tumor
- arises from arachnoid cap cells along dura
- extra-axial in location
- enhancement on MRI T1+C
- dural tail and CSF cleft often present
CNS Lymphoma

- Heterogeneously enhances on MRI T1+C
- Difficult to differentiate from GBM
- Often periventricular
- 90% supratentorial
- 98% are B Cell lymphomas; T Cell rare

Medulloblastoma

- Tumor of immature cells
- Hyper dense on CT
- "Softball" in posterior fossa
- 2/3 found in age <20
- 1/3 found age 21-44

Pituitary Macroadenoma

- Arise from glandular tissue of pituitary gland in sella
- Can secrete hormones or can be a "non-secretor"
- Note location between carotid arteries and below optic chiasm
Acoustic Neuroma
also known as vestibular schwannoma
everting tumor extending into IAC
arises from the schwann cells of the vestibular division of the vestibulocochlear nerve CN VIII
unilateral hearing loss, tinnitus, and vertigo
facial palsy is late finding

Colloid Cyst
forms at the roof of the third ventricle
can block foramen of monro causing hydrocephalus
best seen on CT as hyperdense mass

Epidermoid Cyst
arise from skin cells trapped in neural tube prior to closure
danduff ball
bright on MRI DWI
Case 1

72 year old female presents to the ER with focal motor seizures in her left arm.

PMH:
PEs, currently on Coumadin

Exam:
awake and alert;
speech fluent
4/5 strength in proximal left UE

Does this require urgent surgery?
Case 1

Decadron 10mg x 1, then 4mg q6hrs
Keppra 500mg bid

24hrs
No seizures, strength improved

48hrs
No seizures, strength nearly normal

Case 1

Office visit
no seizures, full strength, feels well
son brings MRI from 7 years prior

What are the benefits of surgery?
What are the risks?

Case 1

OR for right craniotomy for tumor resection
Image guidance to center incision over tumor and minimize tissue disruption
Case 2

54 year old male presents to the ER with word find difficulty and mild right arm weakness x 3 days

PMH:
none

Exam:
awake and alert, but flat affect;
speech fluent, but several errant words;
frustrated that he cannot name certain objects;
4/5 strength in right UE;
Case 2

Differential Diagnosis?

Case 2

Abscess on DWI
GBM on DWI

Case 2

GBM on T1+C
Lymphoma on T1+C
**Case 2**

Decadron 10mg x 1, then 4mg q6hrs  
Keppra 500mg bid

**Goals of surgery:**

1) the most complete resection as safely possible  
2) obtain tissue for diagnosis

Functional MRI highly useful  
Image guided MRI for navigation

---

**Case 3**

48 year old male presents to his PCP with tinnitus in his right ear for 3 weeks. He has started using his left ear when using the phone.

**PMH:** none

**Exam:**  
awake and alert;  
speech fluent;  
decreased hearing in right ear to finger rub;  
5/5 strength in BUE+BLE;  
reflexes 2+ throughout;  
gait normal;
Case 3

Audiogram needed to quantify hearing loss and to help determine approach to tumor

Important to determine whether patient has brainstem signs:
- abnormal corneal reflex
- nystagmus
- facial hypesthesia
- facial weakness
- abnormal eye movements
- upper motor neuron signs
Managing the Pediatric Neurosurgery Trauma Patient from ER to ICU: Not Just Little Adults

MID-LEVEL NEUROSURGERY BOOTCAMP
SEPTEMBER 19, 2017
KELLY SCHMIDT, MD

KALISPELL REGIONAL HEALTHCARE

Neuroscience & Spine Institute
A DEPARTMENT OF KALISPELL REGIONAL MEDICAL CENTER
KALISPELL REGIONAL HEALTHCARE
Objectives

- Why is the developing brain different?
- Pediatric traumatic brain injury (TBI)
  - Epidemiology and Physiology
  - Primary and Secondary injury
- ER evaluation of pediatric TBI
  - ABCs
  - Neurologic evaluation and Pediatric GCS
- CT scans in children
- ICU management of pediatric TBI
- Case Presentations
Stages of Neuronal Development

- **Cell birth, Cell migration, Cell differentiation** occur in the embryonic period
- **Cell maturation** (dendrite and axon growth) begins prenatally, but continues well after birth
- **Synaptogenesis** – formation of 100,000 trillion synapses peaks by age 2, but continues through life
- **Cell death and synaptic pruning** occur through life as well
- **Myelination** of neurons is the final stage of development – concludes in mid-20s
Plasticity and the Developing Brain

- **Plasticity**: The quality of being easily shaped/molded
- Neuronal plasticity in childhood allows for learning
  - Motor skills - playing a musical instrument
  - Verbal skills - second language
- After brain injury, plasticity allows children to recover better than an adult with a similar injury
- However, less developed neurons are also more sensitive to brain injury - particularly hypoxic injury
Pediatric Traumatic Brain Injury

- Leading cause of death and disability in children over 1 year of age
- Most common causes vary by age:
  - Abuse, Falls – younger children
  - Bicycle accidents, MVC – older children
- Primary Injury
  - Results from the trauma itself
- Secondary Injury
  - Results from metabolic factors after the trauma
  - Critical care treatment in ER and ICU is geared towards preventing secondary brain injury
Physiology of Primary Brain Injury
• **Linear forces** due to back and forth or side to side movement of the brain within the skull

• **Rotational forces** centered in the thalamus, basal ganglia, and midbrain

• **Angular deceleration**: collision of the head with a stationary object
  - Up to 15 mph deceleration
Predictors of Poor Outcome in Pediatric TBI

- Age <4 years
- CPR
- Multisystem trauma
- Hypoxia (PaO2 < 60 mmHg)
- Hyperventilation (PCO2 < 35 mmHg)
- Hypotension (SBP < 5\textsuperscript{th} percentile for age)
- Hyperglycemia (glucose > 250 mg/dL)
- Hyperthermia (temperature > 38°C)
- Increased intracranial pressure (ICP > 20 mmHg)
- Inadequate rehabilitation

Secondary Brain Injury
Evaluation of a head-injured child

- **Pre-hospital Care** – EMTs/Paramedics
  - ACS recommends minimizing on scene time

- **Team Approach in ER**
  - ER physician, Trauma/General surgery, Neurosurgery, Anesthesiology, PICU, Nursing

- **Primary Survey**
  - Airway and Cervical spine protection
  - Breathing and Ventilation
  - Circulation
  - Disability / Neurologic Exam and GCS
  - Exposure

- **Secondary Survey and Imaging**
Cervical Spine Stabilization

- Pediatric spine injuries are rare
  - Most injuries are ligamentous and not bone/fracture related
- Most common injuries are cervical
  - Large head
  - Weak neck muscles
- Immobilization of cervical spine before management of ABCs is important
  - Should be done by EMS, but make sure collar fits appropriately

Aspen Cervical Collars provide best sizing options for pediatric patients
Airway Management

- 90% of pediatric patients can be adequately ventilated with Bag-Valve-Mask airway

- Proper endotracheal tube size:
  - Estimate by child’s 5th digit
  - Use uncuffed tube in kids < 8 years
  - Depth = 3 times the size of the tube
    - Example: Size 4 ETT - placed 12 cm at the lip

- Intubation often requires ER, Anesthesia, or PICU physician
Airway Management: Endotracheal Intubation

- Maintain in-line cervical stabilization with C collar in place
- Position with small roll under shoulders
- Rapid Sequence Intubation
  - Drugs: Etomidate as sedation, Succinylcholine as paralytic
  - Avoid ketamine – increases ICP
  - Premedication with lidocaine not recommended
- Avoid securing ETT around neck
Breathing: Oxygenation
Getting oxygen to the tissues

Avoid hypoxia!
- SpO₂ < 90%
- More strongly associated with poor outcome than actual mechanism of injury
- Occurs more rapidly in pediatric population
- A single documented episode of hypoxia results in a 2-4 fold increase in the probability of a poor outcome
- Goal SpO₂ > 95% with 100% oxygen via NRB, BVM, or ETT.

<table>
<thead>
<tr>
<th>SpO₂ (%)</th>
<th>PaO₂ (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>97</td>
<td>90</td>
</tr>
<tr>
<td>95</td>
<td>80</td>
</tr>
<tr>
<td>90</td>
<td>60</td>
</tr>
</tbody>
</table>

Pulse ox reading lags behind the true blood-oxygen saturation by approximately one minute.
Breathing: Ventilation
Movement of air to expel carbon dioxide

- **Hypoventilation** > 40 mmHg
  - Shallow, slow, or irregular breathing or Apnea
  - Correct this! Establish airway and increase RR

- **Hyperventilation** < 35 mmHg
  - **Transient** hyperventilation: \(\text{EtCO}_2 = 30-35\) mmHg
  - Only for signs of imminent brain herniation
    - Cushing response: Hypertension & Bradycardia
    - Asymmetric pupillary dilation
    - Rapid change in mental status or decline in GCS with extensor posturing

**End Tidal CO\(_2\) - Goal = 35-40 mmHg (Normocapnia)**
Circulation: Blood Pressure

- IV Access – can be very difficult in pediatric patients
- Avoid hypotension! Start fluid resuscitation EARLY!
  - 20 cc/kg bolus of isotonic IVF (NS or LR). Give 3 times, then move to blood
Clinical indicators of Shock in the Pediatric Trauma patient:

- Active bleeding / clinical signs of volume loss
- Tachycardia
- Hypotension / loss of central pulses (late sign)
- Capillary refill > 3 seconds

<table>
<thead>
<tr>
<th>Age</th>
<th>Awake Rate (rate/min)</th>
<th>Sleeping Rate (rate/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn to 3 months</td>
<td>85 to 205</td>
<td>80 to 160</td>
</tr>
<tr>
<td>3 months to 2 years</td>
<td>100 to 190</td>
<td>75 to 160</td>
</tr>
<tr>
<td>2 to 10 years</td>
<td>60 to 140</td>
<td>60 to 90</td>
</tr>
<tr>
<td>&gt;10 years</td>
<td>60 to 100</td>
<td>50 to 90</td>
</tr>
</tbody>
</table>
Disability: Neurologic exam & GCS

- **Eye** – no change

- **Motor** – “normal movements” instead of “follows commands”
  - <9 months – can’t localize pain reliably – can use withdrawal from touch

- **Verbal** – changed based on verbal ability of the child
CT Scans in Children: What are the risks?

- Children are more sensitive to radiation
  - Active growth and rapidly dividing cells
- Longer life expectancy = longer window of opportunity for radiation damage
- Require adjusted settings to lower the dose of radiation received
  - CT reports should document that adjusted radiation settings were utilized
  - Virtually standard now for pediatric patients
Cumulative radiation dose in childhood of 50-60 mGy to the head or bone marrow = threefold increase in the risk of brain tumors and leukemia in the future.

How many CT scans does this take?
- Depends on type of CT, age of patient, and scanner settings.
- Brain exposure = 2-3 head CTs at standard settings in children under 15 years of age
- Bone Marrow exposure = 5-10 head CTs at standard settings
CT Scans - How to minimize the risk?

- Scan appropriately!
- Will a repeat scan change the management?
- Consider Rapid MRI for follow up studies, if available.
- Be able to educate parents on the risk

Make sure the potential long term risk of the CT is outweighed by the benefit of the information it will provide
Indications for CT in the pediatric patient

1. Acute ER Presentation
   - TBI, Shunt malfunction, Vascular lesion, etc.
2. Post-operative evaluation
3. Acute neurologic change while in ICU
   - Marked increase in ICP, Seizure, Decline in neurologic exam, Pupil change, etc.
4. Outpatient evaluations
   - Skull-related pathology
Predictors of Poor Outcome in Pediatric TBI

- Age < 4 years
- CPR
- Multisystem trauma
- Hypoxia (PaO₂ < 60 mmHg)
- Hyperventilation (PCO₂ < 35 mmHg)
- Hypotension (SBP < 5th percentile for age)
- Hyperglycemia (glucose > 250 mg/dL)
- Hyperthermia (temperature > 38°C)
- Increased intracranial pressure (ICP > 20 mmHg)
- Inadequate rehabilitation

Secondary Brain Injury
ICU Management of the head-injured child

- **Goal of critical care management in the PICU is to prevent further secondary brain injury**
- **Maintain ABCs**
- **Hyperglycemia (glucose > 250 mg/dL)**
  - Stress hyperglycemia is very common in trauma patients
  - Aggressive insulin therapy may be necessary
- **Hyperthermia (T > 38°C)**
  - Fever is extremely common in the ICU and in TBI patients
  - Can be Central or Infectious – very difficult to prevent, but should be treated aggressively when it occurs
Intracranial Pressure

- Mortality in pediatric TBI is most often related to a refractory rise in ICP
- Elevated ICP in TBI is multifactorial
  - Traumatic mass lesion (hematoma)
  - Hyperemia/Vasodilation
  - Cerebral Edema
- Cerebral Perfusion Pressure (CPP)
  - Pressure gradient across the brain (MAP-ICP)
  - No magic number in pediatric patients
    - Goal is around 50 mmHg (<40 mmHg is associated with worse outcome)
Intracranial Pressure Monitoring

- No level 1 evidence to support guidelines
- Recommendation: Consider ICP Monitoring in infants/children with severe TBI: GCS 3-8
- No pediatric literature that describes at what ICP to treat
  
  ICP > 20 mmHg
Intraparenchymal ICP Monitor

External Ventricular Drain
ICP Management: First Tier Therapy

- **Continued Management of ABCs**
  - Avoid hypoxia, Maintain Normocapnia, Maintain normal BP for CPP

- **Head Elevation and Position**
  - Elevate HOB 30 degrees, maintain midline head position

- **Sedation and Analgesia**
  - Propofol preferred, Versed for longer time frame sedation
    - Precedex – Excellent for pediatric sedation, but limited data on TBI
  - Fentanyl preferred, Morphine second choice for analgesia

- **CSF drainage**
  - If possible. Provides immediate, but transient decrease in ICP
ICP Management: First Tier Therapy

- **Hyperosmolar Therapy** - Reduce cerebral edema
- **Hypertonic Saline (3%)** - 2-10 cc/kg IV bolus
  - Stronger Level II evidence that outcomes are improved with hypertonic saline in pediatric TBI compared to Mannitol
  - Maintains intravascular volume. Useful in hemodynamic instability
  - Can be administered continuously: 0.1-1 cc/kg/hr
- **Mannitol** - 0.25-1 cc/kg IV bolus
  - Excellent for a rapid effect that can last for up to 75 minutes
  - Depletes intravascular volume (increased UOP) → Hypotension
- **Upper limits of Na and Serum Osmolarity:**
  - Na = 160-165, Osmolarity = 360
ICP Management: Second Tier Therapy

- **Neuromuscular blockade / Paralytics**
  - Short acting bolus is best (ex. Vecuronium)

- **Hypothermia**
  - Data is not great. Modest hypothermia (32-33°C) beginning within 8 hours of injury for maximum of 48 hours for refractory ICP. Rewarm slowly!

- **Pentobarbital Coma**
  - Decreases cerebral metabolic rate with goal of burst suppression on EEG

- **Hyperventilation**
  - EtCO2 or pCO2 30-35 mmHg - for impending herniation only.

- **Surgery**
  - Decompressive craniectomy. Think about this early!
Decompressive Craniectomy

- Unilateral, Bilateral, or Bifrontal
- Indicated for severe, refractory, increased intracranial pressure
  - Also effective for mass lesion (subdural hematoma)
- In children, bone can be stored in subcutaneous tissue of abdomen or in a bone freezer.
Bone flap can be replaced when swelling resolves and patient has neurologically improved.

Generally between 1 and 6 months post-injury.

In contaminated wounds, custom implants are made.
Case #1

- 2 ½ year old male s/p unwitnessed fall off a patio deck (approx 8 feet), LOC for a few minutes, possible seizure activity at scene
- Transported by EMS, has size 3 Aspen cervical collar in place, 22 G peripheral IV in place
- Arrival VS: T37.5, HR 175 (mildly tachycardic), SBP 90 (low normal), RR 15 (low) with occasional apneas, 95% O2 sat on 100% FM
- What’s the first step?
Case #2

- 16 month male brought to ER by EMS after witnessed seizure activity. “Fell in the shower” three days before presentation.
- Has size 3 Aspen cervical collar in place, no IV access, ETT in place, extensive facial bruising
- Arrival VS: T 34°C, HR 170 (normal), SBP 100 (normal), SpO2 100%, EtCO2 28
- What’s the first step?
Case #3

- 16 year old male s/p fall out of the back of a truck at 40 mph
- Taken initially to outside hospital where he was stabilized. Head CT was done – no other imaging.
- Arrives at your ER: Intubated, C collar in place, 2 18 G IVs
- Arrival VS: T 38°C, HR 110, SBP 120 (normal), SpO2 100%, EtCO2 35
- What’s the first step?
Conclusion

- Pediatric TBI patients are not little adults. Their brain is still developing!
  - Management has subtle differences and the outcomes can be much better.
  - Kids deserve the chance to recover!

- ER Primary Survey:
  - Airway
  - Breathing: Oxygenation and Ventilation
  - Circulation: Access and Blood Pressure
  - Disability: Neurologic exam and GCS
  - Exposure/Examination

- Secondary Survey and Imaging
- Emergent surgery?
Conclusion

- If injury is initially not surgical: ER and ICU treatment is focused on preventing secondary brain injury
  - ABCs
  - ICP Monitor vs. EVD placement
  - Aggressive ICP management
    - Head elevation and position, Sedation and Analgesia, Hyperosmolar therapy, CSF drainage
    - Paralytics, Hypothermia, Hyperventilation, Barbituates
  - Always consider early surgery (decompressive craniectomy)
Thank You!

Questions?
Cerebrovascular Disease Review

• Cerebral Aneurysms
  – Procedural Considerations
    • Parent Artery Preservation
    • Principle of Proximal Control
    • Endovascular versus Clip Ligation
    • Stent-assistance not favorable in cases of rupture
  – Grading of SAH
    • Hunt-Hess (optional +1 for comorbidities)
      • 1  Asymptomatic or minimal headache / nuchal rigidity
      • 2  Substantial headache, non-focal except CN palsy
      • 3  Drowsiness, confusion, mild focal deficit
      • 4  Stupor, Hemiparesis, Possible decerebrate rigidity
      • 5  Deep coma, moribund appearance
    • World Federation of Neurosurgery (WFNS)
      • Scale from 1-5 based on GCS or presence / absence of motor deficit
    • Fisher (predictive of vasospasm risk)
      • 1  No SAH present
      • 2  SAH in any cistern < 1 mm thickness
      • 3  SAH in any cistern > 1mm thickness
      • 4  Intraventricular or Intraparenchymal Hemorrhage
  – Complications of SAH
    • Seizures
      • Keppra, Dilantin
    • Hydrocephalus
      • External Ventricular Drain
    • Vasospasm (Post-Bleed Days 3-14)
      • Screening Modalities
        • TCD
- Heralding Hyponatremia
- Serial Neurologic Exam
- Treatment
  - HHH therapy
  - Endovascular verapamil / angioplasty

- Aneurysms Natural History
  - ISUIA I: UNRUPTURED Aneurysms
    - No h/o SAH
      - < 10 mm: <0.05% / year rupture risk
      - >10 mm: 1%
      - >25 mm: 6%
    - Prior SAH, rupture at different site
      - < 10 mm: 0.5% / year rupture
      - >10 mm: 1%

- Aneurysms Natural History Continued
  - ISUIA Follow Up: Lancet 2003 (REFINED DATA)
    - 4060 patients: 1692 did not have aneurismal repair, 1917 had open surgery, and 451 had endovascular procedures. No h/o SAH.
    - 5-year Rupture Risk Internal carotid artery, anterior communicating or anterior cerebral artery, or middle cerebral artery aneurysms by size: 0%, 2.6%, 14.5%, and 40% for aneurysms less than 7 mm, 7–12 mm, 13–24 mm, and 25 mm or greater, respectively
    - 5-year rupture risk for pcomm and posterior circulation aneurysms with same size categories: 2.5%, 14.5%, 18.4%, and 50%, respectively, for the same size categories.
    - Patients' age was a strong predictor of surgical outcome, and the size and location of an aneurysm predict both surgical and endovascular outcomes.
  - The International Subarachnoid Aneurysm Trial (ISAT)
    Molyneux, A et al. Lancet October 2002
• Randomized trial of clipping vs. coiling for ruptured aneurysms, multi-center in Europe and Great Britain

• Eligibility Criteria:
  • SAH proven by CT or LP within 28 days
  • Intracranial aneurysm defined by AG or CTA
  • Clinical state that justified treatment
  • Aneurysm judged to be suitable for either technique

• Enrollment
  • 1070 to surgery; 1073 to coiling; well matched groups
  • 9559 patients treated during the trial
  • Majority of patients treated outside the trial
  • Almost all aneurysms in the anterior circulation (97.3%)
  • MCA aneurysms under-represented

• Results
  • Primary end-point: poor outcome as defined by Rankin Score of 3-6 at 1 year (dead or disabled)
  • Coiling group: 23.7%
  • Clipping group: 30.6%

  • Higher re-bleed rates associated with coiling impacts outcomes
  • Procedural advantage for coiling is age-dependent:
    • Age <50 yrs, differences in 1 yr poor outcome 3.3%
    • Age >50 yrs, differences in 1 yr poor outcome 10.1%
  • Re-bleeding after repair 1st year:
    • Endovascular group: 2 per 1276 patient-years
    • Surgical group: 0 per 1081 patient-years

• Carotid Stenosis
  – Symptomatic Carotid Disease: Best Med Tx versus CEA
• NASCET: 2,885 pts w/ TIA or minor stroke within 120 days
  • 70-99% stenosis: 17% (26 to 9%) ARR (65% RRR) / 2 yrs
  • 50-69% stenosis: 6.5% ARR (29% RRR) / 5 yrs
  • ≤50% stenosis: no benefit
  • Therefore favor CEA for 50-99% symptomatic stenosis
  • 13.1% vs. 2.5% with CEA for major ipsilateral CVA
• ECST (reanalysis by NASCET criteria, Lancet 2003;34:514)
  • 3,024 pts w/ TIA, retinal infarction, or non-disabling stroke within 6 months
  • 70-99% stenosis: 21.2% ARR / 5 yrs
  • 50-69% stenosis: 5.7% ARR / 5 yrs
  • <50% stenosis: no benefit (harm if <30% stenosis)

– Asymptomatic Carotid Disease: Best Med Tx vs. CEA
  • ACAS (JAMA 1995;273:1421)
    • 1,662 pts w/ angio or validated doppler > 60%
    • Recurrent stroke from 11 to 5%: 5.9% ARR (53% RRR) / 5 yrs for patients with 60 to 99% stenosis
  • Caveats
    • Required low surgical M&M (1.5%)
    • no stat. sig. benefit for women
  • ACST (Lancet 2004;363:1491)
    • 3120 pts w/ doppler > 60% stenosis
    • 5.4% ARR (11.8→6.4% risk) / 5 yrs
    • Results more robust than ACAS
    • Surgical M&M more realistic (3.0%)

– High-Risk features for CEA
  • Anatomical
    • C2 and higher lesion
    • Contralateral carotid occlusion / stenosis (is relative)
    • Severe ulceration
    • Tandem intracranial stenosis
• Functional
  • Age > 80 (some say 75)
  • Active coronary artery disease (before intervention)
  • Recent major stroke in reference vascular territory

• **Arteriovenous Malformations**
  – Spetzler-Martin Grade: size, venous drainage, cortex eloquence
  – High-risk angiographic features
    • Nidal aneurysm
    • Retrograde venous drainage
    • Post-procedural factors.
  – Historical factors that affect rupture risk
    • Previous rupture
    • Seizure disorder (cortical hyperemia)
  – AVM Treatment options
    • Conservative management
    • Primary Surgery
    • Gamma Knife Radiosurgery (3 cm)
    • Endovascular Embolization
      • NBCA
      • Onyx

• **Ischemic Stroke: TPA versus Mechanical Revascularization**
  • Time is brain
    – 0-3/4.5 hour for iv tpa
      • Recent AHA guidelines/ ECASS III study endorse benefit of IVT from 3-4.5 hours, although the NNT is higher
      • Resumption of MCA flow correlated with improvement (p < 0.01)
    • ATLANTIS (no benefit for 3-5 hour window)
      • 547 pts, 90 days f/u, Barthel, mRS, GOS
    • ECASS II (no benefit at 6 hour window)
• 800 pts, 90 days f/u, modified Rankin scale
  - 0-8 hours for endovascular intervention
• Higher recanalization- Better outcome
  - MERCI, Multi-MERCI, pooled IMS-I and II, Saver meta-analysis
  - IVT results dismal in large vessel occlusion (patients with higher NIHSS)
  - 34% reocclusion and poor outcome after initial improvement with iv tpa
• CT Stroke Protocol: patient evaluation for endovascular therapy
  - Presentation more than 3 hours of stroke onset
  - NIHSS ≥ 8
  - Contraindications for IV t-PA
  - Did not improve after IV t-PA or deteriorate after initial improvement
• Imaging work-up
  - Non-contrast CT- Early ischemic changes, hyperdense vessel sign
  - CTA- Proximal large vessel occlusions, multiple occlusions
  - CT Perfusion: Aquilon 320 Slice scanner
    • Penumbra – Increased Mean Transit Time > 145%
    • Infarct Core- Cerebral Blood Volume (CBV) < 2 ml/100gm tissue
• CT perfusion- Our intuitions
  - Not as reliable as early ischemic changes during the initial 1-2 hours after stroke onset
  - Small core, penumbra > 50% of occluded large vessel territory, young patients- Will benefit revascularization
  - Core > 30% of occluded vessel territory or even small basal ganglia region core- Increased risk of SICH
• Angiography
  - Confirm location of occlusion
  - Assess collaterals
  - Early venous filling from lenticulostriate perforator region- suggestive of basal ganglia core
  - Assess possibility of stenting and to size stents
• Patient Selection
  – Predictors of worse outcome
    • Age > 80
    • Symptomatic ICH after intervention
    • ICA-T and Tandem EC-IC occlusions
  – Higher chances of good outcome
    • MCA distal M1 and M2 occlusions
    • Within 8 hours of stroke onset
    • Age <80
    • Small core, Large penumbra
    • No basal ganglia core, preserved lenticulostriate perforators
• Therapy selection
  – Higher risk of Symptomatic ICH
    • Atrial fibrillation
    • Presentation more than 8 hours of stroke symptom onset
    • Basal ganglia region cores or core > 30% of occluded territory
• Mechanical therapy is our first choice
  – Higher recanalization rates
  – Low Symptomatic ICH rates
  – 17% reocclusion rates after intra-arterial tpa
• Stent-assisted recanalization: SARIS (FDA study of Wingspan stent)
  – Currently used as a bail-out after failed FDA approved modalities
  – Highest reported recanalization
• Mechanical Therapies
  – Proximal Device-Penumbra (FDA Approved)
  – Distal Device- Merci (FDA approved)
• Thrombus disruption
  – Wire manipulation
  – Balloon angioplasty
  – Intracranial Stents
• Pharmacological Thrombolysis
- IA tpa
  - Distal occlusions not reachable with mechanical devices
  - Adjunct to mechanical therapy
  - Higher SICH and 17% reocclusion rates
- Gp IIB/IIIA inhibitors
  - More effective in platelet thrombi (Fresh)
  - Mainly used if there is thrombus formation after recanalization
  - Higher risk of Symptomatic ICH
- Presentation after 8 hours: Higher risk of SICH- around 20%
- Strict patient and therapy selection- 20% patients improve to mRS ≤ 2
- Avoid pharmacological thrombolysis and GpIIB/IIIA inhibitors
- Wake-up stroke
  - Time of stroke symptom onset not known
  - Recanalization rates, SICH rates and outcomes comparable to intervention in patients presenting within 8 hours
- Our policy
  - Patients with higher risk of SICH
    - No IVT/pharmacological thrombolysis
  - Patients without higher risk of SICH
    - IVT + Endovascular intervention- Bridge therapy
- Decision-making Algorithm
  - Clinical Exam, Time of Onset, Age to weigh risk of significant ICH versus penumbra preservation
  - Imaging: CTP, non-contrast head CT, CTA and involvement of basal ganglia
- Technical Nuances: Penumbra, Merci, and intracranial stent (SARIS)
- **Carotid Occlusion: Acute, Chronic and the Case of Moya Moya (EC-IC Bypass)**
  - Medical therapy
    - Antiplatelet agents
    - Anticoagulation for hypercoagulable states
    - Thrombolytics
Blood pressure regulation critical
  • Management of hypervolemia, sodium regulation
  • Beta-blockers, ACE inhibitors / ARB, and r/o Secondary HTN

Surgical Options
  • Synangiosis (i.e. encephaloduroarterial)
  • Low-flow bypass (i.e. STA-MCA)
  • High-flow bypass (i.e. ELANA, vein graft, radial)

Endovascular Options
  • Intra-arterial injection of medication (thrombolysis, vasodilators)
  • Mechanical thrombolysis (Merci, Penumbra)
  • Balloon angioplasty
  • Stenting (coronary stents, balloon mounted, drug eluding, closed cell, open cell)

ECIC bypass failed to reduce the risk of ischemic stroke.
    • International randomized trial
    • 1377 pts enrolled; ICA or MCA stenosis/occlusion
    • Symptomatic with TIA or CVA
    • 714 medical care versus 663 STA – MCA bypass
    • 55.8 months average f/u
    • 30 day surgery mortality 0.6%, morbidity 2.5%
    • Postoperative bypass patency was 96%
    • Nonfatal & fatal stroke occurred more frequently and earlier in surgical patients with no benefit
    • Two subgroups worse with surgery:
      • Pts with severe MCA stenosis (n = 109)
      • Pts with persistence of ischemic symptoms after ICA occlusion (n = 287)
• No sophisticated technology (CTP/PET) available at the time of the trial to monitor physiological parameter
• EC/IC bypass study did not measure CBF / CBV / OE
• St. Louis Carotid Occlusion Study (Grubb et al. JAMA. 1998 Sep 23-30;280(12):1055-60
  • Prospective, blinded, longitudinal cohort study
  • 81 pts enrolled from 1992 to 1996
• Physiology-driven patient selection for EC-IC bypass (p=0.04)
  • Stage I perfusion failure
    • Maximally dilated arterioles
    • No further increase in CBF after CO$_2$ or Diamox
    • “Vascular compensation”
    • “Failure to augment”
    • “Exhausted reserve”
    • Normal OEF
    • Risk of stroke 4.7%
• Stage II perfusion failure
  • Decreased CBF
  • “Metabolic compensation”
  • “Misery Perfusion”
  • Increased OEF
  • Risk of stroke 28.2%
• COSS (Carotid Occlusion Surgery Study)
  • Do patients with stage II perfusion failure benefit from EC / IC bypass?
    • Randomized, non-blinded, controlled trial
    • 372 participants surgical vs. non-surgical treatment
    • ICA occlusion symptomatic within 120 days
    • Stage II hemodynamic failure (PET)
• Insufficient enrollment
  • PET scan not available in many institutions
  • Patients meeting criteria and surgeons do not want to delay surgery
• Reality Check: Indication for EC/IC bypass at our institution:
  • Symptomatic ICA occlusion
  • Symptoms despite medical therapy
  • No other alternative options (endovascular, surgical)
  • Failure to augment with diamox (CTP)
    • STA – MCA bypass to treat hemodynamic ischemia
• The special case of true Moya-moya:
  • Bilateral disease
  • Steno-occlusive disease of ICA, ACA & MCA
  • Non-atherosclerotic disease
  • ‘Puff of smoke vessels’ in the arterial phase
  • Ischemic symptoms an indication for bypass
  • Sparing and judicious use of angioplasty. No stenting.
• Intracranial Atherosclerotic Disease (ICAD) or Stenosis
  • Treatment Alternatives
    • Natural history of IC stenosis (7% - 11% annual stroke risk)
    • Surgery is not favorable (EC/IC trial)
    • Angioplasty results ~ 40% residual stenosis
  • WASID trial: ASA 1300 mg superior to Warfarin (INR 2-3) for ICAD
    • 569 patients randomized with TIA / Stroke and 50-99% ICAD stenosis
    • Terminated early due to inferiority of warfarin versus ASA
      • Death (9.7% versus 4.3%) and sICH (8.3% versus 3.2%)
• SAMMPRIS
  • Ongoing trial examining Wingspan stent for ICAD
  • ICAD remains major cause of ischemic stroke
• Natural History (WASID post-hoc)
  • Stroke risk, Degree of ICAD Stenosis, and Timing of Symptoms
    • 70-99% stenosis: 18% (1 year) and 25% (2 year) stroke risk
    • Risk dropped to 10% if > 30 days since stroke/TIA.
    • 50-70% stenosis: 11% (1 year) and 14% (2 year) stroke risk
• Angioplasty in ICAD carries a >50% restenosis rate
• The Wingspan Registry: Stent Data in ICAD
  • 70-99% stenosis 9.8% (95% CI 5.6-16.3%) 1 year stroke risk
  • 50-70%: No subset analysis for 50-70% but overall Wingspan registry stroke rate of 4.4% in patients with 50-99% stenosis would suggest a substantially lower rate in this subset versus WASID
  • Peri-procedural complication rate 6.2%
  • In-stent restenosis Rate: 25%
    • 5% or 3.8% overall stroke rate for these patients
  • Appears to be a volume-outcome relationship in registry

• Dural Arteriovenous and Carotid Cavernous Fistulæ
  • Dural AVF
    • Revised Djindjian Classification
      • Type I: Anterograde drainage into a dural venous sinus
      • Type IIa: Reflux into other sinuses (retrograde flow)
      • Type IIb: Reflux into leptomeningeal veins
      • Type IIa+b: Reflux into leptomeningeal veins and other sinuses
      • Type III: Direct leptomeningeal venous drainage without venous ectasia (varix)
      • Type IV: Direct leptomeningeal venous drainage with venous ectasia
    • Borden Classification
      • Type I: Drainage into dural venous sinus
      • Type II: Drainage into dural venous sinuses with retrograde leptomeningeal venous drainage
      • Type III: Drainage into leptomeningeal veins (a-simple, b-multiple fistulæ)
  • Treatment Options
    • Type I No neurologic risk, conservative therapy recommended
- Type II+  Risk for intracranial hypertension and hemorrhage:
  - 10% risk for type IIb, 40% for type III and 65% for type IV
  - Intervention recommended
- Treatment options:
- Conservative: radiographic follow-up with ipsilateral compression of neck with contralateral hand 4-6 times an hour for 15-30 seconds at a time while the patient is sitting or recumbent (20-30% cure rate for Type I and IIa). Significant atherosclerotic disease is a contraindication.
- Surgical Options: Exploration and skeletonization of involved sinus with clip ligation or cautery of the venous fistulous site causing drainage into leptomeningeal venous collaterals
- Radiosurgery: Only preliminary evidence of efficacy. Only in cases where treatment is indicated but carries inordinate risk.

- **Carotid Cavernous Fistulae**
  - This a much more variable cluster of arteriovenous fistulae with a cohort actually a dural AVF involving the cavernous sinus
  - Etiology:
    - Trauma: MVAs are the most common cause with basilar skull fractures lacerating the internal carotid artery or its branches. Less frequently penetrating injuries may cause the same.
    - Spontaneous: Ruptured intracavernous internal carotoid artery aneurysms, Ehler Danlos Syndrome (particularly type IV), Fibromuscular dysplasia.
    - Iatrogenic injury: During carotid angioplasty, transphenoidal pituitary surgery or transfacial trigeminal rhizotomy and sphenoidal sinus surgery.
  - Barrows Classification
    - Type A (Direct)  Intracavernous ICA to cavernous sinus
• Type B (Indirect)  Dural ICA branches to cavernous sinus
• Type C (Indirect)  Dural ECA branches to cavernous sinus
• Type D (Indirect)  Dural ICA and ECA branches to cavernous sinus

• They may also be considered etiologically as
  • Type I  Traumatic direct fistula from the ICA
  • Type II  Direct fistula from a ruptured intracavernous aneurysm
  • Type III  Indirect dural type arteriovenous fistula of the cavernous sinus