Society of Neurological Surgeons Junior Resident Course:

*Introduction to the operating room and leadership*

The driving motivation behind this course, and behind academic neurosurgery, is the desire to pass on knowledge and experience to trainees who can benefit from our collective experience. This benefit is then passed on to our patients through improved care, and later, onto our trainees patients. This is one of the primary satisfactions in academic medicine. As a resident attendee of this course you have already attended the SNS fundamentals course and have spent 1-2 years in the clinical practice of medicine. This course will prepare you to make the next major transition in learning: adapting to the operating room and developing leadership skills.

The faculty of this course have generously donated their time, and are sharing their experience with you in this effort. Take advantage of this opportunity to learn from their experience. We thank the faculty, the host institutions, our industry partners, and the AANS staff for all of their hard work in putting this together.

Sincerely,

Richard W Byrne, MD
National Course Director
Society of Neurological Surgeons

Junior Resident Training Course

Curriculum
Competencies

- Professionalism (Leadership)
- Communications
- Patient Care (Technical Skills): Basics of spinal neurosurgery
- Patient Care (Technical Skills): Basics of cranial neurosurgery
- Systems-based practice/Practice-based learning: Quality improvement

Organization

- 2.5 days
  - Thursday (arrival; afternoon sessions)
  - Friday (all day sessions)
  - Saturday (all day sessions with early finish; departure)
- 3 centers (West, Midwest, East)
- Allow PGY1 or PGY2 residents in ACGME accredited programs to participate; each program has number of slots per year equal to their intake, and can distribute according to their curriculum
- Meals
  - Breakfast: Friday and Saturday
  - Lunch: Friday and Saturday
  - Dinner: Friday
I. Thursday (1 to 5:30 pm)
   a. Welcome and Introductions (5 minutes) [1-1:05pm]
   b. Lecture: Safety and Surgical Checklists: Formal (O.R. Procedural Pause) and Informal (20 minutes) [1:05-1:25pm]
   c. Lecture: Informed Consent Exercise (20 minutes) [1:25-1:45pm]
   d. Lecture/Duke video: Breaking Bad News (20 minutes) [1:45-2:05pm]
   e. Informed consent, mentored small groups (25 minutes; 4-8 residents per group) [2:05-2:30pm]
      i. 4 procedural consents; 10 Faculty; 50 Residents
         1. Unruptured aneurysm
         2. Cervical decompression for stenosis
         3. VP shunt revision
         4. Lumbar discectomy
      ii. Group feedback on word choice, missed steps or quoted risks, etc.
   f. Concurrent Sessions I (2 hours) [2:30-4:30pm]
      i. Behavioral scenario simulation – Group A (25 Residents)
         1. Breaking bad news (6 Residents per group; 1.0 hour per session)
            a. Relaying news of a poor prognosis (metastatic cancer, TBI, spinal cord injury); 4 Faculty (2 groups of 2 faculty & 6 residents)
            b. Relaying news of a complication or medical error; 4 Faculty (2 groups of 2 faculty & 6 residents)
      ii. Model based clinical simulations (Sim Man) – Group B (25 Residents)
         1. ICU crisis; 4 Faculty; 1-2 Sim Mans
            a. Scenario:
               i. SAH patient with deterioration
               ii. Pediatrics hydrocephalus
               iii. Spine fracture post-op
               iv. Post-op brain tumor, seizure
               v. TBI
            b. Competencies: Diagnosis, systems based practice, communication
         2. OR crisis; 4 Faculty
            a. Scenario:
               i. Sinus bleeding
               ii. Venous air embolus
               iii. Loss of pin fixation
iv. Uncontrolled brain swelling
v. Uncontrolled bleeding
b. Competencies: Technical management, team communications, leadership
g. Lectures [4:30-5:30pm]
   i. Lecture: Principles of Neuronavigation: Frame and Frameless (30 minutes)
   ii. Lecture: Ventricular Anatomy (30 minutes)

II. Friday AM (7am to noon)

Pre-Study:
- Lecture: Cerebral Vascular Anatomy
- Lecture: Principles of Neuronavigation: Frame and Frameless
- Lecture: Ventricular Anatomy
- Lecture: Surgical Anatomy of the Spine

a. Anatomy lectures (7am-8:20am)
   i. Lecture: Cerebral Vascular Anatomy (40 minutes)
   ii. Lecture: Surgical Anatomy of the Spine (40 minutes)
b. Break – 10 minutes [8:20-8:30am]
c. Concurrent Sessions II (4 hours) [8:30-12:30pm]
   i. Model based skills simulation (4 hours; 30 minutes per station) – Group A (4 residents per station); 6 Faculty, (25 residents), Simulators, 4-8 Stryker heads
      1. Tumor resection (Canadian Research Institute haptic simulator)
      2. Endoscopy
      3. Endovascular → 2 endo simulators/site
      4. Stereotactic frame placement
      5. Frameless navigation registration
         a. Accuracy and safety
         b. Flap design
      6. Mentored leadership discussion (two groups = 4 residents)
ii. Cadaver based cranial surgical skills simulation (4 hours) – Group B (3 residents per station); **8 Faculty**, (25 residents), **8 heads, 8 torsos, 16 drills + suction + head holders + plating + screws/rods, 32 scalpels + retractors + suture kits, 60 personal kits (gloves, protective gear, etc), 4 cusas, 8 kerrisons + lexles + woodsons + disc rongeur, 16 matchstick bits, 32 dural grafts, 2 reciprocating saws**
   1. Basic cranial approaches, including positioning (Cadaver)
      a. Suboccipital
      b. Pterional
      c. Fronto-orbital
      d. Cranial plating for fronto-orbital
   2. Basic spinal approaches, including positioning (Cadaver)
      a. Laminectomy
      b. Pedicle screw placement

III. Lunchtime Lecture: Leadership and Professionalism in an Era of Neurosurgical Exceptionalism (60 minutes) [12:30-1:30pm]

IV. Friday PM (1:30pm to 5:30 pm)
   a. Concurrent Sessions III (4 hours)
      i. Model based skills simulation (4 hours; 30 minutes per station) – Group B (2-4 residents per station)
      ii. Cadaver based cranial surgical skills simulation (4 hours) – Group A

V. Saturday AM (8:30am to 11am)
   a. Concurrent Sessions IV (2 hours)
      i. Behavioral scenario simulation – Group B
      ii. Model based clinical simulations (Sim Man) – Group A

VI. Lunchtime Lecture II: Learning from Failure – Professional and Personal Resilience (60 minutes) [11-12pm]
VII. Saturday PM (12 to 3pm)
   a. Lecture: Post-Operative and Chronic Pain Management in Neurological Surgery (15 minutes) [12-12:15pm]
   b. Lecture: Handoffs (Care Setting, and Team Change) (15 minutes) [12:15-12:30pm]
   c. Lecture: Disclosure of Medical Errors and Risk Management (15 minutes) [12:30-12:45pm]
   d. Lecture: Quality Improvement in Neurosurgery (15 minutes) [12:45-1pm]
   e. Break out QI project design mentored sessions (1 hour; 9 groups of 4) [1-2pm]
      i. DVT/PE
      ii. Surgical Infections
      iii. Handoffs
      iv. Pain Management
   f. QI project proposal reporting (1 hour; 5 minutes per group plus 15 minutes discussion/wrap-up) [2-3pm]

SNS Subcommittee for Boot Camp Courses and Committee on Resident Education (CoRE)

Project Steering Committee:

Nate Selden, Chair
Nick Barbaro
Kim Burchiel
Tom Origitano
Safety and Surgical Checklists

Goals and Objectives
- Care of Neurosurgical Patient
  - Pre, Intra, and Post-Operative Checklists
- Validated Tools in the Neurosurgical Setting
- Environments particular to Neurosurgery
  - Neuromonitoring
  - Intra-Operative MRI
- Sub-specialty Specific Considerations for Process Quality

Surgical Checklists
- Surgical Time Out (WHO and JCAHO)
  - Prospective Data on 7688 surgical patients
  - Death 1.5% to 0.8%; Complications 11% to 7%
- Components
  - Correct Patient, Procedure, and Surgical Site
- Specialty Specific Checklists
- Adverse Event Division of Labor
  - Intra-Procedural Aneurysm Rupture

Checklist Practice Challenges
UCLA Prospective Experience
- Cultural Change: Who leads surgical pause?
- Practice Change: 3-5 minute completion
- Standardization of Time Out
- Potential for Smart Tailored Checklists
Culture of Safety Reporting

- Sources of Errors: Communication
- Multidisciplinary Team
- Provider Roles in Timeout and Checklists
- Berger et al. Safety Reporting Video

Aviation Incidence Guide

- Human Factor Analysis
- Track, Analyze, Categorize Near Misses
  - Severity and Duration
- Ferroli et al. (14 near misses)
  - Human Factors (9/14)
  - Technology (1/14)
  - Organizational Factors (3/14)
  - Procedural Factors (1/14)

Near Miss Factor Analysis

- Human Factors
  - Omission, Lack of Communication, Late Detection
  - Multitasking, Teamwork Failure, Time Pressure
- Technologies
  - Equipment Allocation, Instruments, Interface, Data Interpretation
- Organizational Factors: task allocation/overlap
- Procedural Factors (checklist effectiveness)

Surgical Debriefing

- Systems Based Practice
- Real-Time Quality Feedback
- Diversity of Team Member Perspective
Patterns of Adverse Events in Neurosurgery

- Surgical Technique
- Perioperative medical management
- Protocol Use and Adherence
- Pre-Operative Optimization
- Technology
- Communication

Solutions

- Process and Outcomes Monitoring
- Regionalization and Subspecialization
- Guidelines and Protocols
- Equipment Standardization
- Surgical Checklists

Sub-Specialty Considerations

- Spine
  - Intra-Operative Neurophysiological Monitoring
- Endovascular
- Intra-Operative MRI
Informed Consent Exercise

In this breakout session, you will be asked to obtain informed consent for a variety of procedures. Principles of professional communication will be tested as well as specific issues related to the procedure.

Professional communication essentials: Take your time, introduce yourself, maintain eye contact, and sit down if possible. Allow time for questions. Explain the patient’s condition, differential diagnosis, and potential natural history of their condition, treatment options, risks, surgery and risks/benefits. General risks of any surgery such as anesthesia, bleeding and infection, followed by specific risks of the procedure should be covered. Expectations of the length of the procedure, post-operative course and recovery are common questions. Always ask if there are any questions.

Don’t make things up. If you don’t know the answer, find out the answer from your senior resident or attending.

The exercise may also cover special circumstances such as legal guardianship, language barriers, pediatrics, refusal of consent, emergency procedures and medical necessity.
Communication Skills for Surgeons

National Survey of NSU Program Directors (response rate: 92%)
Skill in Communication Milestones

- Informed Consent
- Delivering Bad News
- Discharging Outcome

- Level 1
  • Describe the ethical principles of informed consent.
  • Describe methods to compassionately break bad news.
  • Identify elements of safe patient handoffs and procedural pauses.
  • Observe and document informed consent.
  • Participate in breaking bad news to a patient or family.
  • Participate in an advanced directive discussion.
  • Quantify evidence for risk-benefit analysis during informed consent for a complex, elective neurosurgical procedure.
  • Manage and document an unexpected outcome (e.g., patient care failure).

- Level 2
  • Lead and document informed consent.
  • Lead procedural pauses.
  • Use checklists and informatics to support patient handoffs.
  • Communicate effectively with patients, family, other team members, and community organizations.
  • Prioritize and convey simultaneous critical clinical events.
  • Lead and document an advanced directive discussion.
  • Supervise patient handoffs.
  • Communicate effectively with physicians, health care teams, and health agencies.
  • Prioritize, convey, and manage simultaneous critical clinical events.
  • Lead response to an adverse event or critical care emergency.
  • Act in a simulation role for other physicians.

- Level 3
  • Design and implement a human subject research study; file an IRB application.
  • Design and implement a team building and communications exercise.

- Level 4
  • Lead and document an advanced directive discussion.
  • Supervise patient handoffs.
  • Communicate effectively with physicians, health care teams, and health agencies.
  • Design and implement a team building and communications exercise.

Comments:
8 of 23 fully or partially covered
Communication Skills for Surgeons

Delivering Bad News:

Look for three things Dr. Anderson could have done better:

Good scenario:

Of the three things you listed, check off if Dr. Anderson did them:

Bad scenario:

Communication Skills for Surgeons

Delivering Bad News:

1. Sit down
2. Start with an Open ended question
3. Listen
4. Say back what you heard
5. Fire a “warning shot” and give news in a direct way
6. Allow them to absorb information
7. Ask permission to proceed
8. Explain in clear language
9. Offer support
10. “What questions do you have?”

Communication Skills for Neurosurgeons

Duke Neurosurgery Residents (14/17)
Pilot Study
November 2012, Two hour session, Five videos
Communication Skills for Neurosurgeons
Pilot Study: Duke Neurosurgery Residents (15/17)
November 2012, Two hour session, Five videos

Taking a History:
Look for three things Dr. Anderson could have done better:

Bad scenario

Communication Skills for Neurosurgeons
Taking a History:
Of the three things you listed, check off if Dr. Anderson did them

Good scenario

Communication Skills for Neurosurgeons
Taking a History:
1. Sit down
2. start with an Open ended question
3. Listen
4. Say back what you heard
5. Explain the plan in clear language
6. Offer support
7. “What questions do you have?”
Obtaining Informed Consent:

1. Sit down
2. Start with an Open ended question
3. Listen
4. Say back what you heard
5. Explain the plan in clear language
6. Offer support
7. “What questions do you have?”
Communication Skills for Neurosurgeons

Delivering a Disappointing Outcome:

Of the three things you listed, check off if Dr. Anderson did them:

1. Sit down
2. Fire a “warning shot” and give news in a direct way
3. Allow patient to absorb information
4. Ask permission to proceed
5. Apologize when appropriate
6. Explain the result in clear language
7. Recognize emotions
8. Offer hope and reassurance
9. “What questions do you have?”

Communication Skills for Neurosurgeons

Summary: Taking History and Informed Consent

1. Sit down
2. Start with an Open ended question
3. Listen
4. Say back what you heard
5. Explain the plan in clear language
6. Offer support
7. “What questions do you have?”
8. SOLS

Communication Skills for Neurosurgeons

Summary: Delivering Bad News or a Disappointing Outcome:

1. Sit down
2. Start with an open question
3. Listen
4. Say back what you heard
5. Fire a “warning shot” and give news in a direct way
6. Allow them to absorb information
7. Ask permission to proceed
8. Apologize when appropriate (disappointing outcome)
9. Explain in clear language
10. Offer support
11. “What questions do you have?”
ICU Crisis

In this exercise using the Sim Man model, you will work with faculty on ICU scenarios that you will commonly encounter. A limited introduction of the pt’s background as might be available to you via a signout will be given. You will be asked to think through likely concerns, describe a differential diagnosis of the patient’s condition and create a treatment plan. You will be asked to enlist the aid of the multidisciplinary team available to you in the ICU and provide leadership.

The patient’s condition will change throughout the exercise, as happens in the real world, and you will be expected to respond appropriately.
Scenario One: Patient comes out of 3-point pin fixation.

Despite appropriate placement of a patient in pins, scenarios can arise where the patient slips out of the pins. This could be due to an unexpected intraoperative wake up, a shifting of the patient with a change in table position and or failure of the fixation apparatus. As always, the best treatment is prevention. Pin fixation should be applied firmly and should be “stress tested” pre-operatively to be certain of adequate fixation. It is best to avoid pin fixation on sloping portions of the skull such as the posterior fossa or just lateral to the orbit. Pin fixation is usually lost during the portion of the operation that stresses the fixation most, scalp elevation and bone flap drilling. Counter-tension can be applied to lessen the pressure applied. Rarely, in patients with very thick skulls, the perforator can become stuck in the skull and removal of the perforator can pull the patient out of pin fixation. This can be anticipated and avoided in these cases by gently rotating the perforator bit just prior to completing the burr hole to create more room for perforator removal.

One can identify the problem by seeing, feeling, or hearing the head release from the pins. Gross loss of navigational accuracy may be another clue. When it is believed that there is loss of fixation, the operative intervention should be suspended. The OR team, especially anesthesia, should be notified. Adequate anesthetic levels should be verified: (IV lines carrying the anesthetic are intact, endotracheal tube connected, etc.). Simultaneous manual stabilization of the head on the field should occur to try to mitigate any further movement which could cause injury. Investigation of the orientation of the head to the pins under the drapes must now be accomplished. It is often beneficial to call a 3rd party into the room for this “under the drapes” maneuver so as to not deprive the operator of a primary assistant should continued intervention be necessary (i.e. control bleeding). Under the drapes, assessment should include the location of the individual pins as related to the anatomy (eye, ear canal) and injury (laceration, bleeding). Maintenance of a sterile field should be a critical priority at all times. If possible, removal of a free, potentially threatening pin should be undertaken. This is often the frontal pin which can oppose the eye. An evaluation of the position of the patient’s head as it relates to finishing the case, need for further manipulation of the table and risk of further head migration will need to be assessed by the operator. Considerations at this time include:
1) Proceed with the operation, with care not to further manipulate the head.
2) Exchange pin fixation for horseshoe rest.
3) Terminate the operation, close, undrape, reset the pins and begin again.
4) Terminate the operation.

Which of these scenarios one proceeds with depends on the nature of the case, the time-line of the case when the issue occurs and the condition of the patient.

Key points to review:

1) Recognize the event by sight, sound or movement under your hands.
2) Notify the surgical team if you think any fixation has deteriorated.
3) Communicate with the anesthesia team about the level of anesthetic: assure endotracheal tube and IV line integrity.
4) Ask for additional help to explore under the sterile field to evaluate stability of the patient’s head and threat to critical anatomy.
5) Consider options to move forward with the operation or terminate.
6) Remember that navigation registration is no longer durable and that retractors fixed to the head holder may move.
7) Maintain a sterile field at all times.
8) After the operation, perform a critical analysis of the reason for loss of fixation: apparatus not performing appropriately, anatomy of the patient, insufficient fixation tension, location of fixation not adequately engaging the skull, lack of adequate fixation of the body to the table allowing for body shift, unexpected awakening from anesthetic due to loss of IV or endotracheal continuity with changes in patient positioning.

**Scenario two: Air Embolism**

Intraoperative air embolism can occur during any craniotomy in which the head is above the heart, resulting in a situation where there is a negative venous pressure. Certainly, there is a higher risk when the patient is in the sitting or semi-sitting position. However, in any craniotomy in which the head is tilted up above the heart and/or one is working on or around major venous sinus/complexes (skull base, posterior fossa, retro-sigmoid, parasagittal, etc.) this complication should be discussed with anesthesia and the OR team. In a case where the head of the bed is above the heart and a major sinus needs to be exposed, it is helpful to lower the head while exposing the sinus. It is far easier to control bleeding than to control air embolism. It should be remembered that air could enter through any venous channel, including those in the bone. Care should be taken to heavily wax bone edges adjacent to sinuses.

Pulmonary air embolism (PAE) can be a life-threatening situation. Therefore, careful preoperative consideration of prophylactic measures and interdiction should be reviewed by the surgeon and the OR
team. A number of devices can be used to monitor for PAE: precordial Doppler, trans-esophageal echocardiography, end expired nitrogen, end tidal CO2 and right heart catheter (which can be used to aspirate the air bubble). The diagnosis may be made by: a change in the Doppler signal, hypotension, decreasing Pa O2, increasing pulmonary artery pressures, increasing Pa CO2, increasing end tidal nitrogen, and decreasing cardiac output.

The presenting clinical symptom of symptomatic PAE is often unexplained hypotension. A characteristic “washing machine” change in the Doppler signal may be heard. The air can be seen on TEE. Should a change in the Doppler signal occur or a PAE be suspected, the wound should be immediately covered with a wet lap and the head lowered to below the heart. Back bleeding from a venous source may be identified and treated with this maneuver. If this is not immediately possible, jugular venous pressure can be intermittently applied for 15-20 seconds to buy time for re-positioning. Aspiration of air from a central venous catheter should then be performed if one is in place. Depending on the scope of the incident consideration for further surgery vs. termination of the operation should be discussed. The head is then gradually raised, carefully watching out for another embolism.

Considerations prior to surgery in which the head of the bed must be elevated:

1) Position of the head. If head elevation is necessary, consider lowering the head while exposing sinuses.
2) Operating on or around major veins/venous complexes/ sinus. Is sinus exposure necessary?
3) Placement of precordial Doppler
4) Placement of right heart catheter
5) Team understanding of risk of PAE and necessary steps should it occur

Scenario three: Dural Sinus Bleeding

Many of our current neurosurgical approaches incorporate operating on or around major venous sinus pathways. Prior to operative intervention the surgeon should have studied the venous anatomy to understand venous drainage dominance, variance and orientation to pathology. Anticipation of the consequences of venous injury is the first step to management. One should question whether alternative approaches can be used to reduce the risk to a dominant venous structure. Prior to any operative approach the need for and availability of blood products should be anticipated. A discussion with anesthesia concerning the risk of blood loss is necessary to provide for adequate pathways for replacement. Appropriate clips, hemostatic agents and premade hemostatic pressure sponges should be readily available and the nursing staff aware of their use.

Most bleeding from dural sinuses is minor and can be controlled with application of hemostatic agents and gentle, patient pressure. Tack-up sutures can also be useful. True laceration of a dural sinus is less common, and can lead to life-threatening scenarios. The best practice is to very carefully
separate dural sinuses from bone prior to completing a craniotomy over the sinus so that this is rarely encountered. If separation cannot be achieved, altering your exposure plans may be the right choice. One can anticipate difficult dural separation in older patients, re-operation, and in patients with unusually thick or irregular bone such as hyperostosis frontalis interna as seen on pre-operative imaging.

Laceration of a dural sinus can lead to considerable blood loss, air embolism, brain swelling and death should it not be appropriately anticipated and managed. As when dealing with any vascular structure exposure is key, both proximal and distal. An understanding of the sinus’s local relationship to the overlying bone and pathology is critical. Laceration of the sinus should be met with calm determination.

First, breathe. Next place a paddy based tampon over the opening and apply gentle pressure. Do not fully occlude the sinus or inject directly into the sinus. This can lead to venous occlusion, venous embolism, venous congestion, leading to massive brain swelling and spontaneous hemorrhage.

Ask for help. If the sinus was lacerated while placing a burr hole, consider gently packing above the hole, isolating that hole and adjusting your bone flap away from the site. If the laceration occurs during bone flap elevation, you will first need to complete the exposure to obtain proximal and distal control. For this reason, in a routine craniotomy adjacent to a major sinus, it is best to complete the portion of the craniotomy away from critical sinuses first so that this portion of the exposure is already done. Head elevation will decrease venous pressure and may stem the bleeding but must be balanced against the risk of air embolism. Once the borders of the sinus are visualized a plan for reconstruction can be formulated. Direct pressure is usually adequate to control small tears. If there is a major tear under pressure, a small fogerty or foley catheter can be placed in the proximal sinus to help stem the bleeding. Primary closure can be assessed with or without grafting. If the sinus which is bleeding has favorable collateral drainage primary occlusion can be considered. When this is not possible an adjacent dural swing flap can be utilized. A section of dura is isolated adjacent to and longer than the laceration. A flap is produced which resembles a book cover. This is swung over hemostatic packing agents, stemming the venous flow. The flap can then be sutured to the dura on the opposite side of the sinus. The flap can also be sewn to the falx or tentorium if the laceration is internal. Often no superior or inferior sutures need to be placed as the flap provides sufficient tamponade. If in the course of reconstruction significant brain swelling is encountered, consideration of inserting a vascular shunt into the sinus to restore flow during the reconstruction is an option.

**Scenario four: Uncontrolled/Unexpected Brain Swelling**

In the course of intracranial surgery uncontrolled/unexpected brain swelling is one of the most worrisome and challenging surgical events. This problem can be divided into 2 primary categories: those events with known causes (acute ischemia due to compromise of a major artery/vein) and those events of unknown etiology. Differential diagnosis includes the following: contralateral epidural and/or subdural hematoma; acute hydrocephalus; venous congestion due to positioning, venous injury or
obstruction; deep/intraventricular bleeding (i.e. aneurysm rupture or retraction and unobserved bleeding from a severed vessel); uncontrolled bleeding from coagulopathy, generalized seizure, insufficient ventilation, elevated airway pressure, uncontrolled hypertension, and insufficient anesthesia. The diagnosis and treatment varies with potential causes. A close working relationship with the anesthetic team is key since many of the causes and treatments are anesthesia related.

Initial treatment with hyperventilation, raising the head of the bed, diuretics, control of hypertension, paralytics, and metabolic suppression (i.e. pentobarbital) can buy initial time for diagnosis. Mild hypotension may help with initial management in severe cases, by must be weighed against potential exacerbation of ischemia. If the surgical pathology is exerting pressure, rapid decompression of the lesion (hematoma, tumor or cyst) should be started in parallel with the other maneuvers. Open adjacent cisterns to release CSF. If generalized seizure is considered, irrigation of the brain with ice-cold saline may rapidly abort the activity. A survey of the operative site may reveal an expanding parenchymal hematoma or a spreading subarachnoid hemorrhage at the edge or in the depth of the field. Intraoperative ultrasound can be diagnostic of deep hematoma and/or dilatation of ventricles. If dura is tented adjacent to a venous sinus, relaxation of the dura may improve venous drainage. In posterior fossa surgery in which communicating hydrocephalus may be precipitated, a prophylactic occipital burr hole should be considered.

In desperate times, with unknown pathology and limited diagnostic abilities, placement of an external ventricular drain may relieve pressure and be diagnostic. When all else fails, consideration should be made for extending the craniotomy to allow optimum decompression with dural relaxation and/or pathological brain resection. This can buy time allowing for emergent CT scanning. The ability to obtain and maintain hemostasis is critical, especially if coagulopathy or venous obstruction is being considered as the etiology for brain swelling. During closure, CT techs should be notified of the emergent need for the scan. If intraoperative CT is available, this could be employed prior to closure. While the patient is obtaining a CT scan the operating room should rapidly ready a room for re-opening or craniotomy extension. It is important that when this kind of event occurs, one considers calling for additional help. You cannot overestimate the benefit of another set of eyes, hands and an objective mind in managing these critical events.
Principles of Neuronavigation: Frame and Frameless

History

- "Stereotactic": From Greek "stereos"=3-dimensional and Latin "tactus"=to touch
- 1908: Horsely and Clarke develop first apparatus for insertion of probes into the brain based upon Cartesian planes and bony landmarks; only used in primates
- 1947: Spiegel and Wycis report first human use of stereotactic device. Goal was to perform minimally-invasive psychosurgery but first use was for movement disorders
- 1948: Leksell develops first arc-centered frame
- 1957: Talairach publishes first atlas based upon ventriculography and intracranial brain landmarks rather than bone landmarks
- 1986: Kelley develops frame-based system for eye-tracking of operative microscope
- 1986: Roberts develops frameless acoustic-based system for tracking operative microscope
- 1991: Bucholz develops the first prototype for frameless sonic navigation of tracking tools and instruments in human cranial surgery
  - Soon after incorporated optical digitizers to reduce inaccuracies from sound echoes

General Principles of Stereotaxy

- Navigation is based upon targeting relative to known reference points
- Fiducial:
  - From Latin "fiducia" meaning trust
  - A point of reference that can be visualized on imaging and identified by the surgeon and/or software package
  - Accuracy of targeting is influenced by the number of fiducials around a target zone and the constancy of fiducials relative to the target
- Frame-based stereotaxy: Fiducials are bars built into cage or box that sits on frame during imaging
- Frameless stereotaxy: Fiducials are reference markers (stickers, bone screws) which are fixed directly to the patient prior to imaging

Co-registration is the fundamental principle of stereotaxy

1906 -- Horsley & Clarke (animal) stereotactic frame
Co-registration is the fundamental principle of stereotaxy

1906 – Horsley & Clarke (animal) stereotactic frame
1947 – Spiegel & Wycis (human) stereotactic frame
1947-1980 – Proliferation of stereotactic frames

Considerations with Frame-Based Stereotaxy

- Method of target localization
  - Indirect vs. direct
- Imaging errors due to frame placement
- Imaging errors due to distortion
Methods of Image-Based Target Localization

- Indirect (Based upon position of AC-PC)
  - Standard coordinates
    - Leksell’s pallidotomy target is classic example
  - Adjusted map
    - Schaltenbrand-Wahren is most common
    - Average AC-PC distance is 23-27mm; greater than 30mm should raise accuracy concerns
- Direct (Target visually chosen from scan)

Axial T2 Measurement of AC-PC

Indirect Targeting: Fixed Coordinates

- Thalamus (Vim)
  - 1-7mm posterior
  - 0-3mm superior
  - 12-17mm lateral
- GPi
  - 2-3mm anterior
  - 3-6mm inferior
  - 18-22 mm lateral
- STN
  - 3-5mm posterior
  - 5-6mm inferior
  - 11-14mm lateral

AC-PC: Sagittal T2 Localizer
Sources of Error: MRI Image Distortion

- Magnetic field inhomogeneities and non-linear magnetic field gradients cause distortion
  - Distortion often worst in coronal sections; measuring Leksell fiducials can determine distortion severity
- Frame may introduce additional distortion
  - Measuring target distance from MCP on preop MRI can guide targeting from framed image
- CT not subject to these distortions; CT/MRI fusion may minimize effects of distortion
- Bandwidth can influence contrast
  - Lower bandwidth increases gray/white contrast to a point
  - Very low bandwidth can worsen distortion

Image Fusion
Eight Things Every Neurosurgery Resident Should Know about Frameless Image-Guidance

What is image-guided surgery and how does it work?

- Image-guided surgery (neuronavigation, "frameless stereotaxy") is an operative technique by which correlation between imaging studies and the operative field is provided.
- This is accomplished by co-registration of imaging studies with the OR patient.

What equipment is involved?

- Localization device (digitizer)
  - e.g., optical, electromagnetic, articulated arm
  - most systems today include a reference frame to enable OR table movement

Matrix Expression

\[ P_{2I} = 2^T_M M^T_W W^T_{3I} P_{3I} \]
What equipment is involved?

- Localization device (digitizer)
  - e.g., optical, electromagnetic, articulated arm
- Computer with registration algorithm
- Effector
  - e.g., pointer and monitor, microscope heads-up display

What types of co-registration strategies can be used?

- Paired-point rigid transformation
- Surface (contour) matching

Some important definitions...

Fiducial registration error (FRE)

the root-mean square distance between corresponding fiducial points after registration

Fitzpatrick & West, 2001
Fiducial localization error (FLE)
the error in locating the fiducial points

Target registration error (TRE)
the distance between corresponding points other than the fiducial points after registration

Accuracy in phantom testing

Clinical application accuracy (comparing seven registration methods)
What are the sources of error?

- Imaging data set
  - resolution
  - e.g., slice thickness, pixel/voxel size
  - spatial infidelity
  - e.g., magnetic field inhomogeneities in echo planar fMRI
  - imaging study fusion
  - e.g., CT–MRI, atlas–MRI

---

Dependence of stereotactic accuracy on image slice thickness

<table>
<thead>
<tr>
<th>CT Slice Thickness (mm)</th>
<th>Measurement</th>
<th>Middle</th>
<th>25% CI for the mean</th>
<th>95% CI for the mean</th>
<th>Middle ± 1 S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.2 ± 0.30</td>
<td>1.8 (1.2)</td>
<td>1.8 [1.2]</td>
<td>1.2 [1.8]</td>
<td>1.2 ± 0.30</td>
</tr>
<tr>
<td>2</td>
<td>2.3 ± 0.31</td>
<td>3.0 (2.3)</td>
<td>2.3 [2.0]</td>
<td>3.0 [2.5]</td>
<td>2.3 ± 0.31</td>
</tr>
<tr>
<td>3</td>
<td>2.9 ± 0.33</td>
<td>3.5 (2.9)</td>
<td>2.9 [2.6]</td>
<td>3.5 [3.2]</td>
<td>2.9 ± 0.33</td>
</tr>
<tr>
<td>4</td>
<td>3.5 ± 0.35</td>
<td>4.0 (3.5)</td>
<td>3.5 [3.2]</td>
<td>4.0 [3.6]</td>
<td>3.5 ± 0.35</td>
</tr>
</tbody>
</table>

Sumanaweera, 1994

Maciunas et al., 1994
What are the sources of error?

- Imaging data set
- Registration process (image–OR space)
  - axes orientation (handedness of coordinate system)
  - algorithm ambiguity
  - fiducial number, configuration, displacement, OR localization (surgeon & digitizer)

Number of fiducials and accuracy

<table>
<thead>
<tr>
<th>Fiducials</th>
<th>Imaging</th>
<th>Mean</th>
<th>SD</th>
<th>Median</th>
<th>95th percentile</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 general</td>
<td>MR</td>
<td>2.45</td>
<td>0.04</td>
<td>2.3</td>
<td>3.9</td>
<td>6.15</td>
</tr>
<tr>
<td>6 general</td>
<td>MR</td>
<td>7.40</td>
<td>0.29</td>
<td>5.1</td>
<td>4.94</td>
<td>9.14</td>
</tr>
<tr>
<td>8 general</td>
<td>MR</td>
<td>1.93</td>
<td>0.34</td>
<td>1.78</td>
<td>3.1</td>
<td>3.95</td>
</tr>
<tr>
<td>10 general</td>
<td>MR</td>
<td>1.98</td>
<td>0.68</td>
<td>1.9</td>
<td>3.1</td>
<td>3.85</td>
</tr>
</tbody>
</table>

TRE has an approximate N^{-1/2} dependence

\[
\langle \text{TRE}^2(\tau) \rangle \approx \frac{\langle \text{FLE}^2 \rangle}{N} \left( 1 + \frac{1}{3} \sum_{k=1}^{3} \frac{d_k^2}{f_k^2} \right)
\]

Fitzpatrick et al., 1998
Error increases as the distance of the target from the fiducial centroid

![Image](image.png)

West et al., 2001

FRE is not a reliable indicator of registration accuracy (!!!)

- FRE is independent of fiducial configuration

\[(FRE^2) = (1 - 2/N)(FLE^2)\]

- FRE is independent of bias errors (e.g., MRI gradient, digitizer camera malalignment, bent handheld probe)

Fitzpatrick et al., 1998

Tips regarding fiducials

1. Avoid linear fiducial configurations
2. Arrange fiducials so that the center of their configuration is close to the region of interest during surgery
3. Spread out the fiducials
4. Use as many fiducials as reasonably possible
5. Mark scalp at fiducial site
6. Avoid occipital region or distorted scalp

What are the sources of error?

- Imaging data set
- Registration process (image–OR space)
- Digitizer performance

<table>
<thead>
<tr>
<th>Tracking Device</th>
<th>Rms Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical tracking device</td>
<td>0.25 mm</td>
<td>0.5 mm</td>
</tr>
</tbody>
</table>
What are the sources of error?

- Surgical field displacement or deformation

How does this relate to intraoperative MRI/CT?

- Numerous implementations
- Facilitated co-registration
- Updated image data-set
- Cost-benefit analyses pending

In what applications has image-guidance been important?

- Tumor (biopsy, resection of glial and met tumor)
- Epilepsy (structural & physiologic data, resection)
- Functional (DBS)
- Spine (instrumentation)
- Radiosurgery (frameless technologies)
- Cerebrovascular (?)
- Other: ENT, Plastics, Ortho, General

What's under development for image-guidance?

- Automated registration
- Ease of use
- Updated imaging/registration
- Increasing accuracy
- Robotics
- Extension of application to other surgeries, other disciplines
**General Ventricular Anatomy**

- The two lateral ventricles communicate with the third ventricle through the foramen of Monro.
- The third ventricle communicates with 4th ventricle through the cerebral aqueduct.
- Lesions can involve the ventricular system and cause CSF communication pathway obstruction and hydrocephalus.
Obstructive Hydrocephalus

Intraventricular Anatomy

Colloid Cyst

Lateral Ventricles

- Each lateral ventricle is c-shaped that wraps around the thalamus
- 5 parts
  - Frontal, temporal, and occipital horns, the body, and the atrium
- Walls are formed by the:
  - Thalamus, septum pellucidum, deep cerebral white matter, corpus callosum, caudate nucleus, and the fornix
Fornix

- C-shaped structure that wraps around thalamus in wall of ventricle.
- Consists of hippocampomamillary tract fibers
  - Originate from hippocampus, subiculum, and dentate gyrus of temporal lobe
- Fimbria arises in floor of temporal horn and passes posteriorly to become crus of fornix
- Paired crura meet to form body of fornix
  - Separates roof of third ventricle from the floor of the lateral ventricles
- Body of fornix separates into 2 columns that arch along the superior and anterior margins of the foramen of Monro in their course toward the mamillary bodies.

Lateral Ventricle

- Frontal horn is anterior to the thalamus
- Body is above the thalamus
- The atrium and occipital horn are behind the thalamus
- Septum pellucidum is the medial wall of the frontal horn and body
- Hippocampal formation in floor of temporal horn
- Fornix arises in hippocampal formation and wraps around thalamus

Foramen of Monro

- Frontal horn of lateral ventricle is anterior and body behind the foramen of Monro.
- The columns of the fornix form the anterior and superior margins of foramen.
- Choroidal fissure is cleft between fornix and the thalamus along which the choroid plexus is attached.
  - Superior choroidal vein
Foramen of Monro Anatomy

- Foramen of Monro
- Sepal Vein
- Choroid Plexus
- Thalamostriate Vein

Venous Anatomy

- Veins from frontal horn and body of lateral ventricle drain into the internal cerebral vein.
  - Thalamostriate and septal veins
  - Thalamostriate v. lies between caudate nucleus and thalamus
- Veins from temporal horn drain into the basal vein of Rosenthal.
- Veins draining atrium drain into basal, internal cerebral, or great vein of Galen
- 2 internal cerebral veins and 2 basal veins drain into the vein of Galen

Arterial Anatomy

- Anterior choroidal arteries send branches to choroidal fissures to choroid plexus
- Anterior cerebral arteries pass around the anterior wall of the third ventricle and anterior wall of frontal horns to roof of lateral ventricles.
- Posterior cerebral arteries pass medial to temporal horns and atria and give rise to posterior choroidal arteries
  - Posterior choroidal arteries pass through choroidal fissure to supply choroid plexus

Third Ventricle

- Midline cavity which connects each lateral ventricle through the foramen of Monro anterosuperiorly and posteriorly with the 4th ventricle through the aqueduct of sylvius.
- Roof has 4 layers
  - Fornix, 2 thin membranous layers of the tela choroidea, and a layer of blood vessels between the sheets of the tela choroidea
  - Tela choroidea forms 2 of the layers in the roof
    - 2 thin semiopaque membranes derived from the pia mater.
    - Velum interpostum is space between 2 layers of tela choroidea
  - Vascular layer consists of medial posterior choroidal arteries, internal cerebral veins and their tributaries
- Choroidal fissure is located in the lateral margin of the roof
ETV

Colloid Cyst: Neuroendoscopic Approach

Interhemispheric Transcallosal Approach to the Lateral and Third Ventricle
Cerebral Vascular Anatomy

Aortic arch and branches

CTA of Carotid

Aortic Arch Normal Variants

Origin of Vertebral Artery

- Right common or Internal Carotid Artery
- Directly from Aortic Arch
- From Subclavian Distal to Thyrocervical Trunk
**MRA: External/Common Carotid**

The carotid sheath is sharply opened from the region of the carotid artery bifurcation to the angle of the mandible and the nervous structures are sequentially identified: 1- sternocleidomastoid muscle, 2- posterior belly of digastic muscle, 3- hypoglossal n., 4- external carotid artery, 5- internal carotid artery, 6- internal jugular vein.

The internal jugular vein has been retracted anteriorly and the carotid bifurcation visualized. 1- transverse process of C1, 2- internal carotid artery, 3- external carotid artery, 4- hypoglossal n., 5- vagus n., 6- occipital artery, 7- spinal accessory n., 8- internal jugular vein.

**External carotid artery**

The internal jugular vein has been retracted anteriorly and the carotid bifurcation visualized. 1- transverse process of C1, 2- internal carotid artery, 3- external carotid artery, 4- hypoglossal n., 5- vagus n., 6- occipital artery, 7- spinal accessory n., 8- internal jugular vein.

**Fig. 3-2.** Anatomic sketch of the external carotid artery (ECA) and its major branches (lateral view). 1- Superior thyroid artery, 2- Anterior thyroid artery, 3- Internal maxillary artery, 4- Facial artery, 5- Temporal artery, 6- Occipital artery, 7- Ophthalmic artery, 8- Maxillary artery, 9- Transverse facial artery.
Figure of External Carotid Artery

Figure of Maxillary Artery
External Carotid Artery

Branches of Distal Maxillary Artery

Fig. 3-4. Diagrammatic sketch of the distal maxillary artery as it branches within the pterygopalatine fossa. 1. Sphenopalatine artery. 2. Sphenopalatine ganglion. 3. Maxillary nerve (V2) and the artery of the foramen rotundum. 4. Vidian artery. 5. Pharyngeal artery. 6. Descending palatine artery. 7. Posterior superior alveolar artery. 8. Infraorbital artery.

Internal Carotid Artery

Cervical and Distal Component

• Anomalous Branches
  – Inferior and Ascending Pharyngeal
  – Vidian
  – Occipital
  – Pro-atlantal Intersegmental anastomosis with the vertebral
  – Hypoglossal anastomosis with the Basilar

Internal Carotid Artery

Cervical and Petrous Component

Internal carotid artery

Embryologic Anomalies
### Internal Carotid Artery

#### Segments

<table>
<thead>
<tr>
<th>Segment</th>
<th>Description</th>
<th>Branches</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1-</td>
<td>Cervical Segment: Bifurcation to Carotid Canal</td>
<td>Vertical, Genu, Horizontal</td>
</tr>
<tr>
<td>C2 &amp; C3-</td>
<td>Petrous &amp; Lacerum Segments: Commonly called the Petrous Segment</td>
<td>Vertical, Genu, Horizontal</td>
</tr>
<tr>
<td>C4-</td>
<td>Cavernous Segment: Petrous to Proximal Dural Ring</td>
<td>Vertical, Genu, Horizontal</td>
</tr>
<tr>
<td>C5-</td>
<td>Clinoidal Segment: Proximal to Distal Dural Ring</td>
<td>Vertical, Genu, Horizontal</td>
</tr>
<tr>
<td>C6-</td>
<td>Ophthalmic Segment: Distal Dural Ring to Posterior Communicating Artery</td>
<td>Vertical, Genu, Horizontal</td>
</tr>
<tr>
<td>C7-</td>
<td>Communicating Segment: Posterior Communicating Artery to Bifurcation</td>
<td>Vertical, Genu, Horizontal</td>
</tr>
</tbody>
</table>

#### Extradural Vascular Supply

- Caroticotympanic Art: Tympanic Cavity
- Vidian Art: Posterior Superior Nasopharynx
- Meningohypophyseal Trunk: Tentorial Artery of Bernasconi and Cassinari
- Dorsal Meningeal Artery
- Inferior Hypophyseal Artery
- Inferolateral Trunk: Cranial Nerves and Dura of Cavernous Sinus
- McConnell’s Capsular Art: Floor of the Sella Turcica

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**Figure of Cavernous Carotid**

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**Figure of Cavernous Carotid**
Right pterional window: right supraclinoid carotid artery, right carotid bifurcation, right MCA, right ICA, right I, II, III, IV, V1 CNs, right SCA, right P1 and P2, basilar tip and right PcomA are visible.

Right orbito-Zygomatic trans-cavernous window: basilar tip, right SCA, both P1, right P2, both PcomA, right II, III, IV, V1, V2 CNs, intracavernous carotid artery, meningo-hypophyseal trunk, gasserian ganglion are visible.

Right orbito-Zygomatic trans-cavernous window: view of mid-portion of the basilar artery through Parkinson’s triangle.

Right orbito-Zygomatic trans-cavernous window: view of mid-portion of the basilar artery through Parkinson’s triangle.
The lateral wall of the cavernous sinus has been removed: View of the intrapetrous and intracavernous carotid artery and foramen lacerum, right VI CN and Dorello’s canal.

**Internal carotid artery**

Intradural Vascular Supply Around Circle of Willis

- Superior Hypophyseal Artery: Hypophyseal Stalk and Anterior Lobe
- Optic Chiasm
- Ophthalmic Artery: Globe and Orbital Contents
- Posterior Communicating Artery: Anterior Thalamoperforators
- Tentorial Nerve, Posterior Hypothalamus
- Posterior Chiasm, Cerebral Peduncles
- Posterior limb of Internal Capsule

**Anterior Choroidal Artery:**

- Posterior limb of Internal Capsule
- Lenticulostriate Artery
- Anterior Choroidal Artery
- Anterior Communicating Artery: Optic Chiasm, Lamina Terminalis

Branches: Clinoidal Segment of Internal Carotid

**Internal Carotid Artery**

Circle of Willis - Classic View

See in 18% of Patients

Fig. 6-2: Anatomic diagram of the circle of Willis. All “Classic” circle of Willis. No component is hypoplastic or absent. This balanced configuration is present in only 18% of all cases.
Circle of Willis: Inferior View

- Right pterional window: right supraclinoid carotid artery, right carotid bifurcation, right MCA, right ICA, right I, II, III, IV, V1 CNs, right SCA, right P1 and P2, basilar tip and right PcomA are visible.

Right pterional window: Supraclinoid carotid artery, anterior clinoid process, posterior clinoid process, optic chiasm, right II and III CNs, right PcomA, right P1 and P2 and basilar tip are visible.

Internal Carotid Artery

<table>
<thead>
<tr>
<th>Variants in Circle of Willis</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypoplasia of one or both Posterior Communicating Arteries</td>
<td>22%</td>
</tr>
<tr>
<td>Absent or Hypoplastic A1 Segment</td>
<td>25%</td>
</tr>
<tr>
<td>Hypoplastic P1 Segment with Fetal Origin of Posterior Cerebral Artery</td>
<td>15%</td>
</tr>
<tr>
<td>Duplicated Anterior Communicating Artery</td>
<td>9%</td>
</tr>
</tbody>
</table>
CTA of Circle of Willis

Internal Carotid Artery

Anterior Cerebral Artery
Medial View Anterior Cerebral Artery

Anterior Cerebral Artery

Medial Lenticulostriate Vessels (A1)
Anterior Perforated Substance
Subfrontal Area
Septum Pellucidum
Para-olfactory Areas

Lateral Angiogram: Internal Carotid Artery
AP Angiogram Internal Carotid Artery

Lateral MRA: Internal Carotid Artery

AP MRA Internal Carotid Artery

Internal Carotid Artery

Middle Cerebral Artery
Middle Cerebral Artery: Inferior View

Middle Cerebral Artery

Lateral Lenticulostriate Vessels
Basil Ganglia
Internal Capsule
Caudate Nucleus

Lateral Lenticulostraiate Vessels

Lateral Angiogram Middle Cerebral Artery
Arteries of Posterior Fossa
Vertebrobasilar System

Lateral Angiogram Verterbral Artery
AP Angiogram Vertebral Artery

Arteries of Posterior Fossa

AP MRA Vertebral Artery

Posterior Circulation
The lateral wall of the cavernous sinus has been removed: View of the intrapetrous and intracavernous carotid artery and foramen lacerum, right VI CN and Dorello’s canal

Left Transcavernous View: Basilar Apex

Left Transcavernous View: Vertebral Confluens

Anterior petrosectomy surgical window: basilar artery, vertebro-basilar junction, and right aica are visible
Left trans-otic surgical window: sigmoid sinus, jugular bulb, left intrapetrous carotid artery, left facial nerve, left aica, left petrosal vein, are visible

Right trans-cochlear surgical window: basilar artery, right aica, right petrosal vein and right VI CN are visible

Right far lateral approach: superior oblique muscle is lifted and extra-cranial vertebral artery is exposed, right occipital artery is visible.

Far Lateral View: Cervical Vertebral
Left far lateral approach: dura is opened and left Pica is visible

Left far lateral approach: Pica, vertebral artery, spinal and cranial XI, XII CNs are visible

Left far lateral surgical window: brunches of Pica, IX, X CNs and choroid plexus of IV ventricle are visible

Trans-facial surgical window: vertebral arteries, vertebro-basilar junction, both VI, left VII, left VIII CNs, aica, anterior spinal arteries and petrosal vein are visible
Trans-facial surgical window: vertebral arteries, vertebro-basilar junction, both VI, left III CNs, both AICAs, both PICAs, anterior spinal arteries, both SCAS, left P1, P2, left PComA, and petrosal veins are visible.

Posterior Cerebral Artery

Origin: PCoA (Anterior) and P1 Segment of PCA (Posterior)

Enter: Posterior Perforating Substance

Supply: Thalamus, Hypothalamus, Subthalamic Nuclei, Nuclei of CN 3 + 4, Oculomotor nerve, Posterior Limb of Internal Capsule
Posterior Cerebral Artery

P2 Segment Branches
Thalamogeniculate Arteries: Thalamus, Posterior Limb
Internal Capsule, Geniculate, optic tract
Medial Posterior Choroidal: Thalamus, Pineal Body, Choroid Plexus
Lateral Posterior Choroidal: Cerebral Peduncle, Posterior commissure, lateral geniculate, Thalamus,
Fornix, Caudate, Inferior Temporal Arteries

Inferior Temporal Arteries

Lateral Angiogram Posterior Cerebral Artery

AP Angiogram Posterior Cerebral Artery
Lateral MRA Posterior Cerebral Artery

Submental Vertex View of PCA

Posterior Cerebral Artery

P3 Segment Branches

Parieto-Occipital
Calcarine
Splenial

Venous Drainage of Head
AP Venous Angiogram

Lateral MRV

AP MRV

Submental Vertex MRV
Venous Drainage of Posterior Fossa

Venous Drainage Around Brain Stem

Ventricular Venous Drainage

Venous Drainage of Head
Cervical Spine

- **Atlas/C1**
  - Ring shaped, anterior/posterior arches
    - Anterior ring articulates with dens of axis/C2
    - Transverse foramen (vertebral arteries)
    - Lateral masses lie anterior and medial
      • Form joints with condyles and axis (C2)

- **Axis/C2**
  - Elongated dens articulates with anterior ring of C1
  - Superior facet articulates with C1
  - Inferior facet articulates with C3
  - Transverse foramen (vertebral arteries)
  - Pars interarticularis versus the pedicles
    - Screw placement
Cervical Spine

- Odontoid screws

C1 lateral mass screw and C2 pedicle screw (Harms)
- Avoid vertebral artery laterally and superiorly
- Avoidance of C2 nerve root (may be sacrificed)
- Robust venous plexus

Subaxial Cervical Spine
Anterior Anatomy of Cervical Spine

• Anterior musculature
  – Platysma
  – Sternocleidomastoid
  – Longus colli

Anterior Anatomy of Cervical Spine

• Anterior musculature
  – Strap muscles (Infrahyoid)
    • Sternohyoid
    • Omohyoid
    • Thyrohyoid
    • Sternothyroid
  – Strap muscles (Suprahyoid)
    • Digastric
    • Mylohyoid

Anterior Anatomy of Cervical Spine

• Important vessels
  – External jugular
    • Superficial to SCM
  – Internal jugular (IJ)
    • Deep to SCM
    • Sits lateral to carotid
  – Common carotid
    • Deep to SCM
    • Sits medial to IJ

Anterior Anatomy of Cervical Spine

• Important nerves
  – Vagus nerve
    • Posterior in sheath
  – Branches of vagus
    • Recurrent laryngeal
      – Lower on left side
Anterior Anatomy of Cervical Spine

- Bony Anatomy
  - Vertebral body
  - Uncinate processes
    - Uncovertebral joint
    - Lateral margin for discectomy
  - Transverse processes
    - Anterior tubercle
    - Posterior tubercle
      - Groove for nerve

Anterior Anatomy of Cervical Spine

Patient Positioning and Preparation

- Soft roll under the C-spine
- Normal lordotic curve is re-established when feasible
- Patients head may be placed under traction

Anterior Anatomy of Cervical Spine
Exposure and Dissection Plane

Surgical Approaches
Anterior

Surgical Approaches
Anterior

Anterior Discectomy
Decompression - Removal of the Posterior Osteophytes

Posterior Anatomy of Cervical Spine
- Posterior musculature (superficial to deep)
  - Trapezius
  - Splenius capitis
  - Semispinalis capitis
  - Semispinalis cervicis
  - Rectus capitis posterior
    - Minor and major
  - Obliquis capitis

Exposure of Posterior Cervical Spine

Posterior Cervical Lamino-foramenotomy
Instrumentation Landmarks of the Posterior Subaxial Cervical Spine

Posterior Anatomy of Cervical Spine
- Schematic drawing of lateral mass screws

Lateral Mass Screws

Thoracic Spine
- 12 Vertebrae
- Kyphotic Curve
- Ribs Attached
- Minimally Mobile
- Facets in Coronal Plane
Surgical Approaches

- Posterior - Laminectomy (all levels)
  - Posterolateral
  - Transpedicular (all levels)
  - Costotransversectomy (thoracic)
- Lateral
  - Lateral extracavitary (thoracic)
- Anterolateral
  - Posterolateral thoracotomy (thoracic)
  - Retroperitoneal (L2-L4)
  - Thoracoabdominal (T11-L1)
- Anterior
  - Median sternotomy (T1-T3)
  - Transperitoneal (L5-S1)

Anterolateral Thoracic
(same for lumbar)

- Lateral decutitus, bean bag
- Flex down leg at knee for stability
- Pad knees with pillow
- Axillary roll
- Arms at 90 degrees
- +/- bend in table (opens up T/L junction)
- Left side up to avoid liver and vena cava
- Good for retroperitoneal approach
Exposure

Exposure
Anterior Surgical Approaches

- Access to T1 from Anterior Cervical approach in rare cases
- T2-4 via Transclavicular, Transmanubrial, T2-6 Trans-sternal/trans-thoracic
- High morbidity due to anatomical structures
Anterior Surgical Approaches

Posterior Approaches

- Midline posterior approaches allow for a variety of procedures
  - Transpedicular
  - Costotransversectomy
  - Posterolateral
  - Lateral extracavitary
  - Transforaminal
Thoracic Pedicle Screw Anatomy

- Identify Transverse process ridge
- Identify lateral 1/3 of facet joint
- 3-4mm pineapple burr for start hole
Thoracic Pedicle Screw Anatomy

- Remove all soft tissue
- Expose key anatomy
- Remove facet capsule
- Locate TP and lamina
- Remove inferior facet

Lumbar Spine

- 5 Vertebrae
- Lordotic Curve
- Facets in Sagittal Plane
Goals of model based skills simulation

**Tumor Resection**

Relax
Rest arms and hands
Surgery done with the fingers
Use two hands
Traction and counter traction
Smooth motion
No sudden motions
Cusa is a paintbrush, not a shovel
Don’t dig holes
Hemostasis

**Endoscopy**

Indications
Positioning
Burr hole location
Dural opening
Advancing to the ventricle
Identify landmarks
Identify all relevant anatomy
Enter 3rd ventricle
Identify landmarks
Perform 3rd ventriculostomy
Post procedure management

**Endovascular Simulation**

Indications
Positioning
Equipment
Personnel in the room
Radiation safety
Vascular access
Guidewire advance
Catheter advance
Coiling
Stent placement
Managing procedural complications
Closure
Post procedure management
**Stereotactic Frame Placement**

Learn the parts of the stereotactic frame  
Choose the correct screws  
Choose pin sites  
Infiltrate with local  
Place frame to proper tension  
Considerations: Pt comfort, no bar pressure, all components tight, pins perpendicular to skull, lesion within the frame volume  
Removing the frame

**Frameless Navigation**

Learn the parts of the image guidance system  
Fiducials or tracing  
Considerations of fiducial placement  
Imaging considerations  
Check the quality of the images well in advance  
T1 with gad vs T2  
Mayfield placement  
Fixing the localizer to the Mayfield  
Location of the camera  
Location of the screens  
Registration  
Mistakes in registration  
Troubleshooting registration  
Using image guidance in surgery  
Marking borders before brain shift  
Adjusting for brain shift  
Stereotactic biopsy options

**Mentored Leadership**

Open discussion of the various aspects of leadership of a medical team in the operating room, the clinic and the hospital. Expectations of the “Captain of the Ship”.
Goals of cadaver based surgical skills-Cranial

General

Nuances of positioning
Skin incision options
Soft tissue dissection
Correct position of burr holes
Dissection of dura from the skull
Proper safe use of the craniotome
Troubleshooting the equipment
Technical issues of the venous sinuses
Identifying and adapting to patients at high risk for dural tear
Dural opening, efficiency and safety
Identifying and adapting to patients at higher risk for dural adhesions
Dural tack ups
Managing dural tears
Dural closure
Technical issues of the frontal sinus

Pterional Craniotomy

Indications
Positioning
Skin incision
Preservation of the frontalis branch
Preservation of the temporalis muscle
Burr hole placement
Middle fossa craniectomy
Drilling the pterion
Brain exposure
Opening the sylvian fissure
Basal cistern dissection
Identify cranial nerves and blood vessels
Dural closure
Replace bone flap

Fronto-orbital Craniotomy

Indications
Positioning
Skin incision
One piece vs. two-piece per faculty
Dissection of skull base dura
Dissection of periorbita
Orbital protection
Orbital osteotomies
Cranialization and exenteration of the frontal sinus
Subfrontal dissection of the basal cisterns
Dural closure
Replace bone flap

**Retrosigmoid craniotomy**

Indications
Positioning
Skin incision
Soft tissue dissection
Identifying the asterion
Identifying the transverse sigmoid junction position
Occipito-mastoid suture
Mastoid air cells management
Exposing the transverse-sigmoid junction
CSF release/cerebellar relaxation
CP angle dissection
Identify cranial nerves and vessels
Dural closure
Replace bone flap

**Goals of cadaver based surgical skills - Spinal**

**General**

Nuances of positioning
Skin incision, midline vs. MIS
Soft tissue dissection
Dissection of the lamina
Joint and ligament preservation
Identifying critical anatomy
Identifying levels
Laminotomy for discectomy
Foraminotomy
**Laminectomy**

Identify levels  
Identify landmarks  
Safe drill usage  
Safe Kerrison usage  
Opening the ligament  
Separation from the dura  
Foraminotomy

**Pedicle Screw Placement**

Lateral recess dissection  
Identifying the nerve roots  
Expose the foramen  
Expose and incise the disc  
Identify the pedicle  
Identify landmarks for screw placement  
Techniques for safe screw placement  
Drilling  
Pedicle probe  
Identify pedicle breaches  
Place pedicle screws  
Prepare for rod placement

**Intradural Exposure**

Safe dural opening  
Dural tacking  
Cauda equina exposure  
Dural closure
Goals of Cadaver based Surgical Skills - Peripheral Nerve

Carpal Tunnel

Indications
Anesthesia choice
Positioning
Skin incisions
Open vs. endoscopic
Closure

Ulnar nerve

Indications
Positioning
Skin incisions
Decompression
Transposition
Closure
Leadership and Professionalism in an Era of Neurosurgical Exceptionalism

Neurosurgical Exceptionalism

- Small guild-like specialty of elite medical professionalism with strong commitment to the study of neurologic disease and the surgical craft
- Sense of history and a close academic community that fosters strong longitudinal relationships
- Fosters unity in crisis

Scope of Professionalism

- Availability and Accountability
  - Spectrum from Physical Presence to Leadership
- Responsibility and Ownership
  - Reporter to Educator
- Compassion and Sensitivity
  - Role of Physician vis-à-vis the Patient
- Clinical Trials
  - Conflict between obligation to patient versus research question

Surgical Ownership and Professionalism

- Physician’s duty defined by patient’s necessity
  - The proverbial push transport to the CT scanner
- Duty Hours Standards and the preservation of the senior resident experience
- Surgeon’s commitment and the audacity of the scalpel
Surgical Ownership and Professionalism

- Continuity of Care
  - Serial neurological exams and perioperative care
- Earned trust between mentor and trainee

Unique Elements of Neurological Surgery

- Long cases
- Need for serial neurologic exams BY THE SAME EXAMINER makes the availability of the involved surgeon critical to resident learning and patient care.
- Serial exams versus the increased imaging required by multiple handoffs segues to the next topic heading.

Entrustment and Competence

- Entrustment occurs when direct supervision is no longer needed
- Faculty understand entrustment more than competence
- Entrustment infers competence
- Doesn’t suggest that graduating residents reach a standard of performance to practice every EPA without direct supervision
- Opens the door for structured learning after residency as part of MOC

Generational Perspective

- Immense collective educational experience
- Guild-like approach to tremendous clinical challenges with unprecedented success
- Neurosurgery as a calling and apprenticeship
- Momentum in the face of winds and tides
Unique Progress in the Clinical Enterprise

- Cerebrovascular
  - Hunterian Ligation to Endovascular Reconstruction
  - New Disease States
- Spine
  - Instrumented Reconstructions
  - Oncology and Scoliosis
  - MIS

Unprecedented Success in the Clinical Enterprise

- Skull base Surgery
  - Keyhole Corridors
  - Gamma Knife Radiosurgery
  - Endoscopy / Intraventricular Surgery
- Functional
  - Electrocorticography, VNS, DBS and the Resurgence of Psychosurgery

Coming of Age in an Era of Neurosurgical Exceptionalism

- Procedural Risk / Benefit Ratios and Complication Profiles were Hard Won
- Sustained Attention and Commitment to Detail
- Captives of Technical Success and High Standard
- Appearance of Effortless Excellence

Technical Procedural Mastery

- Symphony musicians
  - ~ 20,000 practice hours for fine motor mastery
- Sustained commitment to craft
- Centers of excellence to allow sufficient case volume
Art of the Neurological Exam and Technology: Training Metaphor

- The Pride and Patience of Localization
- The Satisfaction of Diagnosis
- The Reflexive Use of Imaging
- Defensive Medicine, Road Trips for Patient Safety and Resource Utilization

Maintenance of Technical Mastery in Duty Hours Era

- Internship: Evolving Ambition
  - Socialization as a Physician
  - Historical Progression
- Preservation of the Senior Resident Experience
  - Professionalism and Surgical Ownership
  - Continuity of Care
  - Supervision and Leadership

Challenges to Education

- Maintenance of Technical Aptitude
- Boundaries of Neurosurgical Practice
- Policy and Academic Resource Environment
- Returning to a Patient-Centered Focus in Clinical Care

Encroachments on Historical Boundaries of the Specialty

- NeuroCritical Care
- Endovascular Neurosurgery
- Peripheral Nerve
- Spine and Deformity
Challenges From Outside Medicine

- Duty Hours Standards a Proxy Battle for Control of Professional Discretion
- By Definition, a Profession must dictate the standards for admission to its ranks
- Role of ACGME in representing the medical and surgical professions

Engagement of the Policy Process and Utilization Review

- Reimbursement and the Academic Mission
- Clinical Research Funding
- Gap between strategic vision and execution often a question of resources
- Patient Care and Affordability Act, ACOs and Shifting Reimbursement

Challenges Bring Opportunities

- Darwinian Selection Pressure for Programs to more efficiently train residents
- From Apprenticeship to ACGME Competencies to Milestones and the Matrix Curriculum
- Deliberate effort to maintain the best traditions of our field

Boot Camp Steps into the Breach

- Interns are the least clinically experienced and least suited to the rigors of residency training, and therefore have the least ability and insight into fatigue.
- Junior residents in surgical disciplines, namely the individuals seeing consults, assisting in surgery, and beginning to make independent clinical judgments, are more well suited to making appropriate care decisions on an independent basis.
Boot Camp II Continues Tradition

- Internship is much less a technical education, and much more a socialization into becoming a doctor and interacting with other members of the care team.

- Obviously, a strong culture beginning with senior residents must be in place to assure adequate supervision of procedures or significant management decisions.

Technical Mastery

- Simulation, Animal and Cadaveric Adjuncts
- SNS/AANS modules
- Screen-sharing and Operative Planning
- Matrix Curriculum and Ongoing Assessment of Competencies
- Living Case Logs and Rational Operative Assignments

Future Curricula

Neurosurgical Exceptionalism: Drawbacks of Duty Hours

- Erosion of Trust between chief and attending
- Definition of a Profession and Shared Experience
- Invest meaningfully in the humanism of the senior resident relationship
- Policy is a Floor, Not a Ceiling
Role Models versus Mentorship

- **Role Model**
  - “A Model in Particular Behavior or Social Role for Another Person to Emulate”

- **Mentor**
  - “the process whereby an experienced, highly regarded, empathic person (the mentor) guides another individual (the mentee) in the development and re-examination of their own ideas, learning and personal and professional development.”

Mentorship

- **A Dynamic Reciprocal Relationship**

- **Origins in the Iliad**
  - Odysseus entrusts his son Telemachus to Mentor during the ten year Trojan War
  - Mentor shapes Telemachus in his personal and professional development

Humanism and the Rise of The Mentor

- Diverse methods of training from didactic to socratic instruction

- Humanistic fields gravitate to the model of apprenticeship
  - Fine Arts of Sculpture, Painting and Music all conform to this model
  - Religious students and Philosophers likewise adopt deliberative and meditative apprenticeships

Career Choice and Mentorship

  - 142 articles abstracted from 3640 citations
  - Less than 50% medical students and 20% of faculty reported mentorship arrangements
  - Examined the prevalence, satisfaction, and bearing of mentorship on academic career choices
Sambunjak et al. and Mentorship

- Personal Development
- Career Guidance
- Career Choice
- Research Productivity
  - Publication Metrics
  - Grant Success

Hippocratic Medicine

- Nexus of science and human intangibles
- Art of compassion, inspiration and nuance
- Surgery is at once requires
  - Profound interpersonal relationships at the defining moments of a patient’s life
  - Technical mastery of artful and delicate procedures
  - Rational progression of inquiry and the scientific method

Charge of the Specialty

- Interview process to Boot Camp
- Internship as Socialization to Being a Physician
- Junior-Senior Resident Relationship
- Preserving the Chief-Attending Apprenticeship
- Seasoned Neurosurgeons the Last, Best Hope to Maintain this Proud Tradition

Athlete Culture of Fatigue

- In competitive sports, athletes always want to play... even if tired or hurt.
- Coaches pull players who are not effective despite that desire.
- Ultimately, patient care responsibility lies with the attending and senior residents.
- We need a culture where the junior, who may not have insight into fatigue affecting his or her performance, is tapped out if felt necessary by the supervising individual...
Culture of Supervised Responsibility: Senior Residents

• I will only reprimand at you for lying. If something is important enough that I would yell about its improper performance, I should do it myself.

• If you think about calling me, call. I will never be upset or bothered you called. If nothing else, I will reassure you that your thought process was correct and set up a decision rule for next time. That is how we learn.

• I will appreciate your work. I realize that I am the one responsible. That means everything you do, if you were unavailable or incapable, I would have to do myself. It is okay if you don’t do everything; I only need to know what is done and what is not to confirm everything ultimately gets done.

Ownership and Professionalism Revisited

• It further remains important to guard against a culture of entitlement which may follow the definition of residents as purely passive vessels to be educated.

• Transporting a patient to CT scan may not be of educational value nor an efficient use of resident time, but we should worry about training a generation of physicians who are not willing to push a gurney to CT if that is what the patient needs.

Neurosurgery and the Continuity Rebuttal

• Surgeons, by contrast, spend their day active and engaged in physical tasks, and are therefore far less susceptible to the fatigue that comes with tedious clerical work or constant time pressure. While these factors are obviously present in surgical practice, they do not dominate the experience.

• Moreover, the patient-surgeon relationship requires immense trust and the expectation the responsible surgeon will be available should untoward events befall the patient during their hospital course. There is an ownership that comes with the audacity of surgically invading someone in hopes of making them better.

Pursuit of Something Greater than Yourself

• Resist Self-Congratulation of Surgery

• Champions
  – Change the Practice of Surgery
  – Train the Next Generation of Surgeons
Signs of Pain in Patients with Poor or Altered Consciousness

- Increased delirium
- Increased agitation
- Increased heart rate
- Increased blood pressure

- LIMITED USE OF OPIATES AND OTHER SEDATING MEASURES TO PREVENT DECLINE AND PERMIT MONITORING MUST BE BALANCED AGAINST ADVERSE EFFECTS OF FAILURE TO ADEQUATELY ADDRESS PAIN
- Blood-pressure control following hypertensive hemorrhage or unsecured aneurysm rupture
- Minimize excessive agitation which can cause injury

Post-Craniotomy Pain

- Up to 80% of post-craniotomy patients experience moderate to severe pain in first several days after surgery
- Up to 50% can experience headache months after surgery
- Post-craniotomy pain is frequently undertreated
- Unnecessary patient discomfort
- Adverse effects which can promote post-craniotomy complications include hypertension, agitation, shivering and vomiting
Post-Craniotomy Pain

- Surgical technique can reduce post-operative pain
- Minimize muscle incision, damage or resection
- Repair temporalis fascia
- Infratentorial procedures associated with more pain than supratentorial procedures
  - Craniotomy associated with less pain than craniectomy
  - Separating muscle and dura with cranial or titanium plate reduces pain
- Employ less invasive procedures where possible (ex. transphenoidal endoscopic resection rather than craniotomy)

Post-Craniotomy Pain Control

- Morphine superior to tramadol and codeine perioperatively without increasing sedation, vomiting or decreased ventilation
- Patient-controlled analgesia (PCA) may be considered but not appropriate for all patients
- Work with anesthesia pain management to determine suitability
- Anti-convulsants (ex. gabapentin) initiated 7 days prior to surgery can significantly reduce post-operative pain scores and opioid use while reducing opioid-induced hyperalgesia

Post-Craniotomy Pain Control

- NSAIDs have been poorly studied
- Chronic NSAID use within 2 weeks of craniotomy associated with post-op hemorrhage
- Transfuse platelets for emergency craniotomy
- Regular ("scheduled") use of NSAIDs after craniectomy may reduce pain and opiate needs but risks remain unclear
- Half of UK neurosurgery centers report perioperative NSAID use but small minority in US
- NSAID use post-craniotomy requires better studies but until such studies the potential risk will continue to minimize use in craniotomy and intracranial hemorrhage patients

Post-Laminectomy Pain Control

- More complex than post-craniotomy pain control since most patients require chronic pain-control pre-op which can cause some degree of resistance
- IV PCA is often preferable to intermittent IM administration of opioids
- Should be used more liberally than in post-craniotomy patients given less baseline brain disease and greater baseline drug resistance
Post-Laminectomy Pain Control

- Opioid therapy alone is often not best choice for post-laminectomy pain control
- NSAIDs can be considered more readily than following craniotomy, although concerns regarding hemorrhage and adverse effects on bone healing can limit dosing
- Steroids can be considered, particularly if post-operative radicular pain suggests ongoing inflammatory component
- Acetaminophen is often useful adjunct to opiates
- Non-pharmacological pain control methods
  - Use of braces/collars to reduce post-operative motion-related pain
  - Surgical technique to minimize muscle incision (limit laminectomy to necessary levels, minimally-invasive/muscle sparing surgery)

Post-Operative Pain Control On Discharge

**Percocet 5/325**
- 1-2 tabs
- Q4-6hrs prn

**Not Strong Enough**
- Oxycontin 10mg 12hr-ATC + Percocet
- Dilaudid 2-4mg q3hrs prn
- Tylenol 3-4 tabs
- Q6-8hrs prn

**Too Strong**
- Ultracet 500mg 2 tabs
- Q6-8hrs prn
- Vicodin 5/500 1-2 tabs
- Q6-8hrs prn

Pain In the US (Millions)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>76</td>
</tr>
<tr>
<td>Diabetes</td>
<td>23.6</td>
</tr>
<tr>
<td>Heart Disease</td>
<td>23.3</td>
</tr>
<tr>
<td>Cancer</td>
<td>11</td>
</tr>
</tbody>
</table>
Back Pain

- 2nd most common cause for office visit
- 60-80% of population will have lower back pain at some time in their lives
- Each year, 15-20% will have back pain
- Most common cause of disability for persons < 45 years
- 1% of US population is disabled
- Costs to society: $20-50 billion/year

Chronic Pain Conditions

- Degenerative disk disease
- Herniated disk pain refractory to conservative and surgical interventions
- Post-laminectomy syndrome
- Osteoarthritis
- Spinal stenosis
- Complex regional pain syndrome (RSD)
- Post-Herpetic Neuralgia
- Cancer, Chemotherapy, and Radiation Pain and Neuropathy
- Diabetic/HIV Neuropathy
- Pelvic and Abdominal Pain syndromes
- Trigeminal neuralgia

Important Terms

- Nociception - ability to feel pain (transduction, transmission, modulation, perception)
- Dysesthesia - abnormal, unpleasant sensation
- Allodynia - normally not painful sensation which now painful
- Hyperalgesia - exaggerated pain response
- Sensitization (peripheral and central) - remodeling pain areas

Pain Categories

- Pain can be classified according to primary etiology
  - Neuropathic
    - Arises within neural elements
    - Often but not always due to trauma or nerve irritation
    - Symptoms: burning, stabbing, electrical, paresthesia
  - Nociceptive
    - Due to activation of nociceptors
    - Aching, deep pain - Often difficult to localize as clearly as neuropathic pain
    - Examples: cancer pain, aching/twisting back pain from failed back surgery
    - Mixed neuropathic and nociceptive
Vicious cycles

Anxiety
Lack of sleep
Lack of exercise

More pain

Break the vicious cycles

Improve sleep

Reduce anxiety
Less pain
Regular exercise

Treatment algorithm

- Based on risks vs. benefits ratio
- Start with non-pharmacological conservative management
- Consider: regular exercise program, regular sleep and relaxation techniques, physical therapy

Pharmacotherapy

- Non-steroidal anti-inflammatory analgesics (Advil, Motrin, Aspirin)
- Acetaminophen (Tylenol)
- Tricyclic antidepressants (Elavil)
- SNRIs (Duloxetine/Cymbalta)
- Antiepileptics (gabapentin)
- Morphine and morphine derivatives (With proper documented indication)
Pharmacological Treatment (Contd.)

- **Antidepressants**
  - Most useful for constant burning neuropathic pain
  - Also helps to regularize the sleep
  - Can have direct analgesic and mood elevating effect
  - **Side effects:** sleepiness, orthostatic hypotension, irregular heart rates, dry mouth

- **Commonly Used Antidepressants**
  - Amitriptyline (elavil)
  - Nortriptyline (pamelor)
  - Duloxetine (Cymbalta)

Pharmacological Treatment (contd.)

- **Anticonvulsants**
  - Best for sharp, shooting, lancinating neuropathic pain
  - Also called membrane stabilizing agents
  - Raises the firing threshold of the impulses
  - **Side effects:**
    - Sleepiness, spacey feeling
    - Carbamazepine: agranulocytosis, hepatitis

- **Commonly Used Anticonvulsants**
  - Gabapentin (neurontin)
  - Pregabalin (lyrica)
  - Carbamazepine (tegretol)
  - Topiramide (topamax)

Pharmacological Treatment (Contd.)

- **Precautions:**
  - No alcohol or sleeping medications
  - No driving till side effects leveled off
  - Do not rush to get up from the bed to avoid "orthostatic hypotension"
  - cardiologist must know all medications

Pharmacological Treatment (Contd.)

- **Analgescics:**
  - Best for nociceptive pain
  - Nonsteroidal anti-inflammatory drugs (Advil, Mobic, Celebrex)
  - Morphine and morphine derivatives (opioids—percocet, oxycontin, dilaudid and methadone)
  - **Analgesic side effects:**
    - NSAIDs: gastric upset, ulcer, bleeding, may affect kidney and liver
    - Opioids: habit forming, drug dependence, tolerance, sleepiness, confusion, may affect breathing
**Opioids : Morphine and its derivatives**

- Long acting preparations: Avinza, Kadian, MSContin, Oxycontin, Opana (extended release oxymorphone), methadone, Nucynta ER (tapentadol), Butrans Patch, Fentanyl patches, Exalgo (long acting hydromorphone)
- Short acting preparations: hydrocodone, hydromorphone, Morphine Sulfate Immediate release, oxymorphone, tapentadol
- High Abuse Potential Opioids
  - Actiq: transmucosal fentanyl preparation
  - Fentora: Fentanyl buccal tablets
  - Long term use of Oxycontin, Opana or any opioid for that matter without proper monitoring

**Common routes of Administration**

- Oral
  - Not feasible for many patients during the perioperative period.
  - 1 to 2 hour lag to peak effect
- IM injection
  - Painful and short acting administered every 3 to 4 hours.
  - Slow and variable absorption, 30- to 60-minute lag to peak effect
- IV bolus
  - Better absorption, faster effect than IM, and less painful
- IV PCA
  - Patient controlled and increased satisfaction
  - Potential for operator error, patient tampering, device malfunction
- Regional
  - Targeted, continuous relief that may reduce need for systemic opioids.
  - Can be combined with IV PCA (peripheral catheter)
  - **Neuraxial administration:** Epidural or intrathecal

**Limitations with Opioids Rx**

- Acute
  - Adverse effects: sedation, vomiting, hypoventilation
  - Hyperalgesia: Intraoperative remifentanil particularly problematic for post-operative hyperalgesia (recent studies suggest 7 days of preoperative gabapentin can reduce post-op hyperalgesia)
- Chronic
  - Do not work on neuropathic pain unless given in high doses
  - Difficult or unclear long-term treatment plan (for how long or rest of life)
  - Continuation of prescriptions when one physician leaves the group
  - How often patient should follow up—monthly!
  - Codeine
    - Ineffective in 10% of population which lack enzyme to demethylate codeine to morphine

- Tolerance to the medication
- Decreasing beneficial effect
- Increasing potential side effects, mental cloudiness, decreased motivation
- Worsening disability
- Addiction and dependence
- Difficulty in discontinuation of therapy

OPIODS CAN BE A PROBLEM!

“USA used 99% of world’s supply of hydrocodone in 2006”

Patients with Hx of Drug Abuse

- Have right to have adequate pain control
- May have developed tolerance
- May have lower pain threshold
- May complicate the care by selectively asking for the pain medication

**Methadone is the best for chronic treatment of these patients but short-term use of any appropriate medication is indicated following surgery or injury with very controlled supervision.**

Limitations of Medical Treatment

- No medication without side effects
- Non-opioids are good for mild pain only
- IV meds tend to work faster than PO but have shorter half-lives
- Kidney and stomach at risks of severe adverse effects
- With opioids: tolerance, dependence, addiction, stigma, DEA regulations, no long term plan

- Corrective neurosurgery (ex. degenerative or complex spine surgery) or pain management neurosurgery (spinal stimulation, intrathecal pumps, rhizotomy/lesions, microvascular decompression) appropriate when conservative management fails and/or pain is accompanied by neurological deficits
The Need for Safer Transitions of Care

- Medical errors result in ~98,000 deaths/year in the U.S.
- Communication errors cited in nearly 65% of sentinel events

![Chart showing communication errors in sentinel events]

Handoffs and Their Importance

- Handoff: definitions
  1. Verbal and written communications between healthcare professionals as they transition between work shifts
  2. Transfer of primary responsibility of patient care to another person

- Cross-coverage is an independent predictor of potentially preventable adverse events

![Table showing characteristics and percentages of preventable adverse events]

- 43% or surgical adverse events attributed to communication errors
- Handoff error or clinician shift change implicated in 66% of these

Gawande et al. Surgery 133:614-21 2003
Modifiable Factors in Deficient Handoffs

- Background noise or activity
- Disorganized communication
- Too much/too little information
- Failure to communicate high-risk status
- Incomplete transition of responsibility
- Hierarchical barriers
  - Junior residents reluctant to hand work off to seniors
- Mismatch of information conveyed
  - Differing levels of resident experience/seniority
  - Differing expectations by provider type
- Communication Breakdown
  - Speaker: overestimates how well the message is understood
  - Listener: failure to listen


Emphasis: Transition of Responsibility

- After finishing a case in the evening, an attending comes to round in the ICU and asks the night float about a CT on a patient that s/he is covering.

“I’m sorry, that’s not my patient” is not acceptable!

- Handoffs transfer professional responsibility of patients in addition to informational content.

Improving Handoffs: Why Now?

- The rate of preventable adverse events remains unacceptably high
  - Conventional, non-standardized handoffs anticipated only 42% of overnight adverse events on surgical patients
- Implementation of duty hours restrictions
  - Number of handoffs increased 40% after implementation in 2003
  - Average of 15 handovers during a 5-day hospitalization since 2011
  - Cultural change in healthcare that emphasizes shifts
- Increasing involvement of non-physician providers

Scoglietti VC et al. Am Surg 76:682-6, 2010

Transitions of Care: From ACGME Common Program Requirements VI.B

- Programs must design clinical assignments to minimize the number of transitions in patient care.
- Sponsoring institutions and programs must ensure and monitor effective, structured hand-over processes to facilitate both continuity of care and patient safety.
- Programs must ensure that residents are competent in communicating with team members in the hand-over process.
Handoffs in Other Fields:
Key Elements

- Face to face transfer of information
- Limited interruptions, quiet environment
- Structured format to decrease omissions
- Written summary with checklist
- Accurate and up-to-date information
- Specific contingency plans
- Unambiguous transfer of responsibility
- Both sender and receiver may ask questions
- "Read-back" to increase memory and familiarity

Data to Convey in Handoffs

<table>
<thead>
<tr>
<th>Written Sign-out List</th>
<th>Verbal Exchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name/MD</td>
<td>Describe each patient</td>
</tr>
<tr>
<td>Age/ID</td>
<td>Identify active problems with current management and ongoing plan for each problem</td>
</tr>
<tr>
<td>Location</td>
<td></td>
</tr>
<tr>
<td>Attending</td>
<td>Presenting studies/plan</td>
</tr>
<tr>
<td>Code Status/ack</td>
<td>Review tasks being signed out</td>
</tr>
<tr>
<td>Dx</td>
<td>Planned admissions</td>
</tr>
<tr>
<td>Operation(s) and date(s)</td>
<td>Expected communications up the chain of command</td>
</tr>
</tbody>
</table>
| Admission
| Focused PMH |
| Tubes/Drains/Lines | |
| Active Issues | |
| Things to Do | |
| Chain of Command | |

Sample Template for Handoffs:

“SBAR”

- Originally developed in the U.S. military, adapted for healthcare
- Most commonly cited handoff tool
- Endorsed by the WHO

| Situation | Patient ID, covering MD and contact info, present illness, procedure details |
| Background | Diagnosis, code status, PMHx, surgical Hx, Meds, Allergies, VS, lab results, significant events during hospital stay, pertinent exam findings |
| Assessment | Specific needs and concerns, cardiovascular stability, surgical complications, relevant cultural factors |
| Recommendation | Treatment plan, discharge plan, preoperative assessment complete or not, etc. |

Time is allowed for dialog and questions at the end.

Handoffs in Neurosurgery

- Specific challenges in neurosurgery handoffs
  - Severity and acuity of illness
  - Risks associated with lumbar and external ventricular drains
  - Management of elevated ICP
  - Indications for surgery vs conservative management
  - Importance of serial neurological exams
  - Many others

- Significant opportunity for improvements in neurosurgery handoffs
  - Survey of 449/795 residents
    - 58 programs
Sample Template for NSG Handoffs: The “SAAFE” Checklist

S: Sick patients
- Relevant information pertaining to the sickest patients on service with a plan for clinical deterioration.

A: After Surgery
- Summary of all recent post-op patients, who are vulnerable to early complications.

A: Admissions
- Recent and expected admissions with treatment plans.

F: Follow closely
- Patients with neurological conditions known to have a natural history of clinical deterioration.

E: Essential run-through
- A complete run-through of the patient list, highlighting diagnosis, pertinent history, course in hospital, active issues and outstanding tasks.

Sample Handoff Form from Washington University

Electronic Form:

Rounding List:

(Data auto-populates from EMR)

Tools for Use in Handoffs

- Presently, >25 mnemonics exist for use as handoff tools
  - May not be “one size fits all”

- Jorm et al. Med J Aust, 2009 asserts that the best handoff tool is created through “flexible standardization” and contains:
  - Minimum core clinical content
  - Customization based on local/institutional needs
  - Specialty-specific content

Summary

- Transfer content and professional responsibility
- Communication strategies
  - Face-to-face
  - Prioritize time on the sickest patients
  - Ask questions
  - “Read-back” to increase memory
- Verbal content with specific contingency plans
- Comprehensive, updated written content
- Tasks to be completed
- Standardize the handoff format
Disclosure of Medical Errors AND Risk Management

No one makes an error on purpose
Everyone makes mistakes every day
No one admits an error if you punish them for it.

Harvey Cushing's Open and Thorough Documentation of Surgical Mishaps at the Dawn of Neurologic Surgery

Katherine Calhoun, MD; Courtney Fadok, MD; Alexander Wind, MD; Nathan A. Cohen-Gould, MD; MD

- “Cushing openly acknowledged and described significant instances of human error, mistakes in judgment and technique, and equipment and supply oversights, regardless of whether these events affected patient outcome.”
Iceberg Model of Accidents and Errors

Institute of Medicine: “To Err is Human”

- 98,000 deaths/year
- 0.2-2% hospitalized patients experience major permanent injury or death secondary to medical care
- Vast majority (90%) due to failed systems and procedures, not physician negligence
- System flaws set good people up to fail

Humans Make Errors

- Limited short term memory
- Being late or in a hurry
- Limited ability to multi-task
- Fatigue
- Stress
- Interruptions
- Environment

However most errors are systems related!

- Interaction of multiple factors at different levels of a complex system

Adverse event: harm related to medical treatment or lack thereof and generally not caused by an error

- Medical errors can have a subjective component
  - Patient’s perspective may be very different than physicians
• “Malpractice suits often result when an unexpected adverse outcome is met with a lack of empathy from physicians and a withholding of essential information.”

• Health care providers often do not disclose medical errors for fear of lawsuits

Disclosure of Adverse Events

- “when a healthcare injury occurs, the patient and the family or representative is entitled to a prompt explanation of how the injury occurred and it’s short and long-term effects. When an error contributed to the injury, the patient and the family should receive a truthful and compassionate explanation about the error and the remedies available to the patient. They should be informed that the factors involved in the injury will be investigated so that steps can be taken to reduce the likelihood of similar injury to other patients.”

Disclosure of Adverse Events

- Emotional effects for patient and physician make communication difficult
- Communication failures may cause distrust of medical team
- Communication should be prompt, compassionate and honest
- Error disclosure may reduce a patient’s intention to file a lawsuit
What If…I Make a Mistake

- Don’t panic, stay calm
- Perform appropriate clinical action to stabilize situation – ask for help if needed
- Contact senior residents and/or attending
  - Hospital risk management
- In advance, plan what should be said to patient/family and by whom

Summary

- Disclosure now viewed as responsibility of healthcare team
- Communication may be difficult but should be prompt and compassionate
  - Emphasize system and personal improvements to avoid similar event
- Appropriate and timely disclosure may not increase malpractice lawsuit risk

More than words: Patients’ views on apology and disclosure when things go wrong in cancer care

Ruthanna M. Higginbotham, Lynn M. Carney, Douglas Byers, Deborah A. Lavery, Christopher L. Finan, Josephine Laffey, Carolyn D. Preston, Kathleen Herman, Thomas L. Lashbrook

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- Provide information on what happened
- Provide apology and expressions of regret
  - Concern, caring, empathy
- Patient’s value an acknowledgment of responsibility
- Emphasize individual and system level changes so that recurrences are prevented for other patients
**Quality Improvement In Neurosurgery**

**Definition of Quality**
Quality of care is the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge.

**Creating National Awareness**
Institute of Medicine Reports
- To Err Is Human 1999
- Crossing The Quality Chasm 2001
- Preventing Medical Errors 2006

*Goal: Improve quality and operational efficiency and reduce costs*

**Why Safety as priority?**
- Ethical obligation to provide reliably safe high quality care
- Complexity of care and potential for inadvertent harm
- Regulation, Pay for performance
- Opportunities to be more efficient
- Malpractice Premiums
- We will all be patients some day
Like it or not, we are being watched

- CMS
- AHRQ
- Agency for Healthcare Research and Quality
- CAHPS
- Consumer Assessment of Healthcare Providers and Systems
- NCOA
- National Committee for Quality Assurance
- State Medical Boards
- PQRI
- Hospitals
- Lawyers

Institute of Medicine: “Quality Chasm” Report

- Best practices as organizational standards
- Use of information technology
- Improve workforce knowledge and skills
- Develop effective teams
- Coordination of care for complex patients
- Develop informative measurements for performance and outcomes

Model for Improvement

What are we trying to accomplish? What do we want to fix? It is measurable.
How will we know that a change is an improvement? Construct a plan that improves the problem.
What changes can we make that will result in improvement? What works?

Act Plan
Study
Do

New System for Patients to Report Medical Mistakes
**Need for Measurement**

Improvement is not measurement. But measurement plays an important role:
- Key measures are required to assess progress on team’s aim
- Data from the system can be used to focus improvement and refine changes

**What can you do now to improve quality?**

- What ideas do you have that you feel could improve patient care?
  - Surgical site infection?
  - Ventricular drain infection?
  - AED use and overuse?
  - Venous thromboembolism prophylaxis?

**A General Approach to Developing Measures**

- Collect data before and after making changes
- Less than six measures
- Useful and manageable
- Feasible!

**Possible EVD Infection Reduction Measures**

- Dressing intact
- CSF sampling protocol followed
- Days in place

**Data Collection for Measures**

- Include the collection of data with another current work activity (check if EVDs are dressed on rounds)
- Develop an easy-to-use data collection form
- Define roles for ongoing data collection
- Set aside time to review data
Why me, I'm just a resident?

- Quality Improvement
  - "It's about the patient!"
- Enhance reputation
- National leadership in quality research
- Leadership opportunity
- Influence policy initiatives
  - Quality measures, P4P, N2QOD
- Grant opportunities
  - CMS/NIH/AHRQ/Foundations

Suggestions

- Junior Resident Projects
  - Lower the incidence of surgical site infections, PVT/PE
- Intermediate Resident Projects
  - Improving Emergency Transfer times.
  - Improving the time to the OR during emergencies
- Senior Resident Projects
  - Improving interdisciplinary care in complex disorders (e.g., Vascular, Functional)
  - Reviewing & publishing outcomes in complex neurosurgical conditions

Physician Quality Reporting Initiative

2009 PQRI Quality Measures

- 153 2009 PQRI quality measures
  - Includes 101 measures from the 2009 PQRI and 52 new measures
  - E-prescribing measure (Measure #125) removed, as required by the MI/PPA
  - 18 measures reportable only through registries

CMS: Carrot then the Stick

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Current Trends & Hot Buttons

- Linking payment to quality
  - “Pay for Performance”
  - “Never” events
- Evidence-based practice initiatives
- Public reporting & consumer-driven health care
- Adoption of information technology

National Neurosurgery Quality and Outcomes Database (N2QOD)

- Goal: to generate performance benchmarks and value of care (locally and nationally)
- Endorsed by AANS, CNS, ABNS, Senior Society
- Multicenter collection of neurosurgery data for most common procedures
- Establish risk-adjusted expected morbidity and one-year outcomes for the most common neurosurgical procedures
- Generate nationwide quality and efficacy data to support claims made to CMS

Institute of Medicine: “Quality Chasm” Report

“Quality problems occur typically not because of failure of goodwill, knowledge, effort or resources devoted to health care, but because of fundamental shortcomings in the ways care is organized”

Trying harder will not work: Changing systems of care will