Society of Neurological Surgeons

PGY1 Boot Camp Course

Reference Guide

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# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Acknowledgements</td>
<td>1</td>
</tr>
<tr>
<td>II. Disclaimer</td>
<td>1</td>
</tr>
<tr>
<td>III. Preface</td>
<td>2</td>
</tr>
<tr>
<td>IV. Dedication</td>
<td>2</td>
</tr>
<tr>
<td>V. Introduction</td>
<td>3</td>
</tr>
<tr>
<td>VI. Statement on Conflicts of Interest</td>
<td>13</td>
</tr>
<tr>
<td>VII. Procedural Skills Stations</td>
<td>15</td>
</tr>
<tr>
<td>VIII. Operative Skills Stations</td>
<td>28</td>
</tr>
<tr>
<td>IX. Lectures</td>
<td>31</td>
</tr>
<tr>
<td>i. Professionalism, Supervision, and Pearls for the PGY1 Resident</td>
<td></td>
</tr>
<tr>
<td>ii. Neurological and Neuro-trauma Assessment</td>
<td></td>
</tr>
<tr>
<td>iii. Emergency Cranial Radiological Assessment</td>
<td></td>
</tr>
<tr>
<td>iv. Emergency Spinal Radiological Assessment</td>
<td></td>
</tr>
<tr>
<td>v. ICP Management</td>
<td></td>
</tr>
<tr>
<td>vi. Unstable Neurosurgical Patient: Case Scenarios</td>
<td></td>
</tr>
<tr>
<td>vii. Emergency Evaluation and Management of Hydrocephalus Shunt Patients</td>
<td></td>
</tr>
<tr>
<td>viii. Making the Incision: Surgical Pause to Scalp Blood Supply</td>
<td></td>
</tr>
<tr>
<td>ix. Patient Safety and Clinical Communications</td>
<td></td>
</tr>
</tbody>
</table>
I. **Acknowledgements:**

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We thank Shirley McCartney, Ph.D., for editorial review.

II. **Disclaimer:**

Medical knowledge is constantly changing. As medical knowledge, clinical experience and research progress, changes in treatment and drug therapy may be required. The contributors to this handbook and the SNS boot camp course directors, on behalf of the SNS, have consulted sources believed to be reliable in their efforts to provide information that is complete and in accord with standards accepted in the neurosurgical profession at the time of publication. However, in view of the possibility of human error by the above-mentioned parties and/or changing standards of care, no party involved in the preparation of this work warrants that the information contained herein is accurate or complete and they are not responsible for any errors or omissions or for the results obtained from the use of such information. Trainees in Accreditation Council for Graduate Medical Education (ACGME) accredited neurosurgical residency programs, for whom this handbook is intended, should always practice according to the clinical, supervisory and all other policies of their residency training program, Program Director, faculty, home institution, and state licensing authority. Drugs should only be administered as directed in the relevant product information sheets and/or in consultation with a pharmacist.
III. Preface

The Learning Tree

“There is nothing new under the Sun…….” (Ecclesiastes 1: 9-14), and so it is with this neurosurgery PGY-1 “survival guide”. Many of us still have a similar guide inherited or created during our residencies.

It is the tradition of medicine and even more so in neurological surgery to pass down knowledge and practice from generation to generation, from mentor to acolyte, from faculty to resident, from branch to branch in a “learning tree” that constantly seeks to grow the quality and safety of the care we deliver to our patients. This guide includes input from a number of North American Neurological surgery residency programs and has been compiled and edited by Program Directors and other senior neurosurgical educators of the SNS. This is intended to be both foundational background knowledge as well as a quick reference.

Nothing in the guide should be construed as specific medical or surgical protocols and all decisions must be made based on the supervision and direction of your clinical faculty and institutional policies and procedures. Nevertheless, the principles, wisdom and experience outlined here should frame for you a general approach and set of values and core practices that will aid you in becoming an outstanding, successful and safe neurosurgical resident.

The changing times have made the transfer of knowledge from senior to junior neurosurgeons more oblique. This guide hopefully serves to bridge the gap. It is a living document. Each neurosurgery resident should feel compelled to suggest additions and improvements to the SNS, via their Program Director. Like a tree, each branch bends to touch the one below. It is our way, our culture and our obligation. Pass it on.

IV. Dedication

This manual is dedicated to our past, present and future patients who have shared in our quest for knowledge and improvement, and share credit for all that we have come to know.
V. Introduction

As neurosurgical residents you have entered the world of the ‘adult learner’. Important in your training is a lifelong commitment to identifying gaps and deficiencies in your own skills and knowledge, and independently seeking to improve. Both vigorous, independent study and mentorship in the clinical environment are critical for successful and safe neurosurgical training. In particular, mentors can assist you in identifying what you don’t know, and guiding you on the most effective path towards knowledge, in a way that will maintain patient safety as paramount.

In the words of one experienced neurosurgical educator:

“It's all about what we know and do not know, about what we think we know.”

Be prepared to abandon your preconceptions as you open mindedly approach one of the greatest fields of human endeavor, “the queen of all specialties”: neurological surgery.

General Considerations

Be prepared to fully engage in the physical, psychological, and intellectual challenges of your professional day. A number of factors come to play in optimizing your engagement. Work hour restrictions have been put in place to assure that you are rested and have the stamina to meet the challenges of the day.

Rest appropriately. Your psychomotor skills may be affected even remotely by inadequate sleep, stimulants (such as excessive caffeine), or sedatives (such as alcohol). Neurological surgery requires adequate focus and attention to the challenges of the clinical service, without personal distractions. The prepared, rested resident learns and functions best.

It is uncomfortable to lack knowledge, particularly for neurosurgical trainees who typically set high standards for themselves, and are accustomed to success. The practice of neurological surgery is high risk, including both clinical decision-making and procedural interventions.

Silence promotes neither learning nor a high quality clinical environment. Ask questions until you understand. Communication is your greatest ally. Remember, your attendings were residents once. They do know how you feel. Give them a chance to help, teach, and advise. If not convinced, at the very least check with your senior residents frequently for similar advice. However, remember that although responsibility for patient care is shared, the ultimate responsibility for most patient outcomes rests with the faculty member overseeing their care. They would rather answer your questions than find out through negative patient outcomes what you don’t know.
Supplement this survival manual with all important phone numbers, laboratory values, angles, drug diseases and data you use daily. Add to it often; pass it on to the PGY-1 who follows you.

Obtain skull and spine models. Study them before and after surgical procedures to deepen your understanding. Always take advantage of any opportunities for simulated procedural and anatomical learning, whether at courses, in the cadaver laboratory, or online. Anatomy is the foundation in which all surgical technique is built.

Finally, wear a clean laboratory coat and present yourself professionally, confidently, but with humility. Overall appearance is a sign of professionalism and will have a great impact on how patients and colleagues perceive you. The human aspect of your interactions with patients, even early in your career, will shape their perception of you, our specialty, and profession. Faced with difficult and serious illness, patients will find your professional demeanor and appearance a source of real comfort and confidence.

**The Rules**

**Rule 1: Hemostasis**

1. The brain is a vascular organ; 15-20% of cardiac output is distributed to the brain at any one time. Much of your neurosurgical training will be focused on how to avoid and stop bleeding.

2. Understand the rheological milieu your patient may possess: avoiding bleeding is easier that stopping it. Coagulation pathologies (both hyper and hypo) present some of the most serious risks to neurosurgical patients and may result in morbidity or mortality.
   a. A partial list of drugs affecting bleeding: aspirin, plavix, Coumadin, other non-steroidal anti-inflammation drugs, alcohol, heparin, tpa, platelet inhibitors, and anti-cancer drugs.
      It is important to remember that there are a variety of sources for medications, which can affect bleeding, such as many over the counter medications, i.e. “cold medications”, and herbal medicines that patients may not list unless specifically asked.
   b. Many medical conditions may also affect bleeding, amongst them: liver failure, renal failure, hematological malignancies, excessive alcohol use, low temperature, antibodies to platelets, and hematological disorders (such as hemophilia).
   c. It is very important to ask patients prior to surgery about their personal and familial history of bleeding or clotting problems. Laboratory studies are also critical to assess bleeding risk prior to surgery, and may include:
      a. PT/INR
      b. PTT
      c. CBC with differential and platelet count
      d. BUN creatinine
e. Liver enzymes  
f. Toxicology screen

3. General Surgical Principles  
   a. Obtain proximal and distal control of major vessels early  
   b. Electrical hemostasis  
      • Understand how the bipolar works  
         o Understand its opening pressure  
         o Understand why there are so many different sizes, shapes, lengths, and tips  
         o Understand why irrigation is important  
      • Understanding the monopolar. Why is it grounded? When is it effective and safe to use? What is the difference between cutting and coagulation current?

4. Mechanical hemostasis  
   a. Finger pressure  
   b. Elevation to control venous bleeding  
   c. Skin clips: Raney vs. Michel  
   d. Warm water  
   e. Cotton (understand why there are so many sizes and shapes of “cottonoids”)  
   f. Contact Agents: surgical flow seal, oxycel, gel foam, etc., bone wax, thrombin, fibrin glue, peroxide, etc.

5. Avoid and Control Bleeding in Potential Spaces  
   a. Epidural: tenting sutures: Why, when and where should they be used?  
   b. The epidural veins of the spine: positioning counts

6. Hematological Resuscitation  
   a. Normalize temperature (patients and fluids)  
   b. Correct platelets (>100K)  
   c. Correct ionized calcium  
   d. Correct PT (INR) to below 1.30 using FFP  
   e. Correct DIC and/or low fibrinogen (<150) with cryoprecipitate.  
   f. Rapid correction in life-threatening circumstances, use Factor VII (restrictions apply and risks may be present)  
   g. Ask for help (senior resident/attending, anesthesia, hematology-massive transfusion protocol team)

**Rule 2:** Know your left from your right and be able to extrapolate that information from the patient to the films to the documentation. Remember all imaging can be mislabeled. Tomographic (CT and MR) imaging studies by convention are displayed in “mirror” image: right on the left side and left on the right side. By contrast, navigational systems often display information without mirroring. However, some systems allow a choice to
be made during the initial stages of data manipulation, introducing the possibility of side errors.

In almost all clinical settings, you are part of a team. Have a constant system of checking facts (name, birth date, medical ID number, date of scan, type of scan, presence or absence of contrast agent, administration of pre-operative antibiotics, etc.). Such checks are part of the ‘time out’ prior to invasive interventions in the operating room, ICU and other settings, but should become a reflexive habit for your practice in all clinical settings. When in a hurry, the pause may seem like an unnecessary delay in getting a case started. It is not, but instead is a proven method of avoiding serious complications, and of enhancing patient safety. If something does not add up, stop what you are doing, engage other participants, and definitively answer the concern before proceeding. Always involve your supervisors in any question of labeling, sidedness, or inaccuracy of clinical records, images or other data. All team members are important and the input of nurses and others should be respected; they will help you and your team prevent errors. Occasionally, the patient can inadvertently give you misinformation. Finally, make sure you document side, site, and patient data in the chart.

Wrong sided/site surgery has been identified by regulators as a preventable event. Even more importantly, it should be the personal goal of every surgeon, working as part of a team, to do his or her utmost to prevent it.

**Rule 3**: Teamwork improves safety and outcomes. Communicate within the supervisory hierarchy well.

Managing patients is a team exercise. Document pertinent information in the chart and minimize the use of ‘cut and paste’. Inform your seniors and attendings what is happening throughout the day with regular updates. Include what tests are being done, or not, who is being discharged, and relate concerns or problems. Do not be afraid to ask for help. If you cannot contact your senior, chief, or attending call another. All training programs are designed around constructive supervision, both to improve patient care and outcomes and to improve your education. Never hesitate to ask for help or advice; it is in everyone’s interest.

**Rule 4**: There are only three possible general answers to any question, and they are mutually exclusive in any individual circumstance:

1. Yes
2. No
3. I do not know

Many residents struggle not from lack of skill or intelligence but from lack of organization and prioritization. This may not be something you have been taught in medical school. You must be able to sort through large volumes of data, organize it, and present accurately and to the point. Directness, accuracy and complete transparency in your
clinical communications are absolutely necessary to the best patient care and outcomes. You will be embarrassed at some points in your career by your own errors in judgment or knowledge. Being in error is a natural part of learning. However, candidly informing your supervisors in a timely fashion of clinical events and before implementing any major clinical or diagnostic decision, and communicating with complete honesty, are necessary to insure that the best care possible is delivered in the training environment.

Details are important. The care of neurosurgical patients can be complex, and exact understanding is necessary for good decisions. If you are not sure what details are important, acknowledge this and seek advice. If you did not perform what you now know is the key part of the examination to answer your attending’s question, say so and go back. This takes practice.

You must be able to identify the sickest patient on the service and prioritize that patient’s care. If you feel overwhelmed with this, ask for help. Everyone you are working with has felt that way at some time in his or her training.

Remember:

**WHO:** Patient name, age, handedness, gender

**WHAT:** Clinical presentation, co-morbidities, medications

**WHEN:** Patient examination, laboratories and imaging studies

**WHERE:** What is your proposed plan?

**HOW:** How are you going to execute the plan?

A neurosurgical resident’s most important characteristic is the reliability of his/her word and trust. Yes means Yes and No means No. Ambiguity is not helpful to efficient team function, safety, outcomes, or your education. As unfavorable as it may be to say “I don’t know”, it is more so to mislead. FIND OUT!! Do not be afraid to make a list. Details, details, details.

**Rule 5:** Keep the Chief Happy

The importance of accurate and reliable communication cannot be over emphasized. Communication up and down the chain of command is imperative to the safety of the patient and to you.

Communication is a skill; it must be practiced.

Respect for the chain of command is essential for good communications. Those ahead of you have earned it. Your example will serve to teach those coming after you. You sow the seeds for your own future success as a young clinical teacher and leader. You
will sometimes be blamed for things that are not your fault. This may come from patients who are frightened or angry or who are afraid to take out their frustration on the attending staff. While this is frustrating and unfair, try to accept it and realize that you will eventually move on to senior status where this is less likely to happen. If you perceive conflict with any patient, colleague, family member or nursing staff, share that with your supervisors and seek advice. They have experienced it and will help with this necessary part of clinical learning and growth, too.

If asked to come to the operating room, be thoughtful of the space around you and other team members that are listening. Before joining or interacting with the operating team, familiarize yourself with where along the operative time line and how the operation is going before you interrupt. If it is a priority then state it is so.

Prepare for every operative case by reviewing the relevant anatomy. Read about the operation, its indications, risks and expected outcomes. If the attending wrote about the approach then pay particular attention to that article. Your senior residents will be good sources of information on how that attending likes to prepare for a procedure. Examine the patient before surgery and review the imaging studies. A prepared resident is easier to teach and you will learn more. Participating in neurosurgical procedures and other aspects of patient care is a privilege. Treat it as such: Be prepared.

**Rule 6: Think before you speak**

Once you speak, everyone including patients and families know how much you know and how much you do not know. Remember what you say can make a strong impression on those around you. Be aware that the patient and family will remember not only what you said but also how you said it. Do not be disparaging about colleagues, nurses, facilities, and competitors even in jest. Do not be afraid to defer answers to questions that you do not feel capable of answering accurately and inform patients of when and from whom they can expect a definitive answer.

Junior residents frequently get into trouble by showing their frustration in front of colleagues, especially nursing staff. This is particularly true when tired, hungry or otherwise stressed. Try to monitor your stress level and be open to constructive criticism in this regard. Denial will lead to more trouble.

Respond using what you actually know not what you think you may know. Be accurate, straightforward, and always be honest. Poor or uncertain answers are apparent and serve neither you nor your audience well. The best way to give excellent and accurate answers is to be well informed, so read often and read for lifelong learning!

**Rule 7: There are a Million Ways to Have Complications; Despite our Best Efforts, There Will Always Be Bad Outcomes but their Occurrence Must be Minimized in Every Way Possible**

- They are not always avoidable.
• They are most commonly the result of care systems that need improvement.
• Care for your patients and concern for their well-being is a high principal; self-blame and anxiety are not good ways to achieve these goals. In fact, attributing either successful or poor outcomes entirely to your own actions is, equally, a form of arrogance.
• Learn from poor outcomes. Be respectful and prepared at morbidity and mortality conference. You can learn a great deal from poor outcomes experienced by others, improving the care of your own patients. Study your own outcomes (such as infection rates from EVD and central line placement) and demand improvement from yourself even in the earliest stages of your career.
• Document complications accurately in the medical record including the time they occurred. Even if your note is written somewhat later because of the clinical situation, an accurate and timely note most clearly documents important clinical events.
• The fact that bad outcomes are not always avoidable does not shelter you from their emotional or psychological impact. Be aware of the impact; find safe venues for managing it and mentors to advise you (faculty and resident). They have been there.
• Do not underestimate the effect that negative outcomes have on your personal life. Your friends and family may not be able or willing to communicate with you that you are becoming emotionally isolated. Having close friends who can is priceless.
• No matter how ashamed you think you are of your performance, honesty will save you.

Rule 8: The Enemy of Good is Perfect

Analyze and specify the goals and end points of each procedure in advance. Goals should always be primarily oriented towards a neurologically and clinically well patient with a durable result, rather than a perfect looking radiological result. Remember that as you fatigue your abilities and judgment decline. Do not be afraid to ask for help at any stage in a procedure (or any stage of your career).

Rule 9: Know the Enemy

• Know the limitations of your own skill level and experience. Do not be arrogant.
• If you are afraid of a second opinion, you should question your own. In the counsel of many there is wisdom.
• Understand what your patient asks.
• Understand the complications that your procedure can inflict and make sure the family understands. If they are prepared for the worst, when it happens, they will suffer, but understand. Disappointment (which includes anger and litigation) comes from failed expectations: set appropriate expectations.
• Communicate openly with patients and families. Let them know you are on their side, and they will support you through the worst of difficulties. (Make sure you are on their side).
• Understand your own fears. Do not let them keep you from the patient’s bedside. Do not avoid the patient or family that is doing poorly. See them twice as often.
• Most experienced nurses know more than you do about patient care. Ask their advice and take it unless you are sure it is wrong (even when sure, ask a senior).
• In the operating room, keep one eye on the monitors, listen to the sound of the pulse oximeter, and ask the anesthesiologist questions about the patient’s condition. Understand the limitations the pathology places on your procedures. Try to go with your senior resident or attending when they talk to the family after a procedure. You will soon become comfortable explaining difficult situations. At first, do not try to explain things you do not understand.
• Serial neurologic examinations by the same person are the most sensitive indicator of a patient’s course. Always document accurately in a straight-forward fashion.

Rule 10: Experience

Experience is extremely valuable and should be sought. The experience of your seniors and that reflected in the literature will prevent you (and your patients) from suffering many problems. Always read, and always ask.

You only have 6 or 7 years of protected learning, value this time and take advantage of the mentorship and wisdom available to you. Ultimately you will train like an athlete and like a concert level musician. You have been given time to sleep, use it, come to work, rested and ready. Come to work educated and prepared. Optimize your service time by optimizing your ability to participate.

Call often and call early. It is better to have called and been wrong than not to have called and been disastrously wrong. Not asking serves neither you nor the patient. It is the desire and requirement of every attending that they be made aware of any event or decision that may materially affect the outcome of their patient’s care. Do not take away from the attending their opportunity to decide how much they need to participate.

Errors of commission are more tolerable than errors of omission. In other words, a caring surgeon who sees the patient at the bedside and formulates an active plan on their behalf will achieve better results (even if their initial impression is wrong) than a surgeon managing that patient over the telephone. The patient, family, their clinical supervisors, and their conscience will all forgive them for imperfection if their care and effort are sincere and real.

You will hear dozens of “rules” from attendings over the years. Many do not appear in the peer-reviewed literature, but are the voice of experience nonetheless. In general they reflect an underlying truism.Crudely put, “It is the stupid things that often hurt your patient”. Here are some examples:

• The drill in your hand turns faster than a jet engine, respect its power to suck and tear.
Lasers can cause fire.
Coagulation can devitalize the skin leading to wound breakdown, infection, and death.
Prep alcohol in the eye can cause blindness, even though you have cured the patient of their tumor.
Do not suck the graft.

The underlying lesson from these rules is that small things may have large consequences, in medicine, particularly in surgery, and very particularly in neurosurgery. This is one of the challenges and joys of your adopted profession, and also one of the great demands.

**Rule 11:** Nothing substitutes for seeing the patient yourself.

The nervous system is the most elegant and eloquent organ in the universe. It is also the least tolerant organ in the human body to damage, and its injury has the most serious and permanent, life-altering implications.

The greatest skill of the experienced neurosurgeon you will become is not technical operative skill (although that is required), but clinical judgment to make the right decision, in timely fashion, and choose the proper intervention to save a life.

No-one but you (or your neurosurgical superior) can know when a patient is OK, or in trouble, and you cannot know without seeing and examining the patient. When the road ahead is unclear, go back and re-examine the patient at intervals, no matter the time of night or day. You will save lives. Know who the sick patients are, focus your attention on them, listen to your gut.

Always awaken a patient to check their neurological condition. Remember that the first sign of increased intracranial pressure is agitation. By overly sedating an agitated patient you may take away your only reliable indicator of their condition. Never allow a nurse or other colleague to talk you out of awakening a patient. “He was so agitated and I just got him to sleep. Please don’t wake him” is less important than evaluating the patient’s condition. Apologize to the nurse and explain why it is important. If necessary, after concluding the patient is OK, stay an extra minute and try to help the nurse re-settle them.

If you are wrong, but you have examined the patient and communicated up the chain of command, you will be forgiven (including by yourself).

**Rule 12:** Document well

Most junior residents consider note writing a necessary evil with little importance except that they get into trouble if they don’t complete this task. This often results in cursory notes with many unintelligible abbreviations and a “cut and paste” approach from day to day. To the contrary, notes have several important clinical functions:
1. They document your presence at a patient’s bedside. When called to see a patient for declining function, the only proof that you did your job correctly is your documentation in the medical record. “I saw him a couple of times during the night and he was OK” is not enough.

2. They allow you to communicate with your colleagues what you found on examination and what your treatment plans are. Simply copying data that anyone can find in the medical record is not helpful. Try to synthesize the exam, laboratory and radiology data into a treatment plan that is useful. Chart based communication is increasingly important in the new era of duty shifts, so that carefully documented neurological examinations may be compared across shift changes.

3. Every note is a medico-legal document. Your note that documents a clinical event or finding, a time of occurrence, and implementation of a treatment plan will almost always be helpful in proving that appropriate care was provided. A one-line note that is timed can be followed later by a more complete documentation.

4. The phrases “benefits, alternatives and risks”, or “procedure, alternative, risks, questions (PARQ)” are used to show that a full discussion of a planned operation was undertaken with a patient or surrogate. A PARQ discussion is required before any invasive procedure or other intervention. In general, PARQ discussions (and documentation) should include consideration of the “alternative of no treatment”. The fact that the attending already did this is fine. If you do it again, the documentation will go a long way in showing that several people explained things to the patient.

5. Notes are also used for billing purposes and to justify care to payors. Specific documentation of complications, treatments such as transfusions, use of antibiotics to treat infections or any reason a patient is staying in hospital will avoid denial of payment. While this may seem unimportant during early training, by getting in the habit of documenting these things, you will avoid extra work to document when payment for care is denied.
VI. **Statement on Conflicts of Interest**

Introduction to Conflict of Interest: Understanding the Dynamic

The Society of Neurological Surgeons thanks all of the industry contributors to the Foundation in Fundamental Neurosurgical Skills: Boot Camp Courses as well as the faculty members who have voluntarily donated their time and efforts to make this course successful. This is the first of many educational courses you will participate in over the course of your career. Welcome to neurological surgery training and to the beginning of a process of lifelong learning.

A conflict of interest (COI) occurs when an individual or organization is involved in multiple interests, one of which could possibly influence the motivation for an act on behalf of the other. An example would be considering prescribing a certain medication because you received the gift of a book, meal or other thing of value from the pharmaceutical company selling the medication.

This course was created by the Society of Neurological Surgeons (aka, the Senior Society, or SNS). The SNS has as one of its most precious trusts the continued development and execution of resident education in neurological surgery. You are encouraged to visit and familiarize yourself with the many benefits of the SNS website, which includes information about the Boot Camp and RUNN (Research Update in Neuroscience for Neurosurgeons) courses, links to course lecture and operative videos, and information about neurosurgical fellowship training.

A course like this is not free. The logistics of putting on the course include such components as hotel, rooms, food, technical assistance, devices, disposables, travel, transportation of the tools and equipment. The actual cost of producing this course approaches $100,000. The expense of this course to you is zero. This is made possible through a carefully constructed venture between industry and organized neurological surgery, in this case the SNS and the CNS. The American Association of Neurosurgeons (AANS) supports the online housing of lecture material from the course, and all three organizations provide other important educational experiences for residents throughout training. These relationships are essential for the advancement of the art and science of neurological surgery. They also present the potential for development of a conflict of interest related to course funding.

In this case, the conflict of interest is managed by a series of proactive measures implemented and maintained by organized neurosurgery through the involved parent organizations (the SNS, CNS, and AANS).

- The course has multiple sponsors
- The organizers and planners must fully disclose any relationship they might have with any individual sponsor
• The educational grants are managed through a code of conduct established by the AANS and CNS for industry relationships as defined by the Accreditation Council for Graduate Medical Education

• In addition, corporate sponsors for the course follow their own ethical guidelines, as prescribed by AdvaMed (the Advanced Medical Technology Association)

Faculty members encourage you to report to us any perception of a conflict of interest during this course. It is each of our responsibility to uphold a professional code of conduct, in order to keep our neurosurgical practices free from inappropriate financial interests and maintain the highest ethical standards that characterize our profession.

As residents, you will use many corporate products throughout your training and will continue to use some of them in your practice. Manufacturers' representatives are often good sources of information about their products, but are not independent of their responsibility to sell these products to hospitals and practitioners. For this reason, many hospitals, medical schools and training programs are required to limit access to residents by product representatives, in part because lower earning residents are felt to be particularly vulnerable to potential conflicts of interest arising from the value of gifts.

You are encouraged as you embark on your careers to investigate and get involved with our parent organizations. They serve as a resource for our continuing education, the development of the art and science of our specialty, and for the promotion of the Interest of our patients as our primary mission, guarding against any other undue influence.
VII. Procedural Skills Stations

I. Subclavian Central and Arterial Line Placement & Sterile Technique

Ia. Subclavian Central Line Placement & Sterile Technique

Note: At this important station, in addition to the technical goals associated with line placement, specific attention must be given to three critical components of bedside ICU procedures in general: sterility, clinical communications, and post procedure clinical examination for complications (radiological examination also, if relevant). These components (marked with an *) will not be repeated in detail at the other procedural stations. These components of practice are important parts of professionalism, and promote patient safety. It is the professional responsibility of the neurosurgeon to not only participate in professional communications but also to lead.

Station Goals:

1. Patient safety and clinical communications*
2. Sterile draping and technique*
3. Cannulation of the subclavian vein
4. Central venous line placement
5. Secure and dress line
6. Documentation*

Critical steps:

- Assure presence of appropriate clinical supervision for the procedure*
- Inform patient, family and nursing staff of planned procedure*
- Consent for procedure (or document emergency)*
- Consider coagulation status, other individual risks and limitations*
- Consider antibiotic prophylaxis at insertion*
- Gather equipment
- Position patient (10 degrees Trendelenburg with towel between the shoulders) with appropriate access to head and neck, and convenient location of sterile field with equipment
- Clip (do not shave) area as needed
- Prepare all needed flushing solutions and local anesthetic injections
- Sterile skin preparation and draping, surgeon sterile scrub, gowning and gloving*
- PAUSE, review consent and preparations with nurse/assistant*
- Inject local anesthesia
- Cannulate the vessel and insert the guide wire without force
- Remove the catheter over the guide wire, retaining manual control of the guide wire at all times
- Nick the skin with an 11 blade; dilate the opening
• After flushing, pass the central line over the wire, retaining manual control of the guide wire at all times
• Remove the wire, assure appropriate flow of venous (non-pulsatile) blood, flush the catheter with sterile saline
• Suture in place
• Apply sterile dressing*
• Auscultate breath sounds and observe respiratory rate (in case of a sudden, large pneumothorax)*
• Confirm location of tip at approximately the clavo-atrial junction with portable radiograph and check for pneumothorax: check the radiograph in timely fashion and relay result to nurse*
• Safely dispose of sharps and other waste
• Document the procedure with a brief chart note*
• Dictate a full procedure note*
• Record procedure in ACGME case log*
• Thank assistants/nurse*

Potential Complications:

• Infection
• Pneumothorax, hemothorax
• Cardiac Arrhythmia
• Arterial placement
• DVT
• Death

Central line removal:

• Inform nurse and obtain verbal agreement/consent from patient
• Position in 10 degrees Trendelenburg
• Remove dressing, prep exit site
• Remove line, apply pressure
• Dress site
• Auscultate breath sounds and observe respiratory rate (in case of a pneumothorax)
• Document the procedure with a brief chart note

Ib. Radial Arterial Line Placement

Station Goals:

1. Cannulation of the radial artery
2. Secure and dress line
Critical Steps:

- Position with arm supinated and extended
- Perform Allen's Test for patency of the ulnar artery
- Inject local anesthesia
- Insert angiocatheter needle bevel up until flash of bright red blood
- Gently advance the guide wire if used (varies)
- Advance catheter
- Remove guide wire
- Check for pulsations
- Connect, flush, secure and dress

Potential complications:

- Arterial spasm, dissection, or thrombosis
- Distal emboli, ischemic hand, tissue loss
- Infection

Catheter removal:

- Communicate line removal with nurse and consider blood sample collection before removal
- Position with arm extended, prep skin, and remove dressing and catheter
- Hold pressure
- Place dressing
- Enter a brief procedure note in the chart

II. CSF Shunt Tap

Station Goals:

1. Tap shunt valve reservoir
2. Measure pressure; drain CSF
3. Program adjustable shunt valve

Critical Steps:

- Identify valve type/configuration (and setting if relevant) on radiograph or CT scout view, or Rickham reservoir
- Insert 23g or smaller butterfly needle into valve reservoir or Rickham reservoir; observe spontaneous flow and read pressure by using tubing as manometer (Note: proximal obstruction may falsely obscure dangerous intracranial hypertension)
- Break seal on small syringe before attaching to butterfly tubing and very gently draw CSF sample
• Label and process/transport CSF tubes as indicated for ‘stat’ processing: generally including gram stain, cell count and differential, protein and glucose levels
• Track and be responsible for timely response to CSF laboratory results
• Enter a brief procedural note in the chart including the findings on tap (opening pressure [which may be misleading in cases of restricted flow], appearance of CSF, volume of CSF sent, and analysis ordered)
• Identify different valve types and shapes, including adjustable valves
• Use valve programmer to adjust valve setting
• Use valve reader to confirm valve setting

Potential Complications:

• Shunt infection
• Precipitation of severe malfunction and sudden or worsened intracranial hypertension
• Neurological injury
• Coma
• Death

III. ICP Monitor Placement

Station Goals:

1. Identify cranial landmarks and ICP monitor placement site
2. Place ICP monitor bolt
3. Zero, place and secure ICP monitor fiber-optic catheter

Critical Steps:

• Make sure all electrical boxes and cables are present and functional
• Mark relevant cranial landmarks prior to draping and choose insertion site (1 cm in front of the coronal suture, at the mid pupillary line = 3 cm lateral to midline, defaulting to the non-dominant right hemisphere)
• Inject local anesthetic in scalp
• Make ‘stab’ incision at entry site
• Attach and adjust drill bit anti-plunging guard if appropriate
• Drill, taking note of ‘tough’ outer table, ‘soft’ cancellous bone, and ‘tough’ inner table
• A ‘catch’ occurs as the tip of the bit begins to traverse the inner bony cortex; advance the drill two to three turns slowly, allowing the drill to advance a mm or two forward against reduced resistance
• Hand turn the drill clockwise while withdrawing it to pull bone fragments out of the twist hole as the bit comes out
• Palpate and then puncture the dura with a spinal needle or similar sharp device; do not use a blunt instrument that may strip the dura from the inner table of the skull and predispose to the formation of an epidural hematoma
• Screw bolt into place until firmly engaged and stable in the skull
• Calibrate (‘zero’) the fiber optic catheter and insert just past the 5 cm (double) line, then withdraw to the double line and secure (avoiding a falsely elevated reading due to brain ‘recoil’)
• Gently but firmly tighten the securing ring and snap the covering sheath into place
• Check wave form and wave form augmentation (generally by simulating valsalva using abdominal pressure if the patient’s airway is protected)
• Place dressing and double secure probe against pull out
• Record brief procedure note in the chart with initial pressure reading

Potential Complications:

• Hemorrhage
• Infection
• Drift (glacial inaccuracy of ICP readings)
• Displacement
• Neurological injury
• Coma
• Death

IV. External Ventricular Drain Placement

Station goals:

1. Identify cranial landmarks and EVD placement site
2. Place EVD
3. Tunnel, secure and dress EVD

Critical steps:

• Make sure insertion tray, external drain, and drainage kit are present, as well as local anesthetic injection and sterile saline
• Mark relevant cranial landmarks prior to draping and choose insertion site (1 cm in front of the coronal suture, at the mid pupillary line = 2.5 to 3 cm lateral to midline, defaulting to the non-dominant right hemisphere depending on imaging findings)
• Clip (do not shave) hair at the insertion site, to include a skin exit site for the catheter approximately 5 cm posterior, to lower the risk of infection of the indwelling catheter
• Inject local anesthetic in scalp
• Make small incision at entry site (consider small hockey stick shaped flap if later ventricular shunt implantation is expected)
• Attach and adjust drill bit anti-plunging guard if appropriate
• Drill, taking note of ‘tough’ outer table, ‘soft’ cancellous bone, and ‘tough’ inner table
• A ‘catch’ occurs as the tip of the bit begins to traverse the inner bony cortex; advance the drill two to three turns slowly, allowing the drill to advance a mm or two forward against reduced resistance
• Hand turn the drill clockwise while withdrawing it to pull bone fragments out of the twist hole as the bit comes out
• Irrigate, use bone wax and clear blood for a clean field before opening the dura
• Palpate and then puncture the dura with a spinal needle, 11 blade or similar sharp device; do not use a blunt instrument that may strip the dura from the inner table of the skull and predispose to the formation of an epidural hematoma
• In a full sized adult, pass the ventricular catheter according to standard trajectory, adjusted as needed for scan findings (intersection of trajectory towards auricular tragus cartilage and medial canthus – should be perpendicular to skull)
• Mentally adjust catheter trajectory to account for shift, mass lesion, or unusual ventricular anatomy as demonstrated on axial imaging (which should be on hand for further review during the procedure)
• Carefully monitor depth markings on the catheter throughout the pass; ventricular entry should be evident with a palpable ependymal ‘pop’ and flash of CSF from around the stylet at approximately 4 cm depth; do not pass the catheter beyond 5 to 6 cm depth without a flash of CSF
• 1 cm after entering the ventricle, ‘soft pass’ the catheter forward off of the rigid stylet until the total catheter depth is 6 to 6.5 cm at the outer table of the skull
• If you do not cannulate the ventricle, remove the catheter and request assistance for a subsequent pass from a supervisor
• Tunnel the catheter to the planned exit site, which should be away from the potential tract of a ventriculoperitoneal shunt should the drain later need to be converted to a shunt
• Place a 3-0 nylon ‘purse string’ around the exit site to discourage CSF leak around the outside of the catheter and infection; use the same suture in continuity to secure the catheter firmly using repeated loops in ‘roman sandal’ fashion, tying each single loop using 3 to 4 knots
• Attach the catheter to a male-female connector with a silk tie and then to the sterile enclosed drainage system before taking down the sterile field.
• Check flow form and flow form augmentation (generally by simulating valsalva using abdominal pressure if the patient’s airway is protected)
• Place dressing
• Record brief procedure note in the chart with initial pressure reading

Potential Complications:

• Non-ventricular placement
• Hemorrhage (including hemorrhage from presenting intracranial aneurysm, AVM or tumor, or catastrophic hemorrhage from injury to the superior sagittal sinus or intracranial vascular structures)
• Infection
• Neurological injury due to hemispheric, thalamic, or brainstem injury or stroke
• Occlusion (due to poor placement and/or presenting intraventricular hemorrhage)
• Displacement
• Coma
• Death

V. Lumbar Puncture and Lumbar Drain Placement

Station goals:

1. Optimally position patient for lumbar puncture
2. Puncture the thecal sac
3. Place, secure and dress lumbar drain

Critical steps (lumbar puncture):

• Review whether the patient may have intracranial hypertension or a mass lesion that might predispose them to brain herniation and neurological deterioration as a result of spinal tap or drainage
• Position the patient in lateral decubitus position with the knees tucked in and flexed, or possibly sitting and leaning forward for a fully conscious and cooperative patient (in either case, an assistant is likely necessary)
• Infiltrate local anesthetic into the skin and then into the dorsal (superficial) interspinous space
• Determine spinal level; the iliac crest is generally level radiographically with the L4-5 interspace, although a finger laid atop the crest will generally exactly parallel a finger resting in the depression between the superficial aspect of the L3 and L4 spinous processes
• The L3-4 or L4-5 interspaces are appropriate for LP and for LD placement in anatomically normal adults and children
• Before inserting the needle, examine it and understand the relationship between the catheter and needle. If there are markings on the catheter, understand what they mean
• Insert needle with a gentle caudal to cranial trajectory parallel to mental image of interspinous processes; the bevel should be parallel with the sagittal plane so it splits the dural fibers
• The needle may glance off the bone of the deep spinous process and/or the adjacent superior or inferior laminae, in order to enter the epidural space
• A pop will be felt as the needle traverses the interspinous ligament/ligamentum flavum complex; remove the stylet to determine if there is CSF flow
• If no flow, replace the stylet and gently advance the needle 5 mm at a time
• Measure the CSF opening pressure with a manometer if indicated
• Use sterile technique to collect and process CSF samples (see VP shunt tap)
• Drain a volume of CSF if planned and indicated
• Replace stylet and remove needle; place dressing

Critical Steps (lumbar drain placement):

• After thecal sac access, rotate the needle such that the bevel is now parallel to the coronal plane and will direct the catheter toward the thoracic spine (the small bump indicator on the needle-stylet hub should be facing toward the head)
• Pass the lumbar catheter gently through the Tuohy needle; the catheter will encounter mild resistance at 10 cm depth as it ‘turns the corner’ at the end of the needle and enters the thecal sac; keep track of the catheter depth measurements throughout the pass
• You may use the catheter with or without the available flexible stylet based on indication and attending surgeon preference
• If the catheter encounters unacceptable resistance during the pass before it is at an adequate depth, do not pull it back through the Tuohy needle (as it may shear and leave a fragment in the spinal canal); if this fails, remove the needle and catheter together as a unit and begin again starting with thecal sac puncture now with the angle of needle slightly more cranial in orientation, so that the catheter may pass more easily in a caudal-to-cranial orientation
• Introduce a minimum of 10 cm of additional catheter into the thecal sac if possible without resistance to avoid early catheter displacement and malfunction
• Remove the Tuohy needle while gently feeding the catheter forward as the needle comes out, so the catheter is not inadvertently removed
• Attach the catheter to a male-female connector with a silk tie and then to the sterile enclosed drainage system before taking down the sterile field
• Check flow
• Place dressing

Potential Complications:

• Venous bleeding
• Epidural hemorrhage
• Nerve root or spinal cord injury and neurological deficit
• Catheter loss in thecal sac
• Catheter pull out
• Infection
• Over drainage resulting in headache or cranial subdural hematoma
• Coma
• Death

VI. Spinal and Cranial Positioning, Cranial Fixation, Cervical Traction
Station goals:

1. Demonstrate positioning principles and complication avoidance
2. Position supine for standard supratentorial craniotomies
3. Position prone for standard midline infratentorial midline craniotomy and spinal procedures
4. Apply 3-point cranial fixation

Positioning Principles:

- Protect your patient, your nurses, and yourself against injury, including the use of sufficient help to avoid dropping the patient or injuring OR personnel
- Position as many patients as possible with senior supervisors, as it is a subtle and sophisticated process with serious ramifications
- Venous structures should be decompressed (e.g., jugular veins should not be compressed by excessive neck flexion, causing intracranial hypertension)
- The anesthetized patient in final position should appear comfortable (as they cannot protect their tissue and musculoskeletal structure by shifting position)
- The position of the intended operative field and adjacent structures (e.g., shoulders) should allow optimal surgical lines of sight and surgeon comfort
- Intended bone or fat harvest sites should be easy to drape and access during surgery
- Positioning should take into account placement of any required neurophysiological monitors
- Intravenous and arterial lines and the airway/ET tube should be accessible to the anesthesiologist
- The age and flexibility of patient should be accounted for
- The need for any intraoperative radiography should be considered (including ability to apply arm traction to better view the distal cervical spine, the type of table utilized and its orientation, and the body habitus of the patient)
- The position of the OR table in the room should be adjusted to optimize the position of the scrub nurse and surgical assistant, the overhead operating lights, the microscope, and other ancillary equipment
- Secure (strap) the patient to the table so that table motion will not cause them to fall
- Pad all potential pressure points and points of contact with the table
- The eyes should be free from any contact or pressure and protected from drying or injury by prep liquids (in collaboration with anesthesia)
- Check the following to assure there is no pressure, deformity or traction: ears, face, lips (endotracheal tube), breast, nipples, genitals (including Foley catheter), panniculus, brachial plexus, rotator cuffs, superficial nerves of arms and legs, and heels; use gel wrapping, padding and protection
- Respect the patients modesty and keep them warm during positioning (and throughout the case)
• Nurses are positioning and skin protection experts; work collaboratively with them but never relinquish personal responsibility

Critical Steps (supine positioning):

• Make sure the operating table is plugged in and functioning properly
• Lock the table and stretcher
• Align the height of the stretcher and table before transfer (on and off)
• If already anesthetized, use a draw sheet to transfer patient
• Use an axillary role for lateral or semi-lateral positions

Critical Steps (prone positioning):

• Plan appropriate frame or system with supervisor:
  o Jackson frame
  o Wilson frame
  o Gel rolls
• Make sure appropriate head positioning device is selected, present and functioning
• Align shoulders with top edge of table
• Roll patient from stretcher onto table

Critical Steps (cranial fixation/immobilization):

• Identify the anatomy of the skull and landmarks for pin placement
• Identify appropriate pressure (based on age and skull thickness)
• For a patient with skull fractures, previous craniotomy, or thin skull (young age), consider using a horseshoe head holder or full circle ‘donut’
• For spinal surgery, caliper or halo traction is an option to maintain cervical alignment
• Orient pins to leave the site of craniotomy accessible; some supervisors will allow placement of the single pin on non-hair bearing forehead but others will not
• Stop to think about whether the patient has a shunt or other object under the skin and be sure that the pins will not damage them
• Assure adequate pin fixation and that pins have not ‘sunk’ into the skull indicating fracture or excessive penetration
• Hold the pin fixation device in the desired orientation (see positioning principles), with the intended operative field being in the most superior position, while an assistant tightens all connections
• Check all connections, including the head holder platform connection to the table
• Recheck pin pressure indicator prior to draping

Potential Complications:

• Skull fracture
• Epidural hematoma
• Scalp laceration
• Pin displacement
• Cervical spine injury
• Brachial plexus injury
• Bleeding at pin site

Critical Steps (Cranial tong fixation for cervical traction):

• Arrange for fluoroscopy or serial spine films during procedure
• Anesthetize the skin properly and consider using systemic analgesics
• Place tongs dependent on desired traction force: neutral (above pinna), flexion (behind pinna), or extension (in front of pinna) traction
• Prepare pin sites: clip hair, prep skin, infiltrate site with local anesthetic
• Tighten pins to desired pressure based on age and skull thickness
• Apply traction weight in measured increments with observation using fluoroscopy; repeat neurological examination between addition of weights
• Any change in neurological examination requires immediate reduction in weight and appropriate imaging
• After successful reduction, reduce weight to no more than 10-20 pounds or fixate ring to halo vest
• Verify persistent reduction
• Make sure wrenches are taped to patient vest in case they are needed to release the vest urgently

Critical Steps (Cranial halo ring fixation for cervical traction or vest application):

• Consider skull thickness, frontal sinus location, fractures, lacerations, and supraorbital/occipital nerves when choosing pin sites (4 pins in adults, additional pins for think skull/young children)
• Seat pins with eyes closed to avoid retraction on eye lids
• Tighten opposite pins at the same time using torque wrench; standard torque is 6 pounds in adults
• Pins should be check for pressure once, 24 hours after application

Potential Complications:

• Pin loosening
• Infection
• Skull penetration/CSF leak
• Scars
• Pressure sores from vest

Critical Steps (Application of traction):
• Always consider the possible presence of atlanto-occipital dislocation and Type II or III Hangman’s fractures before traction application (contraindications)
• Place towels under the shoulders to enhance extension, only if needed depending on fracture type
• Obtain baseline lateral fluoroscopic image at bedside
• For adult patients, apply 10 lbs initial weight
• Repeat fluoroscopy
• Add 5 to 10 lbs additional weight each 10 to 20 min with a neurological examination and fluoroscopic image before and after each additional weight application
• Do not exceed 10 lbs per cervical level to the site of injury (e.g., 50 lbs maximum for C5 injury)
• After radiographically confirmed reduction, reduce weight and reconfirm with fluoro

Potential Complications:

• Iatrogenic distraction
• Exacerbation of traumatic disc herniation
• Neurological injury
• Respiratory failure

VII. Microscope and Basic Neurosurgical Instrumentation

Station Goals:

• Balance the microscope
• Demonstrate ability to adjust microscope illumination for tissue safety
• Name and manipulate basic neurosurgical tools safely
• Demonstrate hand-eye coordination under magnification, using both the principal and observer station oculars
• Understand the differences between the primary surgeon’s and the assistant surgeon’s view under the microscope

Microscope Principles:

• Magnification versus field of view
• Illumination and tissue safety (drying and heat)
• Move eyes away from oculars and announce to assistant before moving microscope

Critical Steps (microscope):

• Locate side attachments, including camera and observer eye pieces appropriate for case
• Set interocular distance and focus oculars
• Balance microscope
• Utilize hand controls for focus, zoom, light intensity, and iris
• Use forceps, scissors and needle driver under magnified vision

Basic neurosurgical instrumentation:

• Scalpel use and safety
• Hemostatic skin clips
• Bipolar forceps
• Types of suction tips and suction regulation
• Scissors types and appropriate uses
• Penfield dissectors
• Kerrison punches
• Rongeurs
• Micro instruments
• Retractors, hand held and fixed

VIII. Clinical Decision Making Simulator

The clinical decision making simulator utilizes a sophisticated simulated patient in a scenario involving neurosurgical critical care. The purpose of the station is to allow you to apply basic knowledge and decision-making skills in a realistic clinical scenario under pressure, without risk to a live patient.

Follow these principles:

• Stick to the basics
• Use common sense
• Behave as if you were in a real emergency department with this patient (you can ask for things to happen and ask for the involvement of other appropriate team members)

An educator in the simulation room will introduce the scenario. The manikin, simulated patient is then available for taking a focused history and performing a focused physical examination. This equipment allows verbal interchange, monitoring of vital signs, and physical examination including cranial nerves. The status of the simulated patient will change over time. You must respond to these changes both diagnostically and therapeutically.

The educator will pause the scenario at certain times to ask you questions, discuss the case, and make suggestions.
VIII. Operative Skills Stations

Work efficiently. Assist your table partner with drilling exercises, trading off so that you both can complete each component of the exercise. There are duplicate materials for the other exercises. A course director will announce the appropriate time to spend on each exercise and announce the time to move on to the next exercise.

Numerous faculty members will be present in the practical laboratory, rotating between tables. Please rely on them for advice and ask questions!

Practical Exercises

1. Overview – 10 minute
2. Drilling: Bovine Scapula – 40 minutes
3. Cranietomy – 40 minutes
4. Dural Closure – 30 minutes
5. Plating – 20 minutes
6. Cranioplasty – 30 minutes
7. Skin Closure – 30 minutes

1. Drilling: Bovine Scapula Exercise

Introduction

- Familiarize yourself with the powered hand piece, which spins faster than a jet engine and can thus draw in bits of tissue or gauze, forming a dangerous “whip”
- Familiarize yourself with the various drill bits
- Shapes: round, match stick, acorn, wire passer/router
- Finishes: cutting vs. diamond
- Perforator bit (how the clutch works)
- Lengths, bends, exposure of the shaft
- Demonstrate using the various attachments with the proper bit
- Learn how to change the hand pieces, attachments, and bits
- Familiarize yourself with the sights, sounds and feel of the power tools as you drill on and through bone
- Understand fatigue for fine motor skills caused by extensive use of the drill

Bovine Scapula: Burr Holes, Bone flap and Tenting suture

- Demonstrate how the clutch mechanism on the perforator bit functions
- Make several burr holes with the perforator
- Try and “defeat” the clutch, causing a dangerous plunge and thus learn how to avoid this
- Change bit to side cutting router bit and attach foot plate
Demonstrate how to angle foot plate such that the dura is safely dissected away from the inner table of the bone
- Connect the burr holes with the craniotome, creating a free bone "flap"
- Discuss the hazards of penetrating/tearing the dura with the footplate craniotome
- Switch to wire passer drill bit and place multiple holes circumferentially around the craniotomy opening for tacking sutures
- Place holes in the center of the bone flap for central tenting sutures
- Place a glove under the bone defect and practice placing dural tack-up sutures
- Describe the use and benefit of dural tack-up and tenting sutures
- Make series of burr holes utilizing the Acorn Bit, noting the sound and feel of "chatter" just as the bit penetrates the inner table of the bone, warning you to stop drilling in order to protect the dura
- Connect the holes again with a foot plated router
- Utilize a diamond bit to smooth the edge of the craniotomy
- Compare the diamond and cutting bits for fine bone edge removal
- Note the generation of heat by the working drill bits, which can be transferred to adjacent neurovascular structures including cranial nerves and spinal roots
- Demonstrate how to irrigate during drilling to reduce heat, without spraying irrigant into the eyes
- Demonstrate how a cotton patty can be sucked into the working drill bit and damage nearby sensitive structures; learn how to avoid this

2. Craniotomy
   - Using your plastic skull model, create frontal, parietal, occipital and suboccipital (midline) craniotomy flaps
   - Place appropriate burr holes
   - Connect with footplate craniotome
   - Understand the confines presented by each approach to that cranial fossa based on the size of the opening and angles involved
   - Draw out the associated standard incision for each craniotomy based on optimal vascular pedicle and best cosmetic result

3. Dural Closure
   - Hydrate dural substitute by soaking
   - Using the brain model with a "dural defect", cut the dural substitute slightly larger in size than defect
   - Practice closing the defect using the dural substitute patch, using both interrupted, simple running sutures, and running locked sutures
   - Discuss the advantages and disadvantages of each closure type

4. Bone Fixation
   - Re-approximate bone flaps with rigid fixation mini plates and screws
• Feel the proper seating of a screw and plate in bone, using the beef scapula
• Over tighten a screw to feel the loss of fixation; try to fix this by moving the plate or using a wider or deeper screw
• Place screws at a 90 degree and 45 degree angle to the bone surface; describe the potential problems with the latter
• Plate back in the craniotomy flaps on your plastic skull model using the various shapes and sizes of plates
• Dogbone plates for simple fixation
• “Snowflake” burr hole covers for burr holes, especially in cosmetically apparent locations (to avoid areas of scalp depression)
• Squares and rectangles to reconstruct more complicates bone flaps, multiple bone pieces, and/or fractures
• Cut the zygoma at its frontal and temporal insertion points and plate it back in place

5. Cranioplasty

• Cut mesh to size and attach it to the bone edges utilizing screws
• Mix up bone cement as describe on packet insert for 45 seconds
• Place over mesh and shape
• Allow to set
• Utilize excess cement to close a burr hole on another craniotomy or to fill the edges of a plated craniotomy (which can yield enhanced cosmetic results on the forehead)

6. Skin Closure

• Review the anatomy of the SCALP
  o Skin
  o Connective tissue (subcutaneous fat and fibrous tissue)
  o Aponeurosis (Galea Aponeurotica)
  o Loose areolar connective tissue (containing major scalp blood supply, just below the galea)
  o Pericranium
• Discuss the importance of the galeal closure for homeostasis and tensile strength
• Using the suture skin model kit and enclosed diagrams, practice the following closures:
  o Simple interrupted
  o Simple running
  o Running locked closure
  o Vertical mattress
IX. Lectures
   i. Professionalism, Supervision, and Pearls for the PGY1 Resident
   ii. Neurological and Neuro-trauma Assessment
   iii. Emergency Cranial Radiological Assessment
   iv. Emergency Spinal Radiological Assessment
   v. ICP Management
   vi. Unstable Neurosurgical Patient: Case Scenarios
      ii. Emergency Evaluation and Management of Hydrocephalus Shunt Patients
   viii. Making the Incision: Surgical Pause to Scalp Blood Supply
   ix. Patient Safety and Clinical Communications
Professionalism, Supervision, and Pearls for the PGY1 Resident

Definitions
- Highly educated
- Impressive competence
- Autonomy
- “Comfortable” salary
- Creative and intellectually challenging work
- Trust
- Strict ethical and moral standards

Professionalism
- Ethical behavior
- Confidentiality
- A duty not to abandon because of inability to pay
- Putting the client’s interests ahead of one’s own
- Moral compass
- Work ethic and motivation
- Willingness to share in the transmission of professional knowledge and values (like today)
- Positive attitude towards the profession

ACGME Outcome Project
- Six Competencies
  - Patient Care
  - Medical Knowledge
  - Professionalism
  - Interpersonal and Communication Skills
  - Systems-based Practice
  - Practice-based Learning and Improvement

ACGME definition:
“Manifested through a commitment to carrying out professional responsibilities, adherence to ethical principles, and sensitivity to a diverse patient population.”

When is it measured?
- Assessments
  - Peer (‘360 degree’) evaluations
  - “On the fly” evaluations (clinical & operative)
  - By rotation
  - Annually

The Society of Neurological Surgeons
Professionalism

• How is it measured?
  – Duty hour adherence and documentation
  – Nursing interactions
  – Patient interactions
  – Demeanor and dress
  – Devotion to patient care
  – Ethical decision making
  – Contributions to the profession

Professionalism

• The essence of professionalism
  – Continuous self-improvement
  – Lifelong learning and a thirst for knowledge
    • You must read constantly
    • You must read systematically
    • You must master the field
    • You must read throughout your career
  – You must share your own ideas with professional colleagues by teaching, speaking and writing!

Professionalism

• Bad outcomes
  – Bad patient outcomes are sometimes unavoidable
  – Perfection is unobtainable

Professionalism

• What is expected of you?
  – Your very best effort
  – Honest acceptance of results
    • Morbidity and mortality tracking, analysis and reporting
  – Constant striving for improvement
    • “Practice based learning”
    • To care about those we care for

Professionalism

• Patients know if you are on their side and if you care about what happens to them
• When you do:
  – They will forgive you
  – You will forgive yourself

Honesty

• Honesty even with patients after an error?
  – Yes!
  – Involve your superiors for their experience in sensitive patient communications...
Supervision

• Main principles of surgical GME
  • Supervision
  • Graduated authority and autonomy
• ACGME
  • Recognition that surgical training is fundamentally different from non-surgical training

One size fits all!

Supervision

• When does supervision apply?
  – In the operating room
    • For the key portion of the procedure
    • For any portion in which you are not independently competent
  – For ward and ICU procedures
    • Until you are specifically cleared for independence
  – For decision making
    • Any time you don’t know
    • Any time you aren’t sure whether you know or not!

Supervision

• How is surgical training different?
  – Close supervision at every training level
    • Attending staff
    • Senior/Chief resident staff
  – Defined psychomotor goals for each training level
  – Hierarchy

No surprises!

• When does supervision apply?
  – In the operating room
    • For the key portion of the procedure
    • For any portion in which you are not independently competent
  – For ward and ICU procedures
    • Until you are specifically cleared for independence
  – For decision making
    • Any time you don’t know
    • Any time you aren’t sure whether you know or not!

Supervision

• How are supervision and hierarchy related?
  – Acquisition of competence
    • Cognitive and procedural
  – Graduated autonomy
    • Experience is the best teacher
  – Ethical behavior
    • Uncompromising excellence in patient care

The student:
I hear and I forget; I see and I remember; I do and I understand. - Chinese Proverb

The teacher:
A teacher is one who makes himself progressively unnecessary.
- Carruthers
i. Professionalism, Supervision, and Pearls for the PGY1 Resident

**Fatigue**

- Fatigue compromises:
  - Patient safety
  - Quality outcomes
  - Resident health

**Fatigue**

- Two imperatives:
  - Regulatory compliance for PGY1s
    - 16 hours shift limit ABSOLUTE
    - 80 hours per week, averaged over 4 weeks
    - One in 7 days off, averaged over 4 weeks
    - 8 hour minimum inter-shift break
    - Direct or on-site supervision (senior resident or faculty)
  - Quality and safety
    - Self monitoring
    - Ask for help, don’t drive tired

**Fatigue**

- Patient hand offs
  - Teamwork approach shortens shifts
  - Transfer of knowledge and responsibility is a chance for dangerous errors and poor outcome
- What to do?
  - Keep meticulous lists of key information, issues
  - Leave time for ordered, careful handovers at each shift change, *without distractions*
  - Leverage the electronic medical record

**Pearls**

- It’s a long road … It’s hard work …
  - If you don’t enjoy the process, it may be difficult to finish it…

  *Hard work without talent is a shame, but talent without hard work is a tragedy.*

  - Robert Half, 20th cent.

  *Goodness without knowledge is weak; knowledge without goodness is dangerous.*

  - John Phillips, 1781

**Pearls**

- What do we mean?
  - You are all smart and talented
    - We are asking for
      - *Diligence*
      - *Humanity*

**Pearls**

- You are about to enter the most exciting profession in the world!
- How did you come to decide to be a Neurosurgeon
  - Every neurosurgeon has a story…
  - Ask your peers to tell you their stories…

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i. Professionalism, Supervision, and Pearls for the PGY1 Resident

**Pearls**

- Neurosurgery is a community
  Relationships define us

- Ask yourself these questions...
  - How many people enjoy what they do every day?
  - How many people feel that they are making a positive contribution to the lives of other human beings every day?
- Ask a Neurosurgeon these questions...
  - The answers will be stereotypical...
  - Almost no neurosurgeon regrets their decision

- It's a long program
  - > 6 year program
  - Clinical Neurosurgery
    - > 36 months
  - 12 months as Chief Resident
  - Neurology (3 months)
  - Neurointensive care
  - Neuroscience, Neuropathology, Neuroradiology, INR
  - Research
    - 80 h/wk X 48 months X 3 years = 11,520 h
    - Training a concert pianist: 10,000 h

**Pearls**

- Rest
  - When you are rested:
    - You look better
    - You learn better
    - You will stay healthier

- Take care of yourself
  - Spend time away from the hospital
  - Be with your family
  - Keep physically active
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i. Professionalism, Supervision, and Pearls for the PGY1 Resident

**Pearls**

- Don’t be afraid to ask
  - Silence is often mistaken for understanding
  - Ask attendings/senior residents when you don’t know
  - It’s OK to say “I don’t know”
    - Particularly to patients
    - Don’t provide wrong information!
  - Most of all, remember that sometimes you don’t know when you don’t know...

**Pearls**

- Prioritize
  - Who are the sickest patients?
    - Emphasize their hand-offs
    - Re-examine them
    - Prioritize their care
  - Stay organized!
  - Keep lists
  - Be practical
  - Brain surgery is really just common sense...

**Pearls**

- Prepare for cases: Operating in a protected learning environment is a precious and extraordinary privilege
  - Be rested
  - Read about the disease
  - Study, understand the goals of the operation
  - Meet the patient if you can

**Pearls**

- Accurate and timely communication up and down the chain of command is critical
  - There are 3 answers to any question: Yes, No, or I don’t know
  - Think before you speak, don’t speculate
  - Nothing substitutes for seeing the patient yourself, repeatedly if indicated
  - Experience is critical and precious

**Pearls**

- Always listen
- You are not expected to know everything, but you are expected to learn
- Always keep your composure
- Avoid becoming argumentative with your supervisors, peers or others (at any level)
  - Your education, and ultimately your success depends upon their willingness to share knowledge
  - Positive professional relationships will allow you to excel and will help your patients

**Pearls**

- Don’t come with problems
  - Come with solutions...

Neurosurgery is defined by the need and the ability to ‘get it done’

The buck stops with YOU
Pearls

• *Take it one day at a time!*

Pearls

“Better is possible. It does not take genius. It takes diligence. It takes moral clarity. It takes ingenuity. And above all, it takes a willingness to try.”

Atul Gawande, 2007
ii. Neurological and Neuro-trauma Assessment

The Society of Neurological Surgeons Bootcamp

H & P makes the diagnosis 90% of the time!
Clinical examination still essential skill

6 Essential Parts of a Neurologic Exam

1) Mental Status and Cognitive Function
2) Language
3) Cranial Nerves
4) Motor System
5) Sensory System
6) Reflexes

Assessment of Mental Status

– Level of Consciousness: (alert, somnolent, obtunded)
– Orientation: (to time, place, examiner, situation)
– Attention span
– Mood and affect: (labile, apathetic, dysphoric, euphoric, anxious irritable)
– Disorders of thinking and perception: (hallucination, delusion, paranoia)

Cognitive Function

• Common Knowledge
  – “Who’s the president?”
• Memory
  – Short term recall
    • Name 3 common objects, then name them again after 5 minutes
  – Long term
    • Verifiable events from the past

Language

• Aphasia
  – Fluent (Wernicke’s) aphasia
  – Non-fluent (Broca’s) aphasia
  – Conduction aphasia
  – Transcortical aphasia
**Aphasias**

<table>
<thead>
<tr>
<th>Aphasias</th>
<th>Verbal Output</th>
<th>Comprehension</th>
<th>Repetition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broca’s</td>
<td>Affected</td>
<td>Intact</td>
<td>Affected</td>
</tr>
<tr>
<td>Wernicke’s</td>
<td>Intact</td>
<td>Affected</td>
<td>Affected</td>
</tr>
<tr>
<td>Conduction</td>
<td>Intact</td>
<td>Intact</td>
<td>Affected</td>
</tr>
<tr>
<td>Transcortical Motor</td>
<td>Affected</td>
<td>Intact</td>
<td>Intact</td>
</tr>
<tr>
<td>Transcortical Sensory</td>
<td>Intact</td>
<td>Affected</td>
<td>Intact</td>
</tr>
</tbody>
</table>

**Assessment of Cranial Nerves**

- **CN I (Olfactory Nerve)**
  - Indications for carrying out this test include frontal headache and seizures, which might be due to an olfactory groove meningioma.
  - Smell is tested by using a non-noxious stimulus such as soap or coffee, testing each nostril individually.

- **CN II (Optic Nerve)**
  - Visual acuity, visual fields, pupillary reaction to light.
  - Check for an afferent pupillary defect by using the swinging flashlight test.

- **CNs III, IV, and VI (Oculomotor, Trochlear, and Abducens Nerves)**
  - Functions of these cranial nerves include pupillary constriction and dilation, eye movements, and eyelid elevation.
  - Dysfunction of one or more of these functions produces pupillary inequality (anisocoria), diplopia, or ptosis.
  - The extraocular muscles work together during the act of conjugate gaze and convergence, which are evaluated during the examination of these cranial nerves.

- **Pupils**
  - Pupils: The pupils should be examined for equality. If anisocoria exists, one must determine which pupil is abnormal.
  - Diplopia: The eyes should be moved into the extremes of gaze in the six gaze directions that test individual muscles (superior rectus: up, inferior rectus: down, lateral rectus: abduction, medial rectus: adduction, inferior oblique: up and in, superior oblique: down and in).
  - Ptosis: The patient should look up for 1 to 2 minutes. Ptosis due to myasthenia gravis usually worsens during prolonged upward gaze. The ptosis of a Horner’s syndrome is usually mild and associated with miosis.
ii. Neurological and Neuro-trauma Assessment

### Assessment of Cranial Nerves

- **CN V (Trigeminal Nerve)**
  - Both motor and sensory divisions of the trigeminal nerve should be tested.
  - The presence of wasting of a temporo-mandibular muscle suggests involvement of the motor root. Jaw deviation on opening the mouth may also be present.
  - The masticatory muscles should be palpated when the patient attempts to clench the jaws.
  - The three sensory divisions of CN V.

- **CN VII (Facial Nerve)**
  - The facial nerve supplies the muscles of facial expression and carries taste sensation from the anterior two thirds of the tongue.
  - Have the patient smile vigorously to assess the strength of the muscles of the lower face, have the patient wrinkle the brow, and to squeeze the eyes tightly together while the examiner attempts to pry them apart.
  - The lacrimal and salivatory glands are also innervated by parasympathetic fibers that are carried in the facial nerves.

- **CN IX and X (Glossopharyngeal and Vagus Nerves)**
  - Cranial nerves IX and X are usually tested together. It is convenient to think of cranial nerve IX as mainly sensory and cranial nerve X as mainly motor.
  - Testing sensation on the posterior third of the tongue and oropharynx is examined by testing the gag reflex.
  - Hoarseness is characteristic of involvement of cranial nerve X and also occurs with lesions in the nucleus ambiguus, the origin of motor fibers to the pharynx and larynx.
  - Unilateral lesion involving CN X reveals uvula deviation.
  - Bilateral lesions of the descending corticobulbar fibers can produce pseudobulbar palsy, in which the palate elevates poorly to saying “ah” but briskly when a gag reflex is elicited.

### Mydriasis

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Cause</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd nerve</td>
<td>Diabetes, aneurysm, trauma, temporal lobe, herpetic, tumor,</td>
<td>Often acute, diabetes: pupil usually spared</td>
</tr>
<tr>
<td>Nerves (Adie’s syndrome)</td>
<td>Iris Surgery, trauma,</td>
<td>Unilateral, pupil often not reactive</td>
</tr>
<tr>
<td>Topical drugs</td>
<td>Glaucoma drugs</td>
<td></td>
</tr>
<tr>
<td>Systemic drugs</td>
<td>Anticholinergics, anti-histamines, MAO, sympathomimetics</td>
<td></td>
</tr>
<tr>
<td>Tonic</td>
<td>Surgery, trauma</td>
<td></td>
</tr>
</tbody>
</table>

### Miosis

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Cause</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horner’s syndrome</td>
<td>Congenital, lesions of the brainstem/roots, C8-T2 roots, Periphereal tumor, carotid, cavernous sinus, diabetic headache</td>
<td>Pupil, depression of the upper lid and impaired ipsilateral upper facial sweating</td>
</tr>
<tr>
<td>Argyll Robertson</td>
<td>Syphilis, diabetes</td>
<td>Irregular pupils</td>
</tr>
<tr>
<td>Systemic drugs</td>
<td>Glaucoma drugs</td>
<td></td>
</tr>
<tr>
<td>Systemic drugs</td>
<td>Anticholinergics, sympathomimetics</td>
<td></td>
</tr>
<tr>
<td>Tonic</td>
<td>Surgery, trauma</td>
<td></td>
</tr>
</tbody>
</table>

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ii. Neurological and Neuro-trauma Assessment

**Assessment of Cranial Nerves**

- **CN XI (Spinal Accessory)**
  - The spinal accessory nerve supplies the ipsilateral SCM and trapezius muscles.
  - Weakness of head turning to opposite side
  - Examination should include observation for muscle atrophy, palpation and movement against resistance.
  - Hemiparesis may be associated with weakness of shoulder shrug and weakness of turning the face toward the side of the hemiparesis.

- **CN XII (Hypoglossal Nerve)**
  - The hypoglossal nerve contains only motor fibers to the ipsilateral tongue.
  - Damage to the hypoglossal nucleus or its fibers leads to tongue atrophy, weakness, and fasciculations.
  - The tongue protrudes toward the side of lesion.

**Assessment of Motor Function**

<table>
<thead>
<tr>
<th>American Spinal Injury Association (ASIA) Motor Key</th>
<th>Root</th>
<th>Function</th>
<th>Muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>Elbow flexors</td>
<td>Biceps</td>
<td></td>
</tr>
<tr>
<td>C6</td>
<td>Wrist extensors</td>
<td>Extensor carpi radialis longus and brevis</td>
<td></td>
</tr>
<tr>
<td>C7</td>
<td>Elbow extensors</td>
<td>Tripeps</td>
<td></td>
</tr>
<tr>
<td>C8</td>
<td>Finger flexors</td>
<td>Flexor digitorum profundus</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>Finger abductors</td>
<td>Abductor digitii minimi</td>
<td></td>
</tr>
<tr>
<td>L2</td>
<td>Hip flexors</td>
<td>Iliopsoas</td>
<td></td>
</tr>
<tr>
<td>L3</td>
<td>Knee extensors</td>
<td>Quadriceps</td>
<td></td>
</tr>
<tr>
<td>L4</td>
<td>Ankle dorsiflexors</td>
<td>Dorsalis posterior</td>
<td></td>
</tr>
<tr>
<td>L5</td>
<td>Long toe extensors</td>
<td>Extensor hallucis longus</td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>Ankle plantar flexors</td>
<td>Gastrocnemius, soleus</td>
<td></td>
</tr>
</tbody>
</table>

**Muscle Grading**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Total paralysis</td>
</tr>
<tr>
<td>1</td>
<td>Palpable or visible contraction</td>
</tr>
<tr>
<td>2</td>
<td>Active movement, full range of motion, gravity eliminated</td>
</tr>
<tr>
<td>3</td>
<td>Active movement, full range of motion, against gravity</td>
</tr>
<tr>
<td>4</td>
<td>Active movement, full range of motion, against gravity and provides some resistance</td>
</tr>
<tr>
<td>5</td>
<td>Active movement, full range of motion, against gravity and provides normal resistance</td>
</tr>
<tr>
<td>NT</td>
<td>Not tested</td>
</tr>
</tbody>
</table>

**Assessment of Dermatomes**

[Graphic of Dermatomes]

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ii. Neurological and Neuro-trauma Assessment

### Deep Tendon Reflexes

<table>
<thead>
<tr>
<th>Examination</th>
<th>Localisation</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biceps Tendon</td>
<td>C5-C6 (musculocutaneous n.)</td>
<td>Contraction of the biceps muscle, Elbow flexion</td>
</tr>
<tr>
<td>Brachioradialis Tendon</td>
<td>C6 (radial n.)</td>
<td>Elbow flexion</td>
</tr>
<tr>
<td>Triceps Tendon</td>
<td>C6-C7 (radial n.)</td>
<td>Elbow extension</td>
</tr>
<tr>
<td>Patellar Tendon</td>
<td>L3-L4 (femoral n.)</td>
<td>Knee extension</td>
</tr>
<tr>
<td>Achilles Tendon</td>
<td>L4-L5 (tibial n.)</td>
<td>Plantar flexion of the foot</td>
</tr>
</tbody>
</table>

### Tendon Reflex Grading Scale

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Absent</td>
</tr>
<tr>
<td>1+</td>
<td>Sluggish</td>
</tr>
<tr>
<td>2+</td>
<td>Normal</td>
</tr>
<tr>
<td>3+</td>
<td>Hypertonic without clonus</td>
</tr>
<tr>
<td>4+</td>
<td>Hypertonic with clonus</td>
</tr>
</tbody>
</table>

### Reflex Examination

- Clonus
- Babinski
- Hoffman
- Bulbocavernosus
- Anal wink

### Assessment of Radiculopathy

<table>
<thead>
<tr>
<th>Root Level</th>
<th>Distribution of Sensory Loss</th>
<th>Motor Weakness</th>
<th>Reflex Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>Shoulder, upper arm</td>
<td>Shoulder abduction</td>
<td>None</td>
</tr>
<tr>
<td>C6</td>
<td>Anterior upper arm, radial forearm, thumb, forearm flexion</td>
<td>Biceps</td>
<td></td>
</tr>
<tr>
<td>C7</td>
<td>2nd, 3rd finger</td>
<td>Forearm extension, wrist, hand grip</td>
<td>Triceps</td>
</tr>
<tr>
<td>C8</td>
<td>4th, 5th finger</td>
<td>Wrist extension, intrinsic hand muscle</td>
<td>None</td>
</tr>
<tr>
<td>L4</td>
<td>Anterior thigh, inner calf, foot</td>
<td>Knee extension</td>
<td>Patellar</td>
</tr>
<tr>
<td>L5</td>
<td>Outer calf, great toe</td>
<td>Foot, toe dorsiflexion</td>
<td>None</td>
</tr>
<tr>
<td>S1</td>
<td>Outer calf, foot, posterior thigh</td>
<td>Knee flexion, foot flexion</td>
<td>Achilles</td>
</tr>
</tbody>
</table>

### Clinical Syndromes

- **Central Cord Syndrome:**
  - Cervical region injury and leads to greater weakness in the upper limbs than in the lower limbs, with sacral sensory sparing.

- **Brown-Séquard syndrome:**
  - Ipsilateral hemiplegia and loss of proprioceptive sensation with contralateral loss of pain and temperature sensations following a spinal herniation.

- **Anterior Cord Syndrome:**
  - Lesion causing variable loss of motor function and sensitivity to pain and temperature; proprioception is preserved.

- **Conus Medullaris Syndrome:**
  - Injury to the terminal spinal cord. Early incontinence, perineal numbness and preserved Knee reflex.

- **Cauda Equina Syndrome:**
  - Injury to the lumbosacral nerve roots in the spinal canal. Asymmetric lower limb weakness, leg pain, numbness and absent reflexes. Delayed incontinence.
ii. Neurological and Neuro-trauma Assessment

**Neuro-trauma Assessment**

- Initial Survey
  - ABCs
  - Blood Pressure
    - GCS
    - Pupils
  - Motor symmetry/strength

**Neuro-trauma Assessment**

- Hypotension (single SBP < 90mm Hg)
  - Doubles mortality
- Hypoxia (apnea or cyanosis, or PaO2 < 60mmHg on ABG)
  - Increases mortality
    - Combination of both
  - Triples mortality
  - Increases the risk of bad outcome

**Neuro-trauma Assessment**

- Hypotension
  - Rarely attributable to head injury except:
    - Terminal stages
    - Dysfunction of medulla
    - Cardiovascular collapse
    - Infancy
    - Blood lost intracranially or in subgaleal space
    - Scalp wounds
    - Enough blood lost to cause hypovolemia

**Neuro-trauma Assessment**

- Neurogenic shock
  - Spinal cord injury above T1
    - Interruption of sympathetics
  - Loss of vascular tone (vasoconstrictors) below level of injury
  - Incidence increases with injuries above T6
  - Parasympathetics relatively unopposed
  - Bradycardia
  - Lower systemic vascular resistance
  - Venous pooling

**External Examination of the Cranium**

- Visual inspection of the cranium:
  - Evidence of basal skull fracture
    - Raccoon’s eyes
  - Battle sign
    - CSF rhino/otorrhea
  - Check of facial fractures
  - Lefort fractures
    - Orbital rim fracture
  - Periorbital edema, proptosis
  - Cranio-cervical auscultation
    - Auscultate over globe of eye: bruits may indicate traumatic C-C fistula
    - Auscultate over the carotid artery

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ii. Neurological and Neuro-trauma Assessment

**Neuro-trauma Assessment**

- Evidence of basal skull fractures
  - Raccoon’s eyes
  - Battle’s sign
  - CSF rhinorrhea/otorrhea
  - Hemotympanum or laceration of external auditory canal

**Clinical Findings of CSF Leak**

- Determining if rhinorrhea or otorrhea is due to CSF leak:
  - Clear drainage unless CSF is infected or mixed with blood
  - Patient with rhinorrhea describes salty or metallic taste
  - Collect fluid and obtain quantitative glucose, beta₂ transferrin
  - Ring sign

**Neuro-trauma Assessment**

- Never insert nasogastric tube into a patient with suspected basilar skull fracture

**Glasgow Coma Scale (GCS) 3-15**

<table>
<thead>
<tr>
<th>Points</th>
<th>Eye opening</th>
<th>Verbal</th>
<th>Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
<td>Follow commands</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>Oriented</td>
<td>Localizes pain</td>
</tr>
<tr>
<td>4</td>
<td>Spontaneous</td>
<td>Confused</td>
<td>Withdraws to pain</td>
</tr>
<tr>
<td>3</td>
<td>To speech</td>
<td>Inappropriate</td>
<td>Decorticate</td>
</tr>
<tr>
<td>2</td>
<td>To pain</td>
<td>Incomprehensible</td>
<td>Decerebrate</td>
</tr>
<tr>
<td>1</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

**Neuro-trauma Assessment**

- Clinical severity is graded by GCS
  - Mild, GCS 13-15
    - Normal to lethargic
    - Mildly disoriented
  - Moderate, GCS 9-12
    - Lethargic to obtunded
    - Follows commands with arousal
    - Confused
  - Severe, GCS 3-8
    - Comatose, no eye opening or verbalization
    - Does not follow commands
  - Motor exam: ranges from localizing to posturing

**Neuro-trauma Assessment**

- Combine clinical cues (mechanism) with radiological findings and physical exam
  - History is critical
  - Exam is localizing
  - Radiology is confirmatory
- Serial assessment is essential
  - Mental status
  - Focal findings
ii. Neurological and Neuro-trauma Assessment

**Neuro-trauma Assessment**
- Combine clinical cues (mechanism) with radiological findings and physical exam
  - History is critical
  - Exam is localizing
  - Radiology is confirmatory
- Serial assessment is essential
  - Mental status
  - Focal findings
  - Radiology

**Neurological Assessment**
- Learn it all
- Learn how to divide it up ("focused exam")
- Never skip the important features
- Document findings so others can understand
iii. Emergency Cranial Radiological Assessment

Objectives

- Develop method for rapid, thorough interpretation of computed tomography (CT) and MR imaging of the head
- Identify basic intracranial structures
- Identify intracranial brain shift, hemorrhage, and fractures
- Be able to communicate accurately to the chief resident or attending the important findings that may impact clinical decision making and emergent patient management.

Your tools

- The CT scan is the workhorse for most neurosurgical emergencies
- Cranial x-rays are rarely helpful except in children with skull fractures
- Emergent MR imaging usually supplements CT for cranial tumor, infection, or stroke cases
- Always interpret the scans in the context of the clinical situation and always select the best imaging modality to the suspected pathology

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CT Scan

- Computed Axial Tomography – A collection of superimposed X-rays
- CALCIFIED STRUCTURES (e.g. bone, ACUTE calcium in BLOOD appear WHITE, or hyperdense)
- Ischemic stroke does NOT show on CT until 12-24 hours after it has occurred – it appears DARK (or hypodense) then
- Slices are taken at plane parallel to anterior skull base floor
- A CT scan is the most frequently ordered study in Neurosurgery -- #1 reason: To Rule Out BLEED

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iii. Emergency Cranial Radiological Assessment

Hematomas
- Epidural Hematoma (EPD)
- Subdural Hematomas (SDH)
- Subarachnoid Hemorrhage (SAH)
- Intracerebral Hemorrhage (ICH)
- Intraventricular Hemorrhage (IVH)

Epidural Hemorrhage
- Between skull and dura, limited by periosteal layer so stops at sutures of skull and thus biconvex (lens) shaped
- Due to middle meningeal artery tear, often associated with skull fracture
- Patients can have concussion at injury, then a "lucid interval" when they reawake from the concussion, and then suddenly worsen due to blood compressing brain
- Treatment is usually emergent surgery (unless extremely small)
iii. Emergency Cranial Radiological Assessment

**Subdural Hematoma: Clot age and CT Imaging Characteristics**

**Acute SDH**
- Emergent evacuation
  - If symptomatic and > 1 cm
- Higher morbidity and mortality than EDH
  - Greater impact than EDH, underlying brain injury
  - 50-90% mortality

**Chronic SDH**
- Avg. age ~ 63 y/o
- ~50% without significant hx. of trauma
- Hypodense/isodense crescentic collection
- Evacuation if:
  - Focal deficit, mental status change, serial enlargement
  - Burr hole drainage
  - Looks like motor oil

**Subarachnoid Hemorrhage**

**Subarachnoid Hemorrhage: Pattern Recognition**

**Traumatic SAH**
- 55 year old male, fell off ladder, no LOC, mild headache

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iii. Emergency Cranial Radiological Assessment

55 year old male, fell off ladder, no LOC, mild headache

Repeat head CT stable, discharged next day with routine follow up

Intracerebral Hemorrhage:
Chronic Hypertension

Intracerebral Hemorrhage

- Hypertensive IPH
  - 50% in basal ganglia
  - 15% thalamus
  - 10-15% pons

IPH, IVH, Acute Hydrocephalus

Intracerebral Hemorrhage: Lobar

Intraventricular Hemorrhage

Frontal Horn Temporal Horn Lateral Ventricle

Frontal Horn Third Fourth Occipital Horn
Intraventricular Hemorrhage
Aneurysmal SAH w/ IVH

Traumatic Contusions
- Coup (direct injury to brain from impact) or contre-coup (injury due to brain hitting skull on opposite side as skull decelerates but brain doesn’t) — usually temporal/frontal
- Can develop extreme amount of edema or blossom, so must follow closely with repeat CT scans
- Surgical evacuation if excessive mass effect, avoidance of important brain structures to access surgically, and meaningful survival possible
iii. Emergency Cranial Radiological Assessment

**Acute Hydrocephalus**

**Ischemic Stroke**
- Typically follow a vascular distribution such as the territory of the MCA, PCA or ACA.
- A stroke may take several hours before it is apparent on a CT scan.
- Typically is seen earlier on an MRI

**MCA Infarcts**

**Infarct with a Midline Shift**

**Cerebral Edema**
- Loss of Grey/White Differentiation
- Cisternal Effacement
  - Midline Shift

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iii. Emergency Cranial Radiological Assessment

Cerebral Edema

- Vasogenic: from brain tumor
  - BBB disrupted
  - Responds to steroids
- Cytotoxic: from trauma
  - BBB closed
  - No steroids

Basal Cistern Effacement

Fractures

- Linear
- Depressed
- Open Depressed
- Basal Skull Fracture

Depressed Skull Fracture
### iii. Emergency Cranial Radiological Assessment

<table>
<thead>
<tr>
<th>Open Depressed Skull Fracture</th>
<th>Reconstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Open Depressed Skull Fracture s/p MVA</th>
<th>Recovery: Two Months Later</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
</tr>
</tbody>
</table>

| ![Image](https://via.placeholder.com/150) | ![Image](https://via.placeholder.com/150) |

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iii. Emergency Cranial Radiological Assessment

Basic Principles of MR Imaging
- Images are created based on signals returning from spinning protons
- Not based on density
- Objects are described in terms of intensity (hypointense, isointense, hyperintense)
- T1 and T2 Weighted Imaging
- T1 Post Contrast Enhancement

T1 Weighted Image of the Normal Brain

T2 Weighted Image of the Normal Brain

Basilar Skull Fracture of the Temporal Bone Seen on Bone Windows
iii. Emergency Cranial Radiological Assessment

MRI: Views in different planes

CT (left) vs. MRI T1 (right)

CT (left) vs. MRI T2 (right)

Brain Tumor

Diffuse Axonal Injury (DAI)

Magnetic Resonance Imaging: Stroke
- Diffusion Weighted Imaging:
  - Ischemia
  - Cytotoxic edema
  - Increase in signal as soon as 5-10 minutes after stroke onset

Left: DWI
Right: ADC map
iv. Emergency Spinal Radiological Assessment

**spine injury: location**

<table>
<thead>
<tr>
<th>Type</th>
<th>Neurologic Sequelae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>Brainstem, Cord or Root</td>
</tr>
<tr>
<td>Thoracic</td>
<td>Cord or Root</td>
</tr>
<tr>
<td>Lumbar</td>
<td>Conus or Root</td>
</tr>
</tbody>
</table>

**spine injury: types**

1. Muscular/Ligamentous
   a. Contusions
   b. Strains
   c. Sprains
   d. Complete Ligamentous Disruption

2. Fractures
   a. Complete Ligamentous Disruption

**spine injury: muscular/ligamentous**

1. Contusions
2. Strains
3. Sprains
4. Complete Ligamentous Disruption

**spine injury: ligamentous**

- Anterior Longitudinal
- Posterior Longitudinal
- Ligamentum Flavum
- Interspinous
- Supraspinous

**cord injury: deficit patterns**

1. Normal (No Neurologic Injury)
2. Incomplete Deficit (Syndromes)
   a. Central Cord
   b. Anterior Cord
   c. Brown-Sequard
   d. Posterior Cord
   e. Conus/Epiconus
3. Complete Functional Transection

**spine injury: location type neurologic sequelae**

1. Cervical . . . . . . . . Brainstem, cord or root
2. Thoracic . . . . . . . . Cord or root
3. Lumbar . . . . . . . . Conus or root

**spine injury: types**

1. Muscular/Ligamentous
   a. Contusions
   b. Strains
   c. Sprains
   d. Complete Ligamentous Disruption

2. Fractures
   a. Complete Ligamentous Disruption

**spine injury: muscular/ligamentous**

1. Contusions
2. Strains
3. Sprains
4. Complete Ligamentous Disruption

**spine injury: ligamentous**

- Anterior Longitudinal
- Posterior Longitudinal
- Ligamentum Flavum
- Interspinous
- Supraspinous
iv. Emergency Spinal Radiological Assessment

spine injury: facet joints

spinal Imaging after trauma - indications

1. clinical indications
   a. spine-region pain
   b. neurologic deficit
      (1) radicular
      (2) cord
   c. severe multisystem injuries
d. altered mental status

2. clinical rationale
   a. prevent cord, root injury (neurologic stability)
b. prevent incapacitating deformity and pain (mechanical instability)

Which patients need imaging of the cervical spine?

Case 1: mild/moderate trauma patient
   - no loss of consciousness
   - normal mental status (and not intoxicated)
   - no neck pain or tenderness
   - no neurologic deficit

   no imaging needed

Case 2: mild/moderate trauma patient
   - altered mental status (patient is obtunded and/or intoxicated)
   - neck pain or tenderness
   - neurologic symptoms or deficit

   imaging needed

Case 3: severe multi-system trauma patient

   imaging needed

Which patients need imaging of the cervical spine?

spinal Imaging after trauma – imaging tools

1. boney - fractures/dislocations
   a. X-rays – AP, lateral, open-mouth odontoid
   b. CT scan

2. ligamentous
   a. MRI scan
   b. flexion – extension lateral x-ray

3. disk injury
   a. MRI scan
   b. CT/myelogram

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iv. Emergency Spinal Radiological Assessment

**Cervical: 7**
- Lordotic curve

**Thoracic: 12**
- Kyphotic curve

**Lumbar: 5**
- Lordotic curve

**Spine Injury: Alignment**
1. Pre-vertebral fascia
2. Anterior marginal line
3. Posterior marginal line
4. Spino-laminar line
5. Posterior spinous line

**Normal Cervical Spine**
- Occiput to T1
- Bone integrity
- Alignment: of vertebral bodies, laminae, facets
- Lordotic curve
- Disk, transverse foramen

**Subaxial Cervical Spine**
- Annulus fibrosis
- Nucleus pulposis

**Ligamentous Injury without Fracture**
- Instability possible even with normal CT; early MRI helpful.
- Stabilize until neck pain resolves, assess competence of ligaments with flexion/extension X-rays or MRI.
iv. Emergency Spinal Radiological Assessment

**Unilateral facet disruption**

**Bilateral facet fracture/dislocation: “jumped” or locked facets**

**Subluxation +/- fracture (major facet disruption)**

**Burst fracture**

**Cord contusion**

**Upper Cervical Spine: C1 – C2**
iv. Emergency Spinal Radiological Assessment

**C1 - Jefferson fracture**
- Axial loading
- Often associated with C2 fractures
- Assess transverse ligament

**C2 - Odontoid fractures/subluxations**
- Type I
- Type II
- Type III

**C2 - Hangman’s fracture**
- Hyperextension/axial loading
- Bilateral C2 pars interarticularis fracture
- Unstable when:
  a. >3.5 mm subluxation of C2 on C3
  b. >11 degrees angulation

**Atlantoaxial subluxation**
- Atlantodental interval (ADI)
- Left: Normal ADI ≤ 3 mm
- Right: C1-2 subluxation

**Thoracic and lumbar vertebra**
- "Minor" fractures:
  a. Transverse process
  b. Spinous process
  c. Minimal compression
  d. End-plate
iv. Emergency Spinal Radiological Assessment

Class A: Vertebral Body Compression

- Compression-fracture
  - Anterior column failure
  - Middle and posterior columns intact
  - Unstable if >50% compression or >20 degrees angulation
- Burst fracture
  - Anterior and middle column failure
  - Retropulsion of bone into canal
  - Often have neurologic deficit
  - Unstable

Class B: Distraction (+ flexion/extension)

- Types
  - Flexion/distraction (Chance, seat belt injury)
  - Hyperextension
- Three-column injury usually unstable

AO Classification - Fractures

- A: Compression
- B: Distraction
- C: Rotation

Injury mechanism

Class A: vertebral body compression

- Compression fracture
  - Anterior column failure
  - Middle and posterior columns intact
  - Unstable if >50% compression or >20 degrees angulation
- Burst fracture
  - Anterior and middle column failure
  - Retropulsion of bone into canal
  - Often have neurologic deficit
  - Unstable
iv. Emergency Spinal Radiological Assessment

**Class C: three-column injury with rotation**

- fracture-dislocation
- shear injury
- unstable
- neurologic deficit

1. know normal anatomy
2. obtain appropriate studies (review every level studied)
   - x-rays
   - CT
   - MRI
   - flexion/extension x-rays
3. assess stability (mechanical and neurologic)
   - determine the integrity of the three columns (bony and ligamentous)
   - recognize fracture types associated with mechanism of injury
ICP Management
The Society of Neurological Surgeons Bootcamp

Objectives
1. Monro-Kellie Doctrine
2. Normal and pathological ICP
3. Indications for ICP monitoring (TBI Guidelines)
4. Normal and pathological CPP (variation by age)
5. ICP Management
   - 1st Tier Therapies
   - 2nd Tier Therapies

Monro-Kellie Doctrine
(Edinburgh, 1783)
• The cranium is a "rigid box" and its total volume remains constant.
• Increase in the volume of the cranial compartments (brain, blood, and/or CSF) will elevate intracranial pressure (ICP).
• If one of these three compartments increase in volume, it must occur at the expense of volume of the other two elements

ICP Management

Monro-Kellie Doctrine
(Edinburgh, 1783)
CSF ↔ Blood ↔ Brain Tissue
(3 Compartments)
Increased ICP may be conceived as the result of an attempt to force excess volume into a rigid container

Intracranial Pressure
Why is it important?

Critical Recognition of ICP
What would be the clinical cost of loss of volume from each of the 3 compartments?

• Look for progressive neurologic signs
• Look at three compartments at risk
• Determine the effect of loss of volume on each compartment

Treatable cause of neurologic decline
**Principles of Treatment of ICP**

- **A-B-C’s of resuscitation**
- Maintain perfusion matched to metabolic need
- Avoid distortion of brain
- Limit spread of brain edema

**CMRO₂ = CBF X AVDO₂**

- CMRO = Cerebral metabolic rate of oxygen
- CBF = Cerebral blood flow
- AVDO₂ = Arteriovenous difference of oxygen

**Autoregulation**

- **Metabolic**
  - Higher or lower CBF proportional to demands of brain (CMRO₂)
- **Pressure**
  - CBF unchanged despite changes in BP, ICP or both
- **Viscosity**
  - CBF unchanged despite changes in blood viscosity

**CO₂ Reactivity**

- **With hypercarbia**
  - Hypoventilation, CO₂ ↑ ∆ -7 Vasodilatation -7 CBF ↑
- **With hypocarbia**
  - Hyperventilation, CO₂ ↓ -7 Vasoconstriction -7 CBF ↓

**Hyperventilation**

- Hyperventilation -7 intravascular CO₂ ↓ -7 extravascular CO₂ ↓ (CO₂ readily crosses BBB) -7 pH ↑ -7 vasoconstriction (H⁺ ion is vasodilator)
- Hyperventilation remains an excellent means for rapidly reducing high ICP
- Preventive hyperventilation retards recovery from severe head injury
- Any hyperventilation is ideally accompanied by some monitoring of cerebral oxygenation (PbtO₂, SjvO₂/AVDO₂, CBF, infrared spectroscopy)
- In the absence of such monitoring, hyperventilation is used as a later step in ICP control and always with sufficient arterial blood pressure (MAP >90 mmHg, CPP >60 mmHg)
Mannitol is used
• To decrease high intracranial pressure
• To decrease brain bulk during operation
• To improve CBF
  – Decreases viscosity -7 Increase in CBF -7
  – Compensatory vasodilation
  ("Autoregulation") -7
  – CBF back to baseline, CBV decreases, ICP decreases

Indications for Intracranial Pressure Monitoring
• Level I
  – There are insufficient data to support a treatment standard for this topic.
• Level II
  – ICP should be monitored in all salvageable patients with a severe TBI (GCS score of 3–8 after resuscitation) and an abnormal computed tomography (CT) scan. An abnormal CT scan of the head is one that reveals hematomas, contusions, swelling, herniation, or compressed basal cisterns.
• Level III
  – ICP monitoring is indicated in patients with severe TBI with a normal CT scan if two or more of the following features are noted at admission: age > 40 years, unilateral or bilateral motor posturing, or SBP < 90 mm Hg.

ICP

<table>
<thead>
<tr>
<th>Topic</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indications for ICP monitoring</td>
<td>There are insufficient data</td>
<td>Intracranial pressure (ICP) should be monitored in all salvageable GCS score of 3–8 after resuscitation and an abnormal CT.</td>
<td>ICP monitoring is indicated in patients with severe TBI with a normal CT scan if &gt; 40 years, blood pressure BP &lt; 90 mm Hg.</td>
</tr>
<tr>
<td>Intracranial Pressure Thresholds</td>
<td>There are insufficient data</td>
<td>Treatment should be initiated with ICP &gt; 20 mm Hg.</td>
<td>A combination of ICP values and clinical and brain CT findings should be used to determine the need for treatment.</td>
</tr>
</tbody>
</table>

Intracranial Pressure Monitoring Technology
• Ventricular catheter connected to an external strain gauge is the most accurate, low-cost, and reliable method of monitoring intracranial pressure (ICP). It also can be recalibrated in situ.
• ICP transduction via fiberoptic or micro strain gauge devices placed in ventricular catheters provide similar benefits, but at a higher cost.
• Parenchymal ICP monitors cannot be recalibrated during monitoring.
• Subarachnoid, subdural, and epidural monitors (fluid coupled or pneumatic) are less accurate.

Guidelines for the Management of Severe TBI
• Developed by the American Association of Neurological Surgeons & the Brain Trauma Foundation
• Updated from 1995 and 2000 editions
• In the most recent edition, Levels of Recommendation were changed from "Standard, Guideline, and Option" to "Level I, Level II, and Level III," respectively. Recommendation Levels I, II, and III, are derived from Class I, II, and III evidence, respectively.
  • Class I – prospective randomized controlled trials (PRCT) – the gold standard of clinical trials.
  • Class II – clinical studies in which reliable data were collected prospectively and analyzed retrospectively.
  • Class III – studies based upon retrospectively collected data, case review/report, or studies, expert opinion.

Glasgow Coma Scale

<table>
<thead>
<tr>
<th>Severity</th>
<th>GCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>GS 14 - 15</td>
</tr>
<tr>
<td>Moderate</td>
<td>GCS 9-13</td>
</tr>
<tr>
<td>Severe</td>
<td>GCS 3-8</td>
</tr>
</tbody>
</table>
Guidelines for the Management of Severe TBI

ICP management protocol

Step-wise ICP Management

<table>
<thead>
<tr>
<th>Treatment is escalated to the next level based upon a goal of ICP &lt; 20 mm Hg and CPP &gt; 50–70 mm Hg.</th>
<th>Hypothermia 33–35°C with surface/IV cooling; Rewarm slowly</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICP Control</td>
<td>Goal ICP &lt; 20 mm Hg</td>
</tr>
<tr>
<td>Treatment is escalated to the next level based upon a goal of CPP &gt; 50–70 mm Hg.</td>
<td></td>
</tr>
</tbody>
</table>

ICP=MAP-ICP

<table>
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<tr>
<th>Topic</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerebral Perfusion Threshold</td>
<td>There are insufficient data.</td>
<td>Aggressive attempts to maintain cerebral perfusion pressure (CPP) &lt; 70 mm Hg with fluids and pressors should be avoided because of the risk of adult respiratory distress syndrome (ARDS).</td>
<td>CPP of &lt;50 mm Hg should be avoided. The CPP value to target lies within the range of 50–70 mm Hg. Ancillary monitoring of cerebral parameters that include blood flow, oxygenation, or metabolism facilitates CPP management.</td>
</tr>
</tbody>
</table>

Step-wise ICP Management

1. **Verify ICP**
   - Check if EVD is still patent
   - Check if wave form EVD is present and adequate
   - Check if EVD ICP correlates with intraparenchymal monitor, if present

2. **Check for 30-degree head elevation**
   - Loosen Cervical collar if in place
   - Assure ET tube tape is not constricting tube
   - Open EVD for ICP > 20 for 10 minutes and then close and transduce ICP
     - Repeat once
     - If ICP > 20 keep open at 15 above midbrain, and proceed with ICP module
3. Hypothermia

<table>
<thead>
<tr>
<th>Topic</th>
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<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prophylactic Hypothermia</td>
<td>There are insufficient data</td>
<td>There are insufficient data</td>
<td>Pooled data indicate that prophylactic hypothermia is not significantly associated with decreased mortality when compared with normothermic controls.</td>
</tr>
</tbody>
</table>

- Sedation
  - Titrate Propofol to a Ramsay score of 4
  - Do not exceed 5 mg/kg/hr for more than 24 hours
  - Check Potassium, triglycerides, CK, and UA for myoglobinuria 0.8 h for 24 h
  - If maximum dose of Propofol is reached and ICP > 20
    - Start Fentanyl drip to 0.8 mcg/kg/hr
    - Apply BIS monitor
    - Titrate Fentanyl drip to a BIS of 30 or to maximum 5 mcg/kg/hr
    - Start Propofol with a loading infusion of 1 mg/kg over 10 minutes
    - Continue maintenance infusion of 0.2 to 0.7 mcg/kg/hr

4. Hyperosmolar Therapy

- Keep Body temperature < 37.5
- There are insufficient data
- Mannitol is effective for control of raised (ICP) at doses of 0.25 gm/kg to 1 g/kg
- Signs of transtentorial herniation
- Hypertonic saline can lower ICP and improve hemodynamics
  - Great in patients with low BP and high ICP!!

5. Hyperventilation

- There are insufficient data
- Prophylactic hyperventilation (PaCO2 of 25 mm Hg or less) is not recommended.
- Hyperventilation is recommended as a temporizing measure for the reduction of ICP.
- Hyperventilation should be avoided during the first 24 hours after injury when cerebral blood flow (CBF) is often critically reduced.
- If hyperventilation is used, jugular venous oxygen saturation (SO2) or brain tissue oxygen tension (PbrO2) measurements are recommended to monitor oxygen delivery.
v. ICP Management

7. Hyperventilation
   - Do not hyperventilate in the first 24 hours (goal of PaCO₂ of 35-40 mm Hg)
   - If PaCO₂ is < 20 mmHg, go to hypoxia module
   - If CBF < 18 mI/min/100g white matter or < 67 mI/min/100g gray matter, go to CBF module
     - If PaCO₂ and CBF is optimized hyperventilate to 33-35 mmHg

8. Radiology
   - If refractory, ICP > 20 despite above intervention, obtain portable Head CT without contrast STAT
   - If no Head CT since ICP is elevated despite maximum therapy

9. Consider Surgery!
   - Decompressive Hemicraniectomy
   - Bilateral Frontal Craniectomy

Case Example
   - 27 y/o patient after ATV accident
   - Needs to be intubated at the scene
   - Does not open eyes
   - No movement in his arms but cramping - extending his legs

Injury

Decompression
v. ICP Management

Case Example: Decompression

Barbiturates/Coma

<table>
<thead>
<tr>
<th>Topic</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anesthetics, Analgesics, Sedatives</td>
<td>There are insufficient data.</td>
<td>Prophylactic administration of barbiturates not recommended.</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>High-dose barbiturate administration is recommended to control elevated ICP refractory to maximum standard medical and surgical treatment. Hemodynamic stability is essential before and during barbiturate therapy.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Seizure Prophylaxis

<table>
<thead>
<tr>
<th>Topic</th>
<th>Level 1</th>
<th>Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antiseizure Prophylaxis</td>
<td>There are insufficient data.</td>
<td>Anticonvulsants are indicated to decrease the incidence of early PTS (within 7 days of injury).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n/a</td>
</tr>
</tbody>
</table>
vi. Unstable Neurosurgical Patient: Case Scenarios

**Learning Objectives**

1. Evaluation of stupor and coma
2. Management of status epilepticus
3. Evaluation and management of hypoxia
4. Evaluation and management of sepsis
5. Expanding posterior fossa mass
6. Back pain and weakness after spine surgery
7. Cerebral vasospasm after SAH

**Possible Causes of Delayed Awakening After Intracranial Surgery**

<table>
<thead>
<tr>
<th>Brain Injury</th>
<th>Medication</th>
<th>Systemic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intracranial hemorrhage</td>
<td>Sedatives</td>
<td>Hypothermia</td>
</tr>
<tr>
<td>(intraparenchymal, subdural, subarachnoid)</td>
<td>Analgesics</td>
<td>Respiratory (hypoxia, hypercapnia)</td>
</tr>
<tr>
<td>Stroke</td>
<td>Neuromuscular blockers</td>
<td>Cardiovascular (hypotension, shock)</td>
</tr>
<tr>
<td>Cerebral edema</td>
<td>Anticonvulsants</td>
<td>Metabolic/endocrine</td>
</tr>
<tr>
<td>Hydrocephalus</td>
<td></td>
<td>Hypo/hypernatremia, hypo/hyperglycemia, panhypopituitarism, adrenal insufficiency, hypothyroidism</td>
</tr>
<tr>
<td>Pneumocephalus</td>
<td></td>
<td>Renal failure</td>
</tr>
<tr>
<td>Seizures (post-ictal state, status, nonconvulsive status)</td>
<td></td>
<td>Hepatic failure</td>
</tr>
</tbody>
</table>


**Red Flags for Neurologic Compromise**

- NEW asymmetry in the neurologic exam
- Exam not trending toward improvement

**Focused Exam**

- Level of consciousness
  - Arousalability
  - Motor responses
  - Verbal output
- Eyes
  - Movements
  - Pupillary light reflexes
- Respiratory pattern
  - ABCs
  - Patterns can help indicated level of injury
  - More difficult to assess in intubated patients

**PATIENT 1**

- You are called by an ICU nurse at 22:00 about Pt 1
  - 48 year old man who just underwent clipping of ruptured R MCA aneurysm earlier today
  - Still comatose over an hour after arrival from the PACU, but he was following commands when left for the OR
- You ask for a CT scan
  - It will take about 10-15 minutes to disentangle yourself from the ED
  - The nurse reassures you that Pt 1 is still mechanically ventilated from the OR, and that airway, breathing and circulation are adequate
- Per your sign-out sheet
  - Pt 1 arrived earlier this morning as a H&H Gr III, Fisher Gr III with moderate hydrocephalus
  - Had a ventriculostomy drain placed
  - Received 1000mg of fosphenytoin and 60 mg of nimodipine prior to going to the OR for surgical ligation
Consciousness is a Continuum

- Levels of consciousness
  - Awake/alert
    - Fully aware of self and environment
  - Lethargic
    - Mildly depressed consciousness, but can be easily aroused to wakefulness
  - Obtunded
    - Moderately depressed consciousness, can be aroused with stimulation to answer questions, for example, but will likely lapse back into an obtunded state without verbal or light tactile stimuli
  - Stuporous
    - Deeply depressed consciousness, those who can only be aroused by vigorous and repeated stimuli and will lapse back into unresponsiveness as soon as such stimuli is withdrawn
  - Comatose
    - Total absence of awareness of self and environment even when externally stimulated, regardless of the stimulus used

From The Diagnosis of Stupor and Coma, 3rd ed. by Plum and Posner

Glasgow Coma Scale

Eyes
- 4 = spontaneous
- 3 = voice
- 2 = pain
- 1 = no eye opening

Verbal
- 5 = oriented
- 4 = confused
- 3 = inappropriate
- 2 = incomprehensible
- 1 = none

Motor
- 6 = obeys
- 5 = localizes
- 4 = withdraws
- 3 = decorticate
- 2 = decerebrate
- 1 = none

The Society of Neurological Surgeons
Management of the Comatose or Neurologically Deteriorating Patient

- **ABCs**
- **History**
- **Physical Examination**
- **Check your equipment**
- **Fix the fixable**
  - Check medications
  - Malfunctioning drains and monitors
  - Treat seizures
  - Fix abnormal lab values
- **Imaging**
- **Intervention**

Status Epilepticus

Seizures are hypersynchronous paroxysmal cortical discharges with either motor (convulsive), sensory, or cognitive dysfunction

- Status epilepticus is defined as a seizure lasting more than 30 minutes, or more than one seizure without a return to neurologic baseline in between
- Epilepsy is recurrence of unprovoked seizures

PATIENT 2

You are called to the ICU to see a patient with generalized tonic-clonic seizure activity. The patient is a 45 y/o F status post uncomplicated resection of a right frontal meningioma. What do you do?

### Table 3--A Suggested Timetable for the Treatment of Status Epilepticus

<table>
<thead>
<tr>
<th>Time, min</th>
<th>Treatment</th>
</tr>
</thead>
</table>
| 0-5       | Diagnosis status epilepticus by observing convulsion and seizure activity or one additional seizure
|           |Give oxygen by nasal cannula or mask, position patient’s head for optimal airway patency. Consider intubation if aspiration or airway compromise is needed
|           |Order and administer intravenous glucose if hypoglycemia is suspected, or any abnormalities on 
|           |electroencephalogram (EEG) monitoring
| 5-10      |Establish IV, draw various blood samples for glucose level, serum chemistries, hematology studies, toxicology screens, and determinations of antiepileptic drug levels
|           |Assess oxygenation with pulse oximetry or periodic arterial blood gas determinations
| 10-20     |If blood glucose is established or a brain glucose determination is unavailable, administer glucose in dextrose, give 100 mg of intravenous insulin followed by 20 mL of 50% glucose by 
|           |direct injection, if serum glucose is less than 60 mg/dL or if manifestations of hypoglycemia persist.
|           |Administer 5.1 mg/kg of benzodiazepine at 7 mg/min or 0.2 mg/kg of diazepam at 5 mg/min by IV if hypoglycemia is apparent. It can be repeated if seizures do not also stop within 5 min. If diazepam is used to stop the status, phenytoin should be administered next to prevent recurrent seizures
|           |Give thiopental, sodium 12-24 mg/kg or phenobarbital in doses of 5 mg/kg to a maximum of 20 mg/kg
| >60       |Stop seizures after 20 mg/kg of phenobarbital, give additional doses of 5 mg/kg to a maximum dose of 30 mg/kg
|           |If status does not stop after 20 mg/kg of phenobarbital, give additional doses of 5 mg/kg to a maximum dose of 30 mg/kg
|           |If thiopental, sodium 20 mg/kg of phenobarbital at 100 mg/kg, when phenobarbital is not effective and seizures are status epilepticus, the rate of parenteral or intravenous is 20 g/kg and assisted ventilation is usually required
|           |If status persists, give anesthetics doses of drugs such as intracranial or pentobarbital; ventilatory assistance and vasopressors are virtually always necessary

### Table 2--The Major Drugs Used to Treat Status Epilepticus

<table>
<thead>
<tr>
<th>Drug</th>
<th>Dose</th>
<th>Route</th>
<th>Intravenous</th>
<th>Intramuscular</th>
<th>Oral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diazepam</td>
<td>0.1-0.3 mg/kg</td>
<td>IV, IM</td>
<td>IV, IM</td>
<td>IV, IM</td>
<td>IV, IM</td>
</tr>
<tr>
<td>Lorazepam</td>
<td>0.1-0.3 mg/kg</td>
<td>IV, IM</td>
<td>IV, IM</td>
<td>IV, IM</td>
<td>IV, IM</td>
</tr>
<tr>
<td>Phenytoin</td>
<td>5-10 mg/kg</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
</tr>
<tr>
<td>Phenobarbital</td>
<td>15-30 mg/kg</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
</tr>
</tbody>
</table>

**Notes:**

- Status epilepticus is defined as a seizure lasting more than 30 minutes, or more than one seizure without a return to neurologic baseline in between.
- Epilepsy is recurrence of unprovoked seizures.

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vi. Unstable Neurosurgical Patient: Case Scenarios

**Which Patients Should Get Emergent EEGs?**
- Patients who are in coma for unknown reasons
  - Between 8-30% of patients, depending on patient population, show some form of seizure activity
- Patients with being treated for status epilepticus who meet the following criteria
  - Receive long-acting neuromuscular paralytic agents
  - Have a prolonged postictal period (> 1-2 hours)
  - Are being treated for refractory SE
  - OR have atypical features of their seizures suggestive of pseudoseizure

**PATIENT 2**
WHAT ELSE?
HCT !!!

**PATIENT 3**
You are called to the bedside of a patient in the ICU who has had a sudden drop in her oxygen saturation. 30 y/o F, hospital day 20, DAI, ventriculostomy, paralyzed, sedated, ICP high teens consistently. What are you thinking?

**Hypoxia**
- Investigations:
  - ABG
  - CXR
  - EKG
- Consider:
  - Cardiac Enzymes
  - CBC (anemia, leukocytosis)
  - DVT Ultrasound (consider upper and lower ext.)

**Respiratory Failure**
- Classic indications for mechanical ventilation
  - Respiratory criteria
    - Hypoxia: PaO2 < 70 on 40% O2/significant desaturation on maximum supplemental O2
    - Ventilatory failure: PaCO2 > 50 on ABG (unless compensated COPD);
      Vital capacity < 10-15 cc/kg (Can the patient count to 10 at least?); NIF < -25 cm H2O
  - Intervention or Procedures
    - Helical Chest CT

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Tachypnea/respiratory distress: RR>30

Neurologic criteria

Decreased mental status (GCS<9, or trending toward decline), as from increasing intracranial pressure

Cranial nerve dysfunction leading to aspiration risk
vi. Unstable Neurosurgical Patient: Case Scenarios

Securing the Airway

- Know the process in your hospital
  - Airway team
  - Code team
- Bag-mask is a viable option until help arrives, as in an LMA
- Once the patient is intubated
  - Initial ventilator settings
    - SIMV, AC, or CMV rates ~12-14
    - Tidal Volume ~6cc/kg of ideal body weight
    - Pressure Support of 10 for SIMV mode
      - PEEP around 5
      - FiO2 of 100%
    - ASV (Adaptive support ventilation)
      - Minute ventilation ~120-150% (combination of rate, TV/PS)
    - PEEP around 5, FiO2 of 100%
- ABG in 30-60 minutes

Ventilator Management

- After the initial ABG, settings can be adjusted
  - Increasing rate, pressure support and tidal volume will increase ventilation (decrease pCO₂)
  - With ASV mode, increasing the target minute ventilation with increase ventilation (decrease pCO₂)
  - Follow ABG or ETCO2 monitor to track progress
  - Increasing FiO₂ and PEEP will increase pO₂
  - Can follow O₂ sats to assess patient response

PATIENT 4

You are called to the bedside of a critically ill patient with multiple injuries which include DAI, pulmonary contusions, pelvic fracture, bilateral femur fractures, status post exploratory celiotomy for ruptured abdominal viscus. The nurse is concerned because the patient, who is a 40 yo m, “looks septic”. Define what this means and what are you going to do?

Sepsis

- Systemic Inflammatory Response Syndrome (SIRS)
- Multiple Organ Dysfunction Syndrome (MODS)
- Sepsis – SIRS plus infection
- Severe Sepsis – Sepsis plus MODS
- Septic Shock – Severe Sepsis with Hypotension

Sepsis Management of Sepsis

- Infection
- Fever
- Hypothermia
- Tachycardia
- Tachypnea
- Altered mental status
- Edema
- Hyperglycemia
- Hypotension
- Leukocytosis
- Leukopenia
- Bandemia
- CRP
- Procalcitonin
- Hypoxemia
- Coagulopathy
- ARF
- Ileus
- Blood products
- Mechanical ventilation
- Sedation, analgesia, and paralysis
- Glucose control
- Renal replacement
- Bicarbonate therapy
- DVT prophylaxis
- Stress ulcer prophylaxis
- Standardized protocols

Management of Sepsis

• Resuscitation
  - Diagnosis
  - Antibiotics
  - Source control
  - Fluid therapy
  - Vasopressors
  - Inotropes
  - Steroids
  - Recombinant human activated Protein C (rhAPC)

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Eval and Management of Sepsis

• Follow the principles of EARLY GOAL-DIRECTED THERAPY (EGDT)
  – Internationally accepted guidelines, often protocolized within hospitals
• Dictate diagnostic and therapeutic measures within the 24 hours of recognized severe sepsis or septic shock
  – Severe sepsis: acute organ dysfunction secondary to infection
  – Septic shock: severe sepsis plus hypotension not reversed with fluid resuscitation

Diagnostic Criteria for Sepsis

• Infection, documented or suspected, plus some of the following
  – General variables
    • Fever (>38.3 °C), hypothermia (core temp <36 °C), heart rate >90, tachypnea, altered mental status, hyperglycemia in the absence of diabetes, etc.
  – Inflammatory variables
    • Leukocytosis (WBC>12K), leukopenia (WBC<4K), etc.
  – Hemodynamic variables
    • Arterial hypotension
  – Organ dysfunction
    • Hypopermia, oliguria, ileus, thrombocytopenia, etc.

EGDT: Initial Resuscitation (first 6 hrs)

• Begin resuscitation immediately in patients with hypotension or elevated serum lactate (>4mmol/L)
  – Do not delay pending ICU admission
• Fluid resuscitation goals:
  – Central venous pressure (CVP): ≥8−12mm Hg
  – Mean arterial pressure (MAP): ≥65 mm Hg
  – Urine output: ≥0.5mL/kg/hr
  – Central venous (superior vena cava) oxygen saturation ≥70% or mixed venous O2 sat ≥65%
• If venous O2 sat is not achieved
  – Consider further fluid
  – Transfuse packed RBCs, if required to hematocrit ≥30% and/or
  – Start dobutamine infusion, maximum 20 μg/kg/min

EGDT: Diagnostic Studies

• Cultures before antimicrobial therapy
  • At least two blood cultures, including one peripherally and one from each vascular catheter that has been in place for <48 hours
  • Culture other sites as appropriate (urine, sputum, CSF, etc.)
• Perform imaging studies, if safe and needed, to confirm or sample any other potential sites

EGDT: Antibiotic Therapy

• Begin IV antibiotics as early as possible and always within the first hour of recognizing severe sepsis or septic shock
• Broad spectrum: one or more agents active against likely bacterial/fungal pathogens with good penetration into presumed source
  – Reassess daily to optimize efficacy, prevent resistance, avoid toxicity and minimize cost
  – Consider combination therapy if Pseudomonas infection is suspected
  – Usually for 3−5 days may be able to de-escalate following susceptibility data
• Duration of therapy typically 7−10 days, or longer if patient is slow to respond, if there is an undrainable foci, or if the patient is immunocompromised
• Stop antimicrobial therapy if cause is found to be noninfectious

EGDT: Hemodynamic Support

• Fluid resuscitate using colloid or crystalloid
• Target a CVP of ≥8−12mm Hg in a mechanically ventilated patient
• Use a fluid challenge technique while associated with hemodynamic improvement
  – Give fluid challenges of 1000mL of crystalloids or 300−500mL of colloids over 30 min, watch closely for improvement in hemodynamic parameters
  – More rapid and larger volumes may be required in sepsis-induced tissue hypoperfusion
• Rate of fluid administration should be decreased if cardiac filling pressures increase without concurrent hemodynamic improvement
EGDT: Vasopressors

- Maintain MAP ≥ 65 mm Hg
- Norepinephrine and dopamine through central venous access should be the initial vasopressors of choice
  - May add vasopressin 0.03 units/min to norepinephrine
  - Use epinephrine as the first alternative agent if BP is poorly responsive
- Do not use low-dose dopamine for renal protection
- Patients requiring vasopressors should be monitored with an arterial catheter

EGDT: Supportive Measures

- Inotropic support
  - Use dobutamine in patients with myocardial dysfunction (as evidenced by elevated cardiac filling pressures and low cardiac output)
- Steroids
  - Consider intravenous hydrocortisone for adult septic shock when hypotension responds poorly to adequate fluid resuscitation and vasopressors
    - Dose should be ≤ 300 mg/day
  - ACTH stimulation test is no longer recommended
  - Do not use hydrocortisone to treat sepsis in the absence of shock unless warranted by an endocrine or corticosteroid history

PATIENT 5

- You are called to the PACU at 18:15 to see PT 5
  - 58 year old woman who is 45 minutes post-op from a suboccipital craniectomy for resection of a cerebellar hemangioblastoma
  - She is having a headache, and the anesthesiologists wants you to evaluate her before escalating her pain regimen
  - While examining her, she quickly loses consciousness, and you notice she is apneic
  - You grab a nearby ambu bag and start masking

ABC vs. ICP

- The anesthesiologist wants to intubate immediately, but you feel that the patient needs a ventriculostomy drain while she is being bag-masked, because you suspect increased intracranial pressure
  - And maybe her exam will return quickly if her CSF space is decompressed, thus she won’t need to be intubated?
- A heated discussion ensues, but you realize that you are going to be outnumbered in the PACU, so the patient is intubated while you gather EVD equipment
  - Once the ventriculostomy drain is placed, you take the patient immediately to the CT scanner

Diagnostic Studies

- CT scan confirms hemorrhage into the resection bed, which has caused compression of the fourth ventricle and hydrocephalus, now partially relieved by the ventriculostomy drain
- The patient is emergently taken back to the OR for hematoma resection and has significant blood loss requiring several units of PRBCs and platelets.
- She returns from the OR with the ventriculostomy drain in place, and is hemodynamically stable, but remains intubated

Increased Intracranial Pressure

The Ultimate Compartment Syndrome!
vi. Unstable Neurosurgical Patient: Case Scenarios

### Bedside Interventions

- **Immediate steps**
  - ABCs
  - HOB up, head midline (blood-targeted)
  - Hyperventilate with ambu bag (blood-targeted)
  - Osmotherapy (brain-targeted)
    - 30-50cc of 23.4% saline through central line
    - 250-500cc of 3% saline is an alternative
    - or 1 gm/kg of mannitol through a peripheral line
    - This must go through a filter
  - Try to reverse the herniation (i.e., return pupil to normal) or ICP spike and get patient to CT scanner to look for reversible and/or neurosurgical causes

- **ADVANCED management to consider**
  - Consider CSF diversion (CSF-targeted)
    - This often done if a ventriculostomy drain is already in place
  - Cool the patient (blood targeted)
    - Can pack in ice if a cooling blanket is not available
    - Watch for shivering!
    - Propofol 0.05-0.1mg/kg bolus or 125-250 mg of thiopental IV (blood-targeted)
    - Will drop the MAP/CPP, and may make it difficult to examine the patient
    - If an ICP monitor is in, consider vasopressors to support CPP unless intracerebral hemorrhage is on your differential diagnosis (blood-targeted)

### Expanding Posterior Fossa Mass

- **Management determined by etiology**
  - Ventriculostomy
    - Caution with possible upward herniation
  - Craniectomy
    - Decompress the posterior fossa and evacuate mass

Patients deteriorate quickly
Patients can make remarkable recoveries

### PATIENT 6

- You get called to the floor at 19:30 to see Pt 6 because he is “sleepy”
  - 76 year old man who had just undergone an L2-L5 laminectomy for spinal stenosis
  - As you are walking to the patient’s room, you read your sign-out sheet
    - History of HTN and 90 pack-years of tobacco smoking
    - Underwent the laminectomy because of low back pain that he treated with NSAIDs
  - When you arrive, you find out from his nurse that CD had received several doses of morphine, both in the PACU and on the floor, because he had been complaining of severe, lancinating incisional pain post-operatively
vi. Unstable Neurosurgical Patient: Case Scenarios

**CD’s Exam**
- Difficult to arouse, but with stimulation, will answer some simple questions and does seem oriented
- Says his back and R leg hurt, worse than before surgery
- Says his legs feel “numb”
- His motor strength is difficult to examine fully, because of the effects of the pain medication, but he seems to be moving his arms with much more strength than his legs
- He still has a foley catheter in place, since his surgery just ended a few hours ago

**Diagnostic Work-up**
- You order a post-operative MRI, after assessing airway, breathing and circulation
- MRI reveals a spinal epidural hematoma, with compression of the dural sac
- The patient is taken back to the OR emergently for decompression

**Spinal Epidural Hematoma (SEH)**
- Usually asymptomatic
- Risk factors include
  - Multilevel laminectomies, preoperative coagulopathies and vascular anomalies, pre-operative NSAID use, intraoperative blood loss of more than 1 liter, age >60 years old, those with Rh + blood types; intraoperative Hgb levels less than 10 g/dL, or an INR>2 within the first 48 post operative hours
- Want to get an MRI to visualize the SEH as soon as it is suspected
  - Early surgical exploration and evacuation gives the best chance for recovery

**PATIENT 7**
- 59 year old male
- New onset focal weaknesses in LUE and decreased levels of consciousness after ruptured MCA aneurysm Clipping

**Cerebral Vasospasm**
- Delayed narrowing of large capacitance arteries at the base of the brain
- Often associated with radiographic or cerebral blood flow evidence of diminished perfusion in the distal territory of the affected artery
- Typical temporal course
  - Onset 3 to 5 days after the hemorrhage
  - Maximal narrowing at 5 to 14 days
  - Gradual resolution over 2 to 4 weeks

**Diagnosing Vasospasm**
- Symptoms often start with acute or subacute encephalopathy
- Focal neurologic deficits can follow, depending on which arteries are in spasm
- Fever and leukocytosis may occur
  - Rule out infection!
- TCD is recommended for the diagnosis and monitoring of vasospasm, although cerebral angiography may be required for definitive diagnosis
  - And has the added benefit of potential treatment
vi. Unstable Neurosurgical Patient: Case Scenarios

Management of Cerebral Vasospasm

- Oral nimodipine (60mg q 4hrs) from the time of admission until PBD #21 reduces poor outcome related to SAH
- Treatment of cerebral vasospasm begins with early management of the ruptured aneurysm, and in most cases, maintaining normal circulating blood volume/avoiding hypovolemia
- One reasonable approach to symptomatic cerebral vasospasm is hypertensive, hypervolemic therapy (add hemodilution to get “triple-H” therapy)
- Cerebral angioplasty and/or selective intra-arterial vasodilator therapy may be reasonable after, together with, or in the place of triple-H therapy, depending on the clinical scenario
  - Consider angiogram for angioplasty if there is a focal deficit

Cerebral Vasospasm

- ‘Triple H’ Therapy
  - Hypervolemia (Albumin; Hetaestarch)
    - Target CVP 8-12 cm H₂O
  - Hypertension
    - SBP up to 180-220 mmHg
  - Hemodilution
    - Target Hct <33%
    - Transfuse for Hct >25%

Vasospasm Treatment

- Pt 7 is already on nimodipine 60 mg per NGT q4 hrs
- Bolus 1 liter NS, increase IV fluid rate
- Use vasopressors (such as phenylephrine) to increase MAP goal to 100-120 mm Hg
- Notify interventional neuroradiology team, especially if above efforts do not quickly reverse focal neurologic deficit, to consider cerebral angioplasty
Emergency Evaluation of Hydrocephalus Shunt Patients

The Society of Neurological Surgeons

**Communicating vs Obstructive Hydrocephalus**

- **Communicating Hydrocephalus**
  - All 4 ventricles are enlarged
  - Causes: IVH of prematurity (grade III/IV), adult IVH, aneurysmal SAH, meningitis
  - May do lumbar puncture

- **Obstructive Hydrocephalus**
  - Dilatation of lateral and third ventricles with small, compressed or normal size 4th ventricle
  - Asymmetry or enlargement of lateral ventricle when obstruction is at Foramen of Monro (e.g., colloid cyst)
  - Posterior fossa mass lesions (tumor, ICH, cyst), intraventricular mass lesions (tumor, IVH, cyst), aqueductal stenosis
  - Do NOT do lumbar puncture

**Communicating Hydrocephalus**

- Enlargement of lateral, 3rd, and 4th ventricle
  - Note sulcal effacement, temp horns, rounded 3rd, and enlarged 4th

**Obstructive Hydrocephalus**

- Aqueductal stenosis
  - Note enlarged frontal horns, temporal tip dilation, rounded 3rd but small or normal 4th ventricle

The average adult brain produces between 450 and 600 cc of CSF every day or about 20 cc/hr

At any given moment, there is ~150 cc of CSF present in the average adult; of this, only ~25 cc is within the brain ventricles

CSF volume turns over 3-4 times every day
vii. Emergency Evaluation of Hydrocephalus Shunt Patients

**Shunt Technology**
- Pressure differential valves
- Antisiphon valves
- Flow regulated valves
- Programmable valves

**CSF Shunt Malfunction: Clinical Presentation**
- Raised Intracranial Pressure
- Headache (frontal, dependent)
- Nausea, vomiting
- Papilledema
- Altered level of consciousness
- Bradycardia
- Brainstem dysfunction
- DEATH

**CSF Shunt Malfunction: Infants**
- Progressive macrocephaly
- Tense anterior fontanelle
- Sutural splaying
- Downgaze, lid retraction
- Esotropia (VIth nerve palsy)

**CSF Shunt Malfunction: Children**
- Developmental delay
- Decline in school performance (esp. verbal IQ)
- Visual loss

**CSF Shunt Malfunction: Myelomeningocele**
- Suboccipital/spinal pain
- Pain/swelling at MM closure
- Decreased grip strength
- Lower extremity dysfunction
- Bladder spasticity/infections
- Progressive scoliosis
- Ventricles may not change

**Radiology**
- Compare ventricular size to “well” bas
  - Infants: Transfontanelle ultras
  - CT
  - MRI
- Shunt x-ray series
  - Disconnection or fracture of tubing
Invasive Studies

• CSF shunt tap
  – Assess flow and pressure (although proximal obstruction may commonly interfere with accuracy)
  – Send CSF for GS/Cx, Glu/Pro, cell counts if infection suspected
  – Relieve pressure if obstructed distally
• Radionuclide shuntogram
  – Assess proximal and distal flow
  – Ventricular reflux and outflow each correlate with appropriate function (but test is imperfect)
• Intracranial pressure monitoring

Presentation

• Fever
  • CSF:
    • WBC>RBC > 1:700
    • + Gram Stain/Culture
  • Abdominal pseudocyst
  • +/-Ventriculomegaly
• Early
  • High fever
  • Peripheral leukocytosis
  • Enyhematos incisions
• Late
  • Low grade fever
  • Normal peripheral WBC count
  • Anorexia

CSF Shunt Infection

• Organisms
  • Staph. Epi (40%)
  • Staph. Aureus (20%)
  • Gram Negatives
  • Diptheroids
  • Yeast
• Therapy
  • Externalize shunt
  • Change hardware
  • Antibiotics
  • Consider LP

Differential Diagnosis of Shunt Infection

• Gastroenteritis
  – Often associated with sick contacts, diarrhea
• Otis
  – May often be detected on physical examination
• Urinary tract infection
  – Important to differentiate from colonization in spina bifida patients

CSF Shunt Complications: Mechanical Failure

• Blockage
  • Choroid plexus
  • Ependyma
• Fracture
• Disconnection
• Valve failure

CSF Shunt Complications: Mechanical Failure

• Distal failure
  • Kinked tubing
  • Malabsorption
  • Pleural effusion
  • Cor pulmonale
  • Shunt nephritis
vii. Emergency Evaluation of Hydrocephalus Shunt Patients

CSF Shunt Complications: Abdominal failure
- Umbilical hernia
- Extra-peritoneal catheter
- Bowel perforation

CSF Shunt Complications: Overdrainage
- Postural (Low pressure) headache
- Subdural hygroma
- Craniostenosis

CSF Shunt Complications: Hemorrhage
- Parenchymal damage
- Raised ICP
- IVH: Valve obstruction
- Ependymal adhesions and multicompartmental hydrocephalus

Shunt Evaluation Protocol in the Emergency Room
- ED Management
  - NPO
  - IV
  - Cardiorespiratory monitor
- Physical examination
- Obtain imaging studies
- Labs
  - CBC with differential
  - If indicated:
    - Anticonvulsant levels
    - Coagulation parameters
    - Electrolytes
    - Urinalysis

Shunt Evaluation Protocol: History
- History
  - Hydrocephalus etiology
  - Exact date of last tap or revision
  - Symptoms of last failure
  - Seizure disorder?
- Latex allergy?

Shunt Evaluation Protocol: Examination
- Neurological Examination
  - Mental status
  - Cranial nerves
  - Fundal
  - Valve
  - Shunt incisions
  - Abnormal
- Medical Examination
  - Vital Signs
    - Heart rate
    - Temperature
  - Pharynx
  - Chest auscultation
  - Tympanic membranes
vii. Emergency Evaluation of Hydrocephalus Shunt Patients

**Shunt Evaluation Protocol: Diagnostic Studies**
- Non-contrast head CT scan (shunt protocol) or ‘quick brain’ MRI
- Shunt x-ray series
- Abdominal ultrasound, if indicated
- Shunt tap, if indicated
  - Formal skin preparation
  - 25g butterfly needle: test OP and valsalva (OP may be obscured by proximal obstruction)
  - CSF sample for G5/Cx, Cell count, Glu/Prot

**Shunt Evaluation Protocol: Admission**
- Immediate intervention for:
  - Definite, acute malfunction
  - Pain
  - Infection
  - Bradycardia
  - Decreased mental and/or vision
- Cardiorespiratory monitoring
- Frequent neurological checks
- NPO except meds
- Anti-microbial shampoo
- Consider steroid prep for latex allergy

**Conclusions**
- Involve experienced team members in significant care decisions
- When in doubt, keep the patient for observation
- Listen to parents
- Myelomeningocele patients may have protean forms of presentation and increased risk for sudden deterioration
- Remember that, above all, shunt malfunction is a clinical diagnosis, supported by imaging studies and other data

**Case 1**
- **History**
  - 6 y.o. with post-hemorrhagic hydrocephalus
  - 3 days progressive fever and malaise
  - Intermittent right sided headaches
  - Last revision 3 years ago for obtundation
- **Physical Examination**
  - Irritable
  - Temperature 102.5 F.
  - Inflamed right tympanic membrane with effusion
- **Imaging**
  - Axial imaging: ventricles unchanged from last well scan
  - Shunt x-rays without disconnection
- **Diagnosis**
  - Otitis media

**Case 2**
- **History**
  - 10 y.o. with myelomeningocele and hydrocephalus
  - One week of progressive frontal headaches and neck pain
  - One day of vomiting
  - Mother states these are typical malfunction symptoms
- **Physical Examination**
  - Alert
  - Baseline
  - No papilledema
- **Radiology**
  - Axial imaging: unchanged from well baseline (small ventricles)
  - Shunt x-rays without disconnection

The Society Of Neurological Surgeons Bootcamp
Emergency Evaluation of Hydrocephalus Shunt Patients

Case 2

- **Diagnosis**
  - VP shunt malfunction
  - Total proximal shunt obstruction was observed at surgery

- **History**
  - 10 y.o. brought to E.R. by ambulance, obtunded
  - EMT: "Has a shunt for hydrocephalus; had headaches at home for last few days"

- **Physical Examination**
  - Unresponsive
  - RR 15, labored
  - HR 70
  - Pupils 4 mm, sluggish
  - Frontal valve-reservoir palpable

- **Treatment**
  - Neurosurgeon attempts to drain CSF; shunt tap is dry
  - 1 gram/kg mannitol is given

- **E.R. Course**
  - Intubated
  - During CT, heart rate drops to 40

Case 3

- **Diagnosis**
  - Severe ventricular shunt malfunction

- **Treatment**
  - Neurosurgeon attempts to drain CSF; shunt tap is dry
  - 1 gram/kg mannitol is given

- **E.R. Course**
  - Intubated
  - During CT, heart rate drops to 40

Case 4

- **Diagnostic Studies**
  - Axial imaging: no change vs. very subtle ventricular enlargement from well baseline
  - Shunt x-rays: no disconnection
  - Shunt tap:
    - Opening pressure = 14 cm H2O; good flow
    - RBC = 1, WBC = 9
  - Gram stain and preliminary culture negative

- **Further Studies**
  - Abdominal ultrasound: positive for pseudocyst
  - Initial CSF culture (special request for 7 day hold) grows rare Propionobacter 5 days later

- **Treatment**
  - Shunt removed and replaced with EVD at presentation
  - 7 days IV Abx and external drainage
  - Repeat ultrasound: pseudocyst resolved
  - CSF WBC = 2
  - New shunt inserted

Case 4
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Making the Incision: Surgical Pause to Scalp Blood Supply

The Operating Room: Orientation and Surgical Environment

- Personnel: surgeons, anesthetist, nurses, techs, neurophysiology, students, lawyers
- Equipment and tools
- Noise generation
- Ongoing communication, respect.
- Understanding what is going on around you
- Be prepared when you arrive. The prepared mind is the teachable mind.
- When assisting, think if you were the surgeon, what would you want done to aid you.
- POSITIONING THE PATIENT IS AN ART FORM. It takes years to learn to do correctly. You and your patient will suffer if you do not learn to do it correctly.

The surgical environment

Right Craniotomy

Concepts in Positioning

- Line of sight
- Patient Comfort
- Venous outflow
- Brain relaxation and auto retraction
- Surgeon Comfort
- If you do not position correctly, you cannot get there from here
- Padding pressure points
- Checking the pressure points: ie foley, breasts, elbows, knees, eyes
- Remember harvest sites
- Consider central venous access sites
- Anatomical Considerations for pin placement
- Work with anesthesia so they have access
- Neurophysiology access
- Turning the table and not making spaghetti
- Cooperation: if everyone is comfortable the case will be more efficient

Mayfield head holder
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Surgical Pause: the TIME OUT

• Stop and Pay attention
• Anyone in the room can pull the stop cord
• There is zero tolerance to not doing it
• Do it correctly, or do it over.
• Do it respectfully
• After it is done, there is time to review with the team the steps and flow of the operation.

The Surgical Pause – Time Out

• Confirm:
  – Confirm patient identity
  – Confirm length, type of procedure and surgical site (left/right; spinal levels)
  – Confirm use of Foley catheter, prophylactic antibiotics, steroids, Mannitol, Dilantin®, etc...
  – Confirm availability of equipment (microscope, CUSA®, c-arm, retractors, implants, etc...)
  – Confirm availability of blood and blood products
  – Confirm availability of ICU, frozen section

Hair and Neurosurgery: know what the attending wants and the patient expects

• Most neurosurgeons prefer to shave hair on the incision site.
• Hair sparing craniotomies are getting common.
• Hair needs to be prepared and draped with standard sterile technique.
• No difference in the incidence of infection.

Prepping and Draping Principles

• Inside to out
• Prep wide, drape narrow
• Let dry: most agents are active on contact
• REMEMBER ALCOHOL IS FLAMMABLE
• Know each attendings RITUALS
• Your Personal Scrub is an important part of the prepping and draping
• Consider changing scrubs between cases to avoid cross contamination especially in cases of infection.

Aseptic technique

• Scrub the skin with betadine or chlorhexidine solution for at least 5 minutes.
• Avoid contact with eyes.
• Cost of infection is high
• Expensive implants (DBS, spinal instrumentation)
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The Scalp

- S = Skin
- C = Subcutaneous tissue
- A = Aponeurosis
- L = Loose areolar tissue
- P = Pericranium

The anatomical basis of scalp incisions: basic principles

- Access to lesion
- Remember the adjuvant treatments to come and the possibility of re-operation
- Wound healing issues: systemic diseases, chemotherapy, radiation, steroids, re-operations
- The closure starts with the opening
- Blood Supply: 5 major arteries and a rich anastomosis
- The incision is a door: It rotates on its hinges
- Innervation: to block, to make a numb skull or to cause paralysis and atrophy
- Know the boney anatomy of the skull including: the number and location of each bone; geometric shape and orientation; sutures; and muscular attachments
- Get a skull and study it.

The Scalp – Arterial Supply

The Frontalis Branch of the Facial Nerve

The Frontalis Branch of the Facial Nerve (Confusing nomenclature)


Standard craniotomies

Innervation

- Supratrochlear nerve and the suprachiasmatic nerve from the ophthalmic division of the trigeminal nerve
- Greater occipital nerve (C2) posteriorly up to the vertex
- Lesser occipital nerve (C2) behind the ear
- Zygomaticotemporal nerve from the maxillary division of the trigeminal nerve supplying the hairless temple
- Auriculotemporal nerve from the mandibular division of the trigeminal nerve

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Incisions Types
- Curvilinear
- Bicoronal
- Straight “lazy S”
- Reversed question mark
- “U shaped”
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Neurological Surgery Residents

- Represent your Service and Attendings
- Are elite and held at the highest standards
- Are called on to manage the terror
- Must remember the burden of their patients and families
- Must carry themselves with the utmost respect for patient, family, co-workers and staff

Purpose and Importance

- Share information with other healthcare providers: provide continuity
- Living history of patients illness
- Medical legal document: anything you write can and will be used in a court of law and public opinion
- Billing and coding
- Part of teamwork
- Primary patient safety issue
- Single most important aspect of communication is to stop, focus, and listen. There is no multitasking in communication.

Communication and Documentation Considerations

- In Neurological Surgery we may never have the opportunity to talk with our patient
- Communication with the family is also our responsibility
- Understand whom is the legal voice of the family
- Elicit the level of the patient or families understanding of the situation
- Ask if you are understood and if there are any questions
- Be patient
- Do not be afraid to say, “I do not know”.
- Remember to summarize and reinforce your discussion: families and patients under stress may be distracted.
- Patients whom are having difficulties need more communication not less

Key Elements of Documentation and Communication

- Timing and Timeliness
- Critical events and values
- Accurate, detailed, and concise.
- Do not use abbreviations: i.e. perrla
- Never alter a medical record unless stating that you are correcting an error
- Read before you countersign
- Minimize copy and paste
- No derogatory statements, chart wars, subjective remarks, or non-patient care information
- If it is not written, you did not do it

Types of and people with whom we communicate: How we do it determines our success

- Verbal
- Non-verbal
- Written
- Nurses/Allied Health providers
- Patient: expectations
- Family: expectations
- Colleagues
- Respect, Respect, Respect, Respect and Respect
- Billing and Coding Personnel
Types of Documents

- History and physicals/Admit Notes
- Consultations
- Consents
- Operative/Procedural Reports: include time out and sidedness
- Phone Interactions
- Progress Notes
- Discharge Summaries
- Hand-off Documents and Communication
- Hospital and Physician Billing Documents

Admission/H&P

- History of present illness: Include chief complaint and history of present illness.
- Review of Systems: 2-9 components
- Medications: include non prescribed medications, supplements and holistic treatments
- Allergies: include food
- Family History
- Social History: How does illness effect ability to work
- Detailed Examination: 5-7 systems or 12 points on one
- Review of Studies
- Assessment
- Plan

Consults

- Restate the patients clinical condition
- Summarize in detail the neurological examination
- Summarize in detail the radiological studies
- Clearly state the Assessment and Treatment Plan
- Leave a page number of additional questions
- Answer the Question
- Contact the service asking for the consult and talk with them specifically making sure you have answered the question.
- Be timely, prompt and courteous. If people ask you to see a patient it is because they are asking for your help.

Operative/Procedural Notes

- Pre and Post operative diagnosis
- Indications and consent
- Procedure: side, site, levels.
- Surgeon and assistance
- Anesthetic type
- Blood loss and fluid replacements
- Findings
- Surgeons presence
- Specimens
- Postoperative condition and disposition
- Your audience: yourself, billing and coding, future surgeons and care givers, legal review.

Consent: It is a Process

- Consent is a conversation: Document it
- Condition
- Procedure
- Alternatives
- Risks
- Benefits
- Questions
- Agreement

Consent Consideration

- Given Voluntarily and can be withdrawn
- It is a timed document
- Should be procedurally and patient specific
- Is necessary for all therapeutic and diagnostic procedures
- Must be obtained by knowledgeable physicians
- The signed form is an important documentation of the informed discussion conversation. Include side, site and level.
- Special issues: minors, difficult patients, emergencies, cognitive disabilities, power of attorney, language/cultural/religious barriers
- Understanding whom is an appropriate and legal interpreter
- Treatment without consent can be construed legally as battery. Failure to obtain proper informed consent can be construed as malpractice.
Discharge Summary

- Extremely Important for Continuity of Care
- Include Key elements of Course of Care: Chief complaint; Diagnostic findings; therapies and procedures; response to treatment, disposition at discharge; appropriate dates of events; medications on discharge; and discharge instructions (including follow-up appointments)

Hand-offs

- Is a major source of medical errors
- Are reflection of team’s ability to communicate
- Are a major source of malpractice claims
- Can place a patient at risk
- Remember, the most sensitive test to follow a patient’s course is serial neurological examinations by the same observer.
- The Structured Hand off: SEAM
  a) Summary, situation and/or status
  b) Every Active major clinical status
  c) Management and planned next steps related to each major clinical issue
- It is important for the clinician on the receiving the information to be able to ask questions
- Call early, and Call often. Do not be afraid to call your Chief or Attending for information and advice. Especially over the weekend the attending may be the person whom has the most continuity of care.
- The Nurses spend 8-12 hour shifts at the patient’s bedside. They make serial observations. When they call go see the patient.

Billing and Coding

- Might not seem important right now but will be vital in your future
- Generated off of your documentation
- Has medical and legal consequences
- Codes: CPT, ICD-9, inpatient, out-patient, procedural, modifies, new vs. established
- Components: History, Examination, Medical decision making
- Contributing Components: Extent of counseling coordination of care with others, nature of the presenting problem(s), complexity and time.

Conflict: the lack of communication

- Conflicts are inevitable, expect them.
- In Conflict you have a choice.
- Patient safety is our primary goal.
- Try to see what is the benefit to the other person.
- Are you going to work with this person again?
- Does your boss really want to hear what you said?
- Keep the patient not your ego at the center of the discussion.
- Some conflict is good and necessary for the long term benefit of the patient.
- Conflict can hinder communication. The lack of communication can be a patient safety issue.

Summary

- Communication and Documentation are part of your professional responsibility
- Accurate, timely, and pertinent documentation is crucial for good patient care and a potent force against malpractice
- Communication and Documentation play a critical role in durable Hand-offs which are crucial to good patient care and a potent force against malpractice
- Communication and Documentation is part of the ongoing process of patient care and education between the physician, patient, family and health care partners