ABNS (American Board of Neurological Surgery) - Quick Read on the morning of Oral Exam

APPROACH BOARD CASES

Be safe!
Think about neurological mimickers
Do not pass case to colleague or another service (even if in reality you would do so – examiners are not interested to hear your lack of experience)

Errors in your replies will happen – recognize it even in the middle of the case and give correct answer (e.g. operating on brain tumor and realizing it is tumefactive MS → recommend steroids and interferon and MRI in 3 months)

If will need medicine postop – mention now so not to forget! (or maybe operate on Aspirin)

DIAGNOSIS

History ("any other pertinent history?" or better ask specific targeted questions "Any smaller HA in the past"? [sentinel bleeds])

"I am going to examine the patient"

Exam

Always ask about VITAL SIGNS, esp. in ***lethargic and trauma*** patients!
– ABC, intubate if necessary! (coma, penetrating TBI, face*, combative)
– it takes 2 seconds to say that during exam!
hypoxia, hypotension, hypothermia + intoxication, sedation, paralytics + other major injuries

Always check **peripheral pulses** in nerve trauma – vascular injury is emergency!

Give impression – ***anatomical compartment*** where pathology is located

Labs (ask for "set of labs – Hb, WBC, coags, etc")

Imaging

Traumas – entire neuraxis CT + CTA (→ DSA)

Describe imaging (e.g. "Sagittal T1 of C-spine shows intramedullary enhancing mass with perilesional edema", "Extra-axial hyperdensity, likely hematoma")

"My differential is"

- *if images not clear what it is* – start "Seems like primary brain tumor in the left temporal lobe, no enhancement, so suspect low grade," → then ask for **additional slices** or "**Does radiology agree with my differential**?"
- after reviewing **DSA**, ask "any concerning features?"

Multiple lesions: hemorrhages (embolic infarcts, amyloid angiopathy), abscesses, demyelinations, immune-related lesions (2/2 systemic therapy) → only then multifocal glioma vs mts vs lymphoma

MANAGEMENT

What can I do immediately?

dex, brace, Foley (± urodynamic study)
BP control
start ASA 325 + statin + HTN treatment

Admit (e.g. ICU – all bleeds!; stroke unit)
Pregnant – OB/GYN consult
Pediatric – pediatrics consult for weight-based medications + genetics
Ophthalmology
ENT
Endocrinology

Treatment Options

Do not jump on surgical plan!!! (even if case is surgical – Boards caveats are here!)

1. ***Discuss options*** observation / biopsy / resection; brace / fusion
2. Start ***conservative management*** (e.g. for any pain, esp. HNP *) but do not linger on it – if examiner pushes that "patient is worsening", it is time to operate

*bedrest and steroid trial

Tumors: Performance status + staging CT CAP, PET scan → discuss at Tumor Board:

1. Metastatic burden - ask for life expectancy (aim > 6 mos)
2. If not planning tumor resection (multifocal / thalamic* / corpus callosum / deep insular tumor, poor KPS) → **noninvasive tests** (AFP, hCG in serum, CSF cytology) vs. **biopsy** → adjuvant treatment.

*thalamus bx is dangerous (better skip it)

If planning surgery:

1. **Comorbidities**:
   a. **elective** - SOB, chest pains - ask for "medical clearance"
   b. **emergency** – coags, Hb
2. **Counsel** patient "It is benign tumor but surgical risk is substantial, incl. need for postop PEG and trach, chances of subtotal resection" + talk about prognosis (esp. for tumors)
3. Do not be dogmatic – ***mention all surgical options*** (as next slide may show something different you chose) → "but I think the safest thing to do is…."
4. **Consent** for "[emergent] right/left …… procedure for microsurgical resection of brain tumor" + surgical adjuncts "toys" (3M + nav)

SURGERY

Preparing outside OR:

1) additional "concerning" lesions: panspine MRI, CTA, adrenal CT

   Beware of **tandem lesions** (spine, carotid, etc) – ask for neuraxis MRI ("it is free on Boards")

2) bleeding: **Hb**, **coags**, preop **DSA**:
   a. feeder localization → intraop early control
   b. artery of Adamkiewicz localization
   c. **embolization** (intraventricular tumors, large supratentorial meningiomas fed by ECA [not for ethmoidal feeders!], vertebral tumors)
3) surgical corridor: fMRI + DTI (for lesions in eloquent areas)
4) localization: before thoracic surgery: **panspine CT/XR** – "*how many ribs and lumbar vertebrae, any transitional vertebrae – intraop localization is a concern*" – **radiology marking** to help fluoro localization (esp. middle thoracic spine + call radiology intraop), use navigation

   N.B. make sure MRI scout view shows all vertebrae!
   N.B. count index level same way on preop MRI and intraop XR – either both from C2 down or both from sacrum up.

Preparing in OR:

1) medicines (4): **steroids, mannitol, AED, abx** (and tetanus in trauma) + hyperventilation
2) CSF drainage: preop EVD (esp. posterior fossa with HCP) or Lumbar Drain

Routine **preop EVD** for ventricular tumors, conditions with HCP (clamped / open)
Lesions within brainstem parenchyma / 4th ventricle → placement of **defibrillator pads** before surgery!

Dangers (3):
1) **blood loss**:
   Monitor:
   - starting Hb, coags
   - peds – calculate blood volume - **circulating blood volume** 70 mL/kg
   - A-line, two large bore IVs

   Resuscitate:
   - type and cross 2 units of blood
   - CellSaver (for spine cases)

   Stop bleeding:
   - TXA (for spine cases)
   - large-bore suction
   - tray of aneurysm microclips
   - **proximal vessel control** (**tumor** feeders, parent vessel for **aneurysm**)
2) **air embolism**: precordial Doppler, central multichannel line
3) **difficult localization** – verbalize:
   craniotomy - **side** and anatomical **landmarks**!
   spine surgery - **side** and **level**! – "*localize incision with fluoroscopy* - on **skin** and on **bone**"!!!; if difficult to see on intraop XR – use oblique views, spin O-arm, **long cassettes** (that includes sacrum) instead of fluoroscopy, call radiology

Intercrestal line always bisects the lumbar vertebra above the last

Toys (3M + nav):
1) (awake) mapping
2) monitoring (for spine* and cranial cases!): SSEP, MEP, EEG, BAER, cranial nerves, EMG; stimulation for PNS cases
   *cervical OPLL, intramedullary tumor, thoracic disc; *stimulate lumbar pedicle screws*!
3) microscope
4) navigation (even for posterior fossa!) + 5-ALA (for grade 3-4 gliomas), intraop US (to compensate for shifts) (no to iMRI)
   + resection tools – CUSA, SONOPET, Nico Myriad, laser

"My standard spine/cranial protocol"

1) **space:** position + table + fixation (incl. [radiolucent] Mayfield frame with retractor attachment)
   e.g. *prone on open Jackson table,* tumor in upper most point of the filed, maximize venous drainage and gravity assisted brain retraction
2) **protect:** all pressure points padded + eye protection (corneal shields)
3) Foley
4) SCDs
5) timeout:
   – anesthesia type (not to interfere with mapping), local anesthetic

- MAP goal (for spine cases)

6) prep with chlorhexidine, 3 mins to dry, drape

Procedure

1) **skin**: incision beveled along hair follicles to minimize incisional alopecia
2) **scalp**: pericranial flap, frontalis protection, muscle cuff
3) **bone**: dural tack up stitches! + wax bone edges

Drain **CSF** early!
Secure vascular control early (tumors, vascular lesions)
Always send for **frozen pathology** – to confirm preoperative diagnosis!

4) **finish** procedure after hemostasis is complete + irrigation + drain
5) postop EVD (esp. if intraventricular bleed – protect foramen if Monroe with cotton balls)

Vessel intraop visualization
Doppler
IC green
Yellow 560 – nicely shows filling of tiniest perforators
Completion DSA

POSTOP

Controlled emergence from anesthesia
BP goal

Dispo
Flat / HOB up

Pain and nausea control
DVT prophylaxis
Steroids + Glycemia control (wound healing)
AED

Imaging (→ second look sx for ependymoma)
Tumor Board
Follow up
e.g. penetrating TBI - repeat CTA in several weeks.

PT and rehab

Neuro decline: *Do not rush in emergency to order CT without examining patient (what if seizing?)*

TRIALS

- cite only to justify your decision:

ARUBA >>

at 33 months, event rate (death or symptomatic stroke) was 3 times higher in intervention group (30% vs 10%)

ISUIA >>

ISAT >>

SAMMPRIS

stenting increases stroke risk in intracranial atherosclerotic stenosis

MOMS >>

Thrombectomy

MR RESCUE – no benefit

MR CLEAN – 1.67 times more likely favorable functional outcome

DAWN – benefit up to 24 hours from onset

DHC trials

HAMLET, **DESTINY**, **DECIMAL**: DHC within 48 hours of large MCA infarcts reduces mortality (49% absolute risk reduction).

DESTINY II - equal benefit for patients > 60 yrs

TBI

NABIS: H II >>

BOOST-2 >>

CRASH: steroids in TBI are harmful

CRASH-3: TXA within 3 hrs of TBI reduces mortality in mild-moderate TBI; no adverse effects

DECRA vs. RESCUEicp >>

SCI

NASCIS >>

MePred improves outcome of acute SCI if given for 24 hrs (started within 8 h of injury) + trend toward higher rates of complications

STASCIS >>

19.8% vs. 8.8% improvement of 2 AIS grades in the early (< 24 hrs) vs late surgery groups (for cervical SCI)

ICH – SBP control

INTERACT2 - intensive treatment has no significant effect on *hematoma growth*

ATACH-2 – early intensive treatment (SBP goal < 140) has no significant effect on outcome and even results in ↑renal complications (thus, 140-180 is no worse)

ICH – surgery: >>

STITCH II >>

operate early lobar ICH within 1 cm and GCS 9-12

MISTIE III CLEAR III

tPA improves mortality but not functional outcome

STICH II

Carotid disease
ACAS
NASCET - benefit of CEA:

Stenosis (%)	Relative Risk Reduction (%)	Absolute Risk Reduction (%)	When perioperative morbidity and mortality
SYMPTOMATIC DISEASE			
50-69	**29**	6.5	**< 6%**
< 50	20	4	
ASYMPTOMATIC DISEASE			
60-99	53	6	**< 3%**

CEA gives 29% relative risk reduction (for stroke); patients with stenosis > 70% benefit even more
CREST - CAS ≈ CEA

Patchell in spine mts >>
significantly more patients in the surgery group than in the radiotherapy group were able to walk at 3 months and retained ambulation significantly longer
Patchell in brain mts >>
survival was significantly longer in surgical group (40 vs. 15 weeks)
SPORT >>
strong benefit of surgery (for lumbar stenosis) at 4-year follow-up that appeared to diminish by 8 years
surgery has a significantly greater benefit (over nonsurgical treatment) of degenerative **spondylolisthesis** in **obese** patients

COMPLICATIONS

– how to avoid / treat

1. Go see and examine the patient immediately (even on the weekend)
   ICU is calling for worsening → "*I am going immediately to see the patient*"
2. Express your concern

POSTOP NEUROPATHIC PAIN

Unrelenting burning pain + poorly responsive to NSAIDs, opioids, steroids

1. Rule out **surgical cause**: hematoma, residual disc, nerve constriction, screw
2. GABAPENTIN (or PREGABALIN): start 300 tid → titrate (until pain control or intolerable side effects: drowsiness, peripheral edema); if need to wean off – do gradually!
3. If all fails → SCS or PNS

POSTOP WOUND INFECTION

At 1-4 weeks postop – malaise, fever, pain, swelling, redness, dehiscence, drainage (dif – CSF leak)
Check **WBC, ESR, CRP** + blood culture!
Be aggressive!
If suspect meningitis → check CSF

Do not start abx until intraop culture is taken!

- if patient is *already taking abx*, cannot trust cultures – will need ***broad-spectrum*** abx! ☹

Spinal
Superficial (no systemic signs)
Deep → culture + irrigation, debridement of necrotic material + drains
IV abx for 2 weeks
instrumentation - leave in place (in acute infection), IV abx for 6 weeks (or until ESR / CRP normalizes);
if osteomyelitis develops → remove hardware

Cranial (incl. erosion ÷ epidural abscess): remove bone flap, debride, drains (!!!), abx

- cranioplasty no earlier than in 3-6 months.

POSTOP HEMATOMA

Prophylaxis: Dural tack ups!!!! Drains
Diagnosis – CT (brain) / MRI (spine)
Treatment – prompt evacuation.

DUROTOMY

Primary repair
If too much tension, use patch (e.g. thoracolumbar fascia)
Valsalva to check
Collagen matrix
Glue
May leave a drain – remove next morning.
LD is controversial.
Watertight closure: approximate muscles with nonabsorbable braided #0 sutures → interrupted stitches for fascia, reinforced with running stitch.

CSF LEAK

RING (HALO) TEST
glucose concentration: in CSF ≥ 30 mg/dl (in lacrimal secretions / nasal mucus < 5 mg/dl)
β2-transferrin assay (present in CSF) - most accurate diagnostic test for CSF!

Risk after spine surgery – 3% (↑ after revision surgeries), same with MIS (but intact muscles contain CSF)
Orthostatic headache, pseudomeningocele / visible CSF leak
CT (pneumocephalus)
MRI (alternative – myelogram)

- to localize leak - inject through LD: Omnipaque (→ CT myelogram) or fluorescein (→ endoscopy)

Spinal
Keep flat + hydrate
Blood patch – mainly for post-LP headache
Open direct repair is the best! add glue, lumbar or cervical CSF drain.

- thoracic CFS leak into pleural cavity (hard to control due to negative pressure) – definitely need lumbar or cervical CSF drain

Cranial (CSF leaks into mastoid air cells, frontal sinus – wax!)

- HOB up
- Diamox

A. **Early leak** – from poor closure H: **resuture / explore** - **direct dural repair with vascularized flap** (e.g. galeal)
B. **Late leak** (> 2-3 weeks postop) - do LP first:
   a) infection → **treat meningitis** (CSF leak will stop)
   b) CSF contaminated with blood, bone dust, necrotic debris → inflammatory & mechanical interference at arachnoid villi → CSF pressure↑ / hydrocephalus H: **lumbar drain** at 10 cc/hr (if leak recurs → **shunting**)

CSF from frontal sinus ("failed pericranial flap"): 3-5 days LD → endoscopic repair → open exploration
Persistent CSF leak – likely due to ICP↑→ **VPS**

HYPONATREMIA

plasma [Na^+] < 135 mEq/L caused by **TBW > total body Na content**.

Consciousness ↓ , neurodeficits ↑ → seizures (esp. if < 120)

Check 5 labs + CVP

1. Serum [Na]
2. **Urine [Na]**
3. **Kidney function** (creatinine normal < 1, BUN normal 5-20)

4. Serum osmolality – only to rule-out ***pseudohyponatremia*** if serum osmolality > 275 (due to mannitol, hyperglycemia)
5. Urine osmolality – only to rule-out ***water intoxication*** (urine osmolality < 100)
   Normally concentrated urine has Osm > 100

+ **central venous pressure (CVP)** [normal 1-8 cmH_2O (1-6 mmHg)]

A) urine [Na] < 10 = ***extrarenal Na depletion*** (GI losses, ascites), so kidneys trying to conserve sodium
B) urine [Na] > 20-60 + kidney function↓ = pathologic urine Na loss due to ***kidney pathology***
C) urine [Na] > 20-60 + kidney function normal = "normal kidneys misbehave due to hormones":
   a) **cerebral salt wasting** – Na spill into urine → hypovolemia (CVP < 5-6) H: **volume replacement** with colloids (e.g. albumin) + NS (depending on acuity) + if patient is eating, add NaCl tabs
      + if hyponatremia severe (esp. brain edema, seizures) - add 3% NaCl*, FLUDROCORTISONE

   b) **SIADH** – kidneys conserve water (so urine gets concentrated) → hypervolemia (CVP↑) H: **fluid restriction** < 1 L/24 hrs;
      + if hyponatremia severe (esp. brain edema, seizures) - add 3% NaCl*, LASIX, CONIVAPTAN [vasopressin receptor antagonists]

SIADH and CSW look similar in labs (both are hypotonic hyponatremias) but SIADH causes hypervolemia and CSW causes hypovolemia – treatments are different!!!

Boards: post-SAH = CSW (albumin, saline, salt tabs);
other conditions = SIADH (fluid restriction)

- patient with ***normal renal function*** is well maintained by 0.2-0.3% SALINE with 20 mEq/L K in 5% dextrose solution; other electrolytes (e.g. Mg, Ca) are not routinely added.

*if risk of brain herniation: 3% NaCl 100 mL over 10 minutes x3 PRN
less severe symptoms: 3% NaCl 0.5-2 mL/kg/hr
do not correct faster than 10 mEq / 24 hrs (18 mEq / 48 hrs) → central pontine myelinolysis (locked-in, AMS, T2 signal in pons and thalamus)

STATUS EPILEPTICUS

Cranial patient: good neuro status → unresponsive, fixed and dilated – do not order STAT CT – first rush examine ABC + operative site with drains: this is trick of Boards – you find clutched teeth and rhythmic jerking:

1) ask nurse how long it's been this way, send STAT labs
2) ask intubation team to head to the room, meanwhile, **place oxygen mask**

3) LORAZEPAM 0.1 mg/kg (repeat PRN in 1 minute) + 20 mg/kg FOSPHENYTOIN or 60 mg/kg KEPPRA
    - if unknown patient – give thiamine and D50
4) if still seizing – intubate, start IV drip (PROPOFOL or MIDAZOLAM), vEEG (ask for neurology)

VASOSPASM

Neuro decline days after aSAH
1) examine + vital signs, labs, review meds, TCD
2) CT, CTA
3) vEEG

Risk correlates with **Fisher grade** → treat prophylactically: NIMODIPINE (does not prevent vasospasm but improves outcome) + avoiding hypovolemia + permissive hypertension + daily TCDs

Symptomatic vasospasm → HHH (modern – mainly induced hypertension) + EVD at 0; if no improvement → endovascular angioplasty + PAPAVERINE

ANEURYSM (RE)RUPTURE

RUPTURE INTRAOP

Preparation

- check **CTA** (e.g. if fetal circulation, cannot sacrifice PComA)
- type and cross 2-4 U **pRBC** and keep in OR (± Cell-Saver)
- *prep and drape neck for rapid carotid proximal control* (absolutely for **ophthalmic** aneurysms, strongly recommended for **PComA** aneurysms)

Measures to avoid INTRAOPERATIVE ANEURYSMAL RUPTURE:

A. During **initial exposure** (pre-dissection – poor prognosis)
1) adequate anesthesia (systemic and local)
2) avoidance of hypertension
3) do not drain CSF (EVD or LD) before dura is opened.

Management:
1. Induce hypotension + administer neuroprotective agent (e.g. PROPOFOL)
2. Compress ICA in the neck through drapes
3. May resect portions of frontal or temporal lobes
4. Temporary clip across ICA as it exits from cavernous sinus.

B. During **aneurysm dissection** (majority of rupture cases):
1) establishment of **proximal vascular control**:
    1. where ICA becomes intradural

2. where VA first becomes intradural

2) minimal brain retraction (esp. on lobe attached to dome) - paramount in aneurysm surgery!
3) lumbar/EVD CSF drainage
4) completely mobilize aneurysm.
5) at final stages of aneurysm approach:
   a. hyperventilation
      1. hypothermia 34°C
   b. systemic hypotension
   c. focal hypotension with ***temporary clips*** (low closing force - for 5 mins, then 2 minute reperfusion) on parent artery + if occlusion > 5 minutes, if long segment of ICA is trapped - administer 5000 U HEPARIN IV.

Management:

1. Alert anesthesia – need blood, maintain BP, **burst suppression** with neuroprotective agent (e.g. PROPOFOL, THIOPENTAL)
2. 2x large bore **suctions** → tamponade with cottonoid over bleeding point (gentle pressure with sucker)
3. Place temporary clip for proximal (and distal) control / temporary aneurysm clip
   N.B. avoid placing clips blindly (will injure vessel)
4. Dissect aneurysm neck → permanent clip;
   rupture at neck → cotton-clipping technique
5. Last resort: **transient asystole** with ADENOSINE bolus IV: escalating doses 6 mg, 12 mg, 18 mg, 24 mg and 36 mg - 1 mg adenosine results in ≈1 s of asystole (i.e. up to 30 seconds of asystole - effect is seen 10–20 s after bolus injection)

ANEURYSM PERFORATION WITH COIL

First sign – sudden BP↑↑↑ (reaction to ICP ↑)

1) notify **anesthesia:**
   – immediately lower BP
   – hyperventilate
   – raise EVD
   – 50 mg of PROTAMINE (protamine should always be available during the procedure!)
      o if antiplatelet agents were used – give platelet transfusion.
2) inflate balloon (if using balloon assistance)
   - if perforation at aneurysm dome - don't stop, do not remove coil, continue rapidly coiling with additional coils.
   - if perforation at aneurysm neck / parent vessel – balloon, may need to embolize

Place **EVD**.

Postop – CT (hematoma needing evacuation?)

RERUPTURE IN ICU

1) lower BP
2) raise and flush EVD
3) TXA?

VESSEL OCCLUSION DURING DSA

1. HEPARIN (verify ACT)
2. Intra-arterial:
    a) TPA – make sure aneurysm well coiled before administering thrombolytics!
    b) REOPRO
    c) **thrombectomy** (if large vessel)

VESSEL INJURY (OPEN SURGERY)

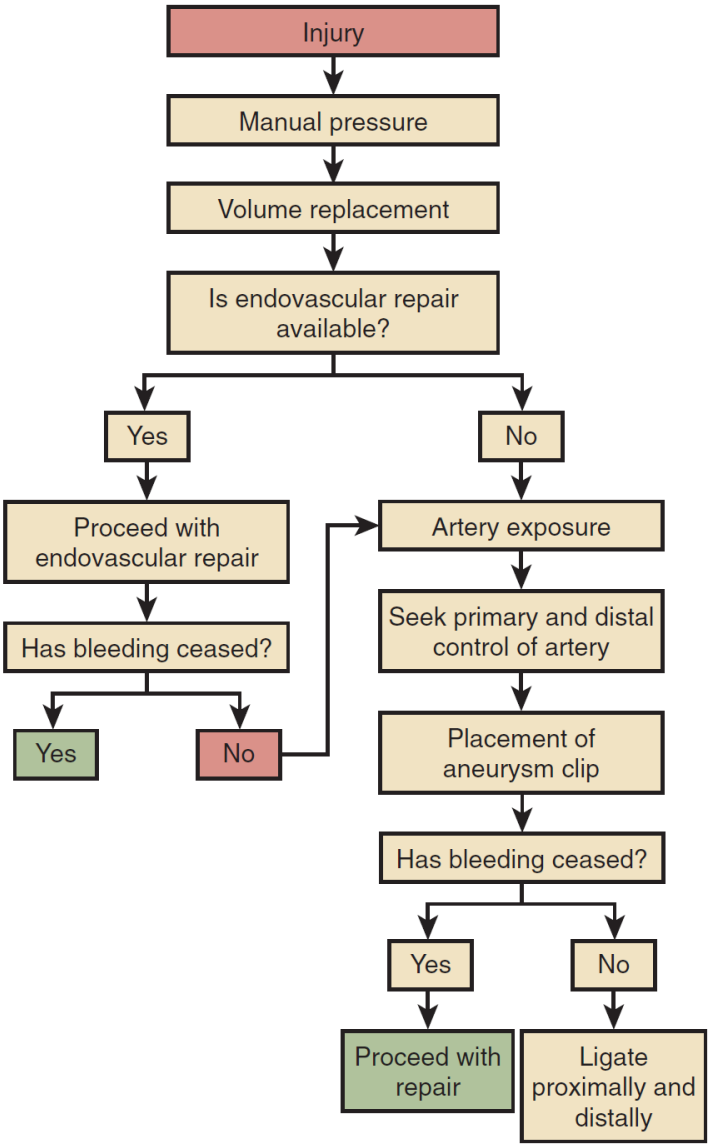
Etiology
Trans-sphenoidal surgery
Spinal surgery:

1) C2 screws
2) lateral dissection over C1 - always use sharp dissection, e.g. with Penfield#1, not with Bovie
3) longus colli dissection
4) Kerrison bit in foramen
5) lumbar discectomy – avulsion of segmental vessel (→ intraop hypotension)

Action Early recognition is lifesaving!

1. Large-bore **suction** → **tamponade** (Surgicel + Gelfoam/muscle)
2. Alert **anesthesia** - blood **transfusion**
3. Alert **IR**
4. Repair if can (expose vessel, temporary clips above and below, 7-0 to 9-0 Prolene), else tamponade
5. Postop **DSA** – stent / embolization (if good contralateral flow)
    N.B. ensure vessel is occluded and not partially injured (→ pseudoaneurysm, AV fistula, source of emboli)
6. Start ASPIRIN at 6 hrs postop.

- **CTA** before discharge – look for: pseudoaneurysm, AV fistula



On Boards – if cord is exposed, protect cord during packing (pack laterally)

Specifics

***VA injury during lateral dissection over C1**:

if injury sharp, rapidly dissect and repair vessel;
if injury with Bovie – impossible to repair
if injury inside bone (e.g. ponticulus posticus) – place **bone wax**.

***VA injury during C2 screw**: do not drill bone to find bleeding spot! (will bleed to death), just tamponade (shorter screw + no screw to other side → sublaminar wiring Dickman and Sonntag); if need exposure at V3 exit of C2 transverse foramen: transect C2 nerve (preganglionic cut) – VA is in front of ganglion.

*__VA injury during PCF__: tamponade with shorter screw (do not place opposite screw – use laminar screws instead); else expose VA through full width foraminotomy with diamond drill bit (may need remove pedicle) → temporary clips → repair.

*__VA injury during ACDF__: tamponade; else expose VA through foramen transversarium one level above and below injury with diamond drill bit and Kerrison → temporary clips → repair.

*__ICA siphon injury during TSR__: Abandon the rest of tumor resection!

1) alert anesthesia - **call for blood** and **start resuscitation** (maintain slight HTN – to promote perfusion)
    - anesthesiologist **compress carotid in the neck**; at extreme – ADENOSINE bolus IV to allow for carotid inspection and targeted patching.
2) **large bore suction**
    - try to **bipolar** if it is a small wall laceration or side branch avulsion.
3) **pack** tightly (Gelfoam wrapped in Surgicel; best thromboplastic material – muscle*, then fat) to stop bleeding (do not occlude carotid!) - often times, there is no need for high pressure!

    *have thigh prepped or cut piece of tongue (last resort, but tongue is right there)
    - place endoscope in opposite nare and apply pressure with cottonoid
4) keep **intubated** with tight **BP control** → transport straight to DSA: stenting, sacrifice; vs need surgical bypass)

    N.B. delayed pseudoaneurysm formation! – presents with profuse nose bleed; treatment: coiling + pipeline stent.
5) if still bleeding → **angiography**:
    a) **covered ICA stent**: Jostent – very stiff and difficult to navigate; load with Aspirin and Plavix in OR.
    b) **ICA coiling** (patient may wake up asymptomatic; if TIAs → ECA-ICA bypass)

    Look at CTA (if available) – if *circle of Willis is incomplete* – cannot sacrifice carotid!

*__segmental vessel injury during lumbar discectomy__: alert vascular / general surgery → resuscitate + rapidly temporarily close with 2-3 through-and-through stitches → flip into supine → prep abdomen (if patient is stable, may go to IR instead).

N.B. sometimes bleeding is recognized postop: abdominal bruising (Grey Turner sign), Hb ↓ , BP ↓ → rush to IR / back to OR

MALIGNANT INTRAOP BRAIN EDEMA

Etiology:

1) **hematoma** – ICH (e.g. aneurysm rerupture), remote SDH/EDH.
2) **venous obstruction**: jugular vein kink at neck, Gelfoam strip protruding into venous sinus lumen
3) massive **vasodilation** (e.g. hypercarbia)

Prophylaxis
Place LD / EVD preop (if tumor, e.g. meningioma, is big – keep drain clamped until dura is opened)

Treatment

Anesthesiologist – extracranial:

1. Elevate HOB
2. Straighten neck (no jugular compression)
3. Hyperventilate, no PEEP
4. Increase depth of anesthesia
5. Avoid high SBP

Anesthesiologist – intracranial:

1. Mannitol bolus
2. Drain CSF: EVD / LD, accessible cisterns

Surgeon:

1. Check for contralateral hematoma! (use US)
2. Enlarge dural opening / craniotomy (veins compressed against bone?)
3. Resect temporal or frontal lobe / tumor / drain cyst
4. Do not place bone flap back

- primary scalp closure maybe difficult H: release incisions in galea (from underside)

VENOUS SINUS INJURY

Central line, **blood** ready
Also think air embolism!

1. Tamponade - large* thrombin-soaked Gelfoam patch, then patty over – usually bleeding stops (→ remove patty, leave Gelfoam in place)
   TACHOSIL® – fibrin sealant patch (sticks to sinus wall!)
2. Elevate HOB - once laceration is covered but still bleeding, raise HOB (not too much – risk of air embolism)
3. May need to repair sinus: wide **exposure**, large-bore **suction**, suture over dura flap / piece of muscle** → optional ICG angiography to confirm sinus patency

*to make sure it does not protrude into sinus lumen!
**e.g. during retrosigmoid crani

- if bleeding is too brisk and finger pressure blocks view for repair → proximal sinotomy to place **Fogarty balloon catheter**.
- anterior 1/3 (or 25%) of SSS can be sacrificed!
- bleeding from **CAVERNOUS SINUS** – inject fibrin glue into it!

AIR EMBOLISM

PREPARATION

Preop

- **transthoracic Doppler echocardiography** to detect any right-left shunt (e.g. patent foramen ovale) ← contraindication for sitting craniotomy – risk of brain air embolism.
- **MRV** - check patency of contralateral venous sinuses.

Intraop

- place **precordial Doppler ultrasonography** - early detection of intracardiac air: "Machinery sounds"
- place **multichannel central venous catheter** (in Right atrium) to aspirate any large emboli
- **end-tidal CO_2** monitoring (↓ along with BP↓, pO2↓, CVP↑)
  normal end-tidal CO_2 5-6% = 30-40 mmHg (i.e. slightly diluted pCO2 35-45)

MANAGEMENT

1) occlude site of air entry - soaked Raytec and ***flood with saline, wax bone edges***
2) lower head
3) rotate patient LEFT side down (attempt to trap air in right atrium)
4) jugular venous compression (bilateral best; second choice: right only)
5) aspirate air from right atrium via CVP catheter
6) ventilate with 100% O2 + discontinue nitrous oxide (may expand AE)
7) if *patent foramen ovale* exists, stop PEEP (PEEP increases R-to-L shunting).

- if nothing helps, terminate surgery and transport to ICU intubated.

ENTRY INTO FRONTAL SINUS

If entry is small, mucosa intact

- carefully remove sinus mucosa from ***bone flap*** pockets; leave mucosa intact in sinus → cover with vascularized pericranial flap → Tisseel / DuraSeal.

If mucosa violated, inflamed (sinus is no longer sterile)**, posterior wall fracture** – need **sinus cranialization-exenteration**: remove posterior wall of frontal sinus, pack with muscle plug, cover ostia with pericranial flap over, fibrin glue

DIC

Trauma crani: starts oozing blood from everywhere (blood looks like dilute "Kool-Aid")

Treatment

Minimize manipulation, obtain hemostasis and finish case ASAP
FFP, platelet, cryoprecipitate

C5 PALSY

Happens after anterior and posterior procedures.
Deltoid, supraspinatus, infraspinatus, biceps – within 6 wks postop!
MRI – rule out hematoma, residual compression

Delayed onset – good recovery H: **PT**
Immediate onset postop with complete palsy – less certain prognosis; if no recovery (regular EMG) → **nerve transfer**:

1) spinal accessory nerve → suprascapular
2) radial nerve (triceps branch) → axillary
3) intercostal nerves - usually 3rd, 4th and 5th intercostal nerves → musculocutaneous
   OR
   ulnar nerve (fascicle to flexor carpi ulnaris) (**Oberlin procedure**) → musculocutaneous

POSTOP NEW RADICULOPATHY/NEUROPATHY

Patient wakes up (e.g. from CTR / TLIF) with burning pain, weakness
PNS surgery - **inspect wound** for hematoma (vs. local anesthetic effect) **→ evacuate**
Spine surgery - **CT, MRI** – hematoma?, malpositioned screw?, disc fragment? – if none, likely root retraction injury H: GABAPENTIN

ESOPHAGEAL INJURY

Risk of lethal mediastinitis! **Killian's Triangle** - anterior to C5-C6 disc

After ACDF: pain ↑ , dysphagia, neck swelling, fever, wound drainage + WBC, ESR, CRP
N.B. wound infection after ACDF is esophageal perforation until proven otherwise!
Coughing up food = tracheo-esophageal fistula

Diagnostic triad
CT with contrast (free air, abscess), ENT consult and endoscopy, Gastrografin swallow study;
+ **swallow dye** (e.g. methylene blue) → watch if dye shows up in the drain

Treatment

Small leaks + no esophageal obstruction may close spontaneously with good nutrition; for Boards – need operative exploration

1. **NPO + PEG tube**
2. **Revise** cervical **hardware** (replace with iliac autograft → staged posterior supplementation)
3. Super small injury – simple **repair** with inverted sutures + **drain**
4. All other injuries – add **muscle flap** (SCM, sternohyoid, pectoralis major) or free omentum.
5. Broad-spectrum **abx**

IONM

Alarm:
BAER wave 5 latency ↑ > 1 msec
SSEP / MEP / D-wave amplitude ↓ > 50%
SSEP latency ↑ > 10%
In order of importance: MEP > SSEP latency > SSEP amplitude

INTRAOP ALTERATIONS IN EVOKED POTENTIALS

Just legs or arms & legs?
If signals changed after positioning on the table – consider different table/neck position change.

- check ***electrodes***
- check **mechanical factors**:
  - prompt cessation of dissection / manipulation.
  - any retractors should be loosened; inspect the entire operative field.
  - reverse last maneuver, e.g. removal of any oversized graft.
  - perform further decompression if stenosis is present
- verify the **depth of anesthesia** - decrease gases to MAC (maximal allowable concentration) < 0.5 or switch to TIVA (propofol, fentanyl, and etomidate) [add KETAMINE], check TOF
- check for presence of **hypotension** or **hypothermia** or **hypoxia** or **anemia**.
  - increase **blood pressure** (MAP > 85) - use an arterial line!, may press to MAP > 100
  - cord **irrigated** with **warm** normal saline ± **papaverine**.
  - increase ***oxygen*** concentration (placement of HYDROGEN PEROXIDE in the wound may increase local oxygen saturation)
  - **transfuse** blood if needed.
- **steroids**.
- consider CALCIUM CHANNEL BLOCKER (topical, IV)
- if nothing helps:
  a) do **Stagnara wake up test** (under REMIFENTANIL)
  b) **terminate surgery** (consider expansile duraplasty + additional decompression to allow for cord swelling).
  c) go for immediate **postop MRI** (but keep OR sterile!)
  d) consider **epidural hematoma** from cranial pin sites.

EEG decline → reposition aneurysm clip, ICG angio

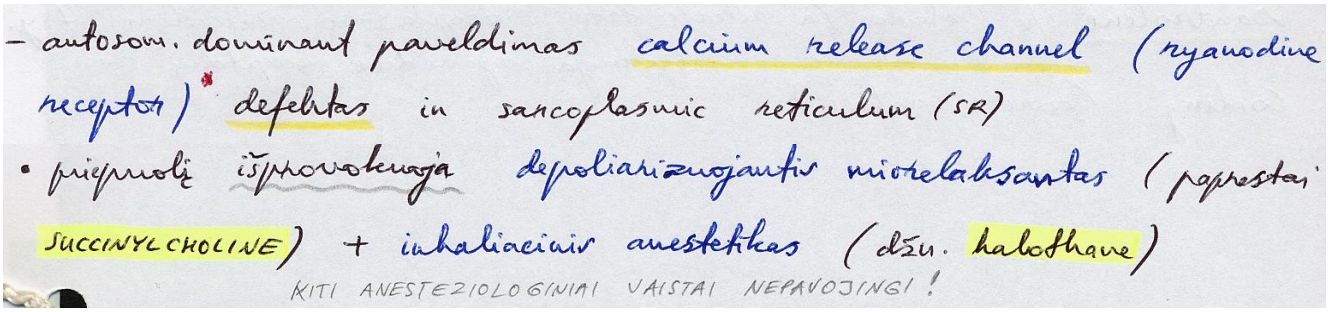
NEW NEURODEFICIT IN PACU

NALOXONE – to completely reverse anesthesia and perform exam (plus, naloxone has been shown to reverse ischemic neurologic deficits)

If deficit is real, esp. if worsening, consider taking back to **OR immediately** skipping imaging, esp. if the deficit is believed to be a result of hematoma or screw malpositioning.

- if no apparent abnormality is demonstrated at surgical exploration → **emergent MRI** (include spine rostral and caudal to surgical site - distant epidural hematoma?) → if still no explanation → **steroids**, maintain **normotension / slight hypertension**

MALIGNANT HYPERTHERMIA



- 50% patients had previous anesthesia without MH.

PRESENTATION

1. Earliest possible sign: increase in end-tidal pCO_2 + decreasing pO_2 (total body O_2 consumption increases x 2-3).
2. Tachycardia (early) and other arrhythmias
3. With progression:
    - hyperkalemia + metabolic acidosis
    - temperature may reach +44°C at rate of 1°/5-min
    - pulmonary edema
    - DIC (bleeding from surgical wound and body orifices)
    - limb muscle rigidity (common, but late); rigidity may involve masseters – difficulty intubating
    - rhabdomyolysis - elevated CPK & myoglobin (late)
4. Terminal: hypotension, bradycardia, cardiac arrest

TREATMENT

- **stop operation**, D/C anesthesia gases (change tubing on anesthesia machine).
- **hyperventilation** with 100% O2
- **cooling**: IV, wound, NG, PR
- DANTROLENE 2.5 mg/kg IV, infuse until symptoms subside, up to 10 mg/kg
  N.B. rigidity cannot be blocked with muscle relaxants (vs. neuroleptic malignant syndrome)!
- BICARBONATE 1-2 mEq/kg for acidosis
- IV INSULIN + **glucose** (lowers K+)

DIAGNOSIS

Family history + muscle biopsy

GENERAL TOPICS

In pentobarbital coma pupils become paralyzed!

Frazier burr hole: 6 cm superior to inion and 4 cm off midline - this places burr hole 1 cm anterior to lambdoid suture - aim at ipsilateral medial canthus to depth of 10 cm.

FORAMEN OVALE

- fluoroscopy (C-arm) – work under **AP** with beam aligned along trajectory head rotated away from operated side – should see foramen ovale (where top of petrous bone meets clivus)
- **Härtel's landmarks**:
    - needle entry point – 2-3 cm lateral to mouth corner.
    - insert **index finger in mouth**; keep needle medial to coronoid process.
    - needle is aimed at inner aspect of ipsilateral pupil + at point 3.5 cm anterior to external ear canal at level of zygoma (practically, it is inverse EVD target).

NEUROSARCOIDOSIS

1. **Eosinophilia**.
2. ↑**ACE** in serum
3. CXR - hilar adenopathy
4. Biopsy (meningocortical)

PREDNISONE 60 mg/d

PREGNANCY

Pregnant patient – always consult OB/GYN

- **AVM (that never bled), aneurysm, Chiari** – just follow obstetrical principles (but have nsgeon on standby); also OK with **thrombolysis**

    Board answer: any aneurysm (except cavernous ICA) → C-section
- **MRI** - gadolinium *is contraindicated*

Best exam – noncontrast MRI (TOF if need vascular)

- shield belly for DSA

Open spine table.

PHACOMATOSES

Tests: genetic testing → annual head MRI + ophthalmology + BEAR (in NF2)

- ***spinal MRI*** only for symptomatic cases.

Feature	NF1	NF2
Proportion	90%	10%
Gene - product	**NEUROFIBROMIN** **Constitutive Ras activation** → increased cell proliferation and survival.	**MERLIN**
Skin	*frequent cutaneous findings ("external NF")*: cafe-au-lait, axillary freckles	*relative paucity of cutaneous findings*
Tumor type	primarily *NEUROFIBROMAS*	primarily *SCHWANNOMAS*
Malignization	3-10% to MPNSTs	almost unheard
CNS	*lower incidence of CNS tumors* Optic nerve, brainstem, cerebellar gliomas! + unidentified bright objects (UBOs)	*higher incidence of CNS tumors* Bilateral CN8 schwannomas! Multiple meningiomas!
Eye	*Lisch nodules* in iris (90-95%)	*Posterior subcapsular (juvenile) cataracts*
Prognosis	better	worse

Disorder	Gene	Main Features
Sturge-Weber syndrome (encephalotrigeminal angiomatosis)	SPORADIC phacomatosis	ipsilateral capillary venous ANGIOMAS in leptomeninges (*"tram-track" brain calcifications → seizures)*, skin of face ("port-wine stain" s. nevus flammeus), eye (may lead to glaucoma → buphthalmos)

TUBEROUS SCLEROSIS

VOGT triad: ***Seizures*** (CBD!; immediately after failure of 2 medications → palliative **tuberectomy plus** with SEEG), ± ***Mental Retardation***, and ***Adenoma Sebaceum + Ash Leaves***

tubers, subependymal nodules – MRI every 2 years before age of 20 years - do not grow; if grow, it is SEGA – enhances and grows!

N.B. *early SEGA resection at first symptoms or documented growth* (modern approach)

mTOR inhibitors: everolimus

DBS COORDINATES

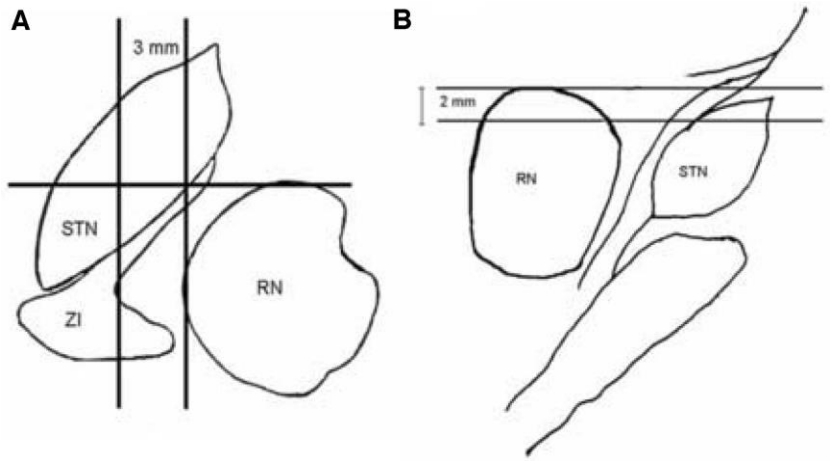
relative to midcommissural point: (AP, superior-inferior, lateral)

STN

(T2) -4 / -4 / 12 induces dyskinesias!

In axial plane - tangent to anterior border of red nucleus, extending 2 mm lateral to medial border of STN (3 mm lateral to lateral border of red nucleus)

In coronal plane (z axis) - 2 mm inferior to superior border of red nucleus.



1) **anterolateral** - corticospinal tract; corticonuclear fibers → conjugated binocular deviation toward contralateral side.
2) **medial** – CN3 – monocular deviation.
   N.B. eye deviation with stimulation:
   a) one eye only – too medial (CN3)
   b) both eyes (conjugate) – too lateral (corticonuclear fibers from frontal eye field)
3) **posterior** - lemniscus medialis - paresthesias.
4) **deep** – SNr - profound depression.
5) **anterior** – risk of permanent hypophonia

VIM

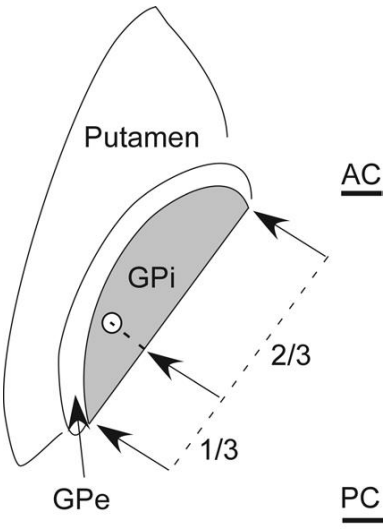
(T1)

- 6 mm posterior (anterior to PC by 20% of AC-PC length)
- 0 mm
- 10-11.5 mm lateral + ½ width of 3rd ventricle = 10-11.5 mm from thalamus border

GPi

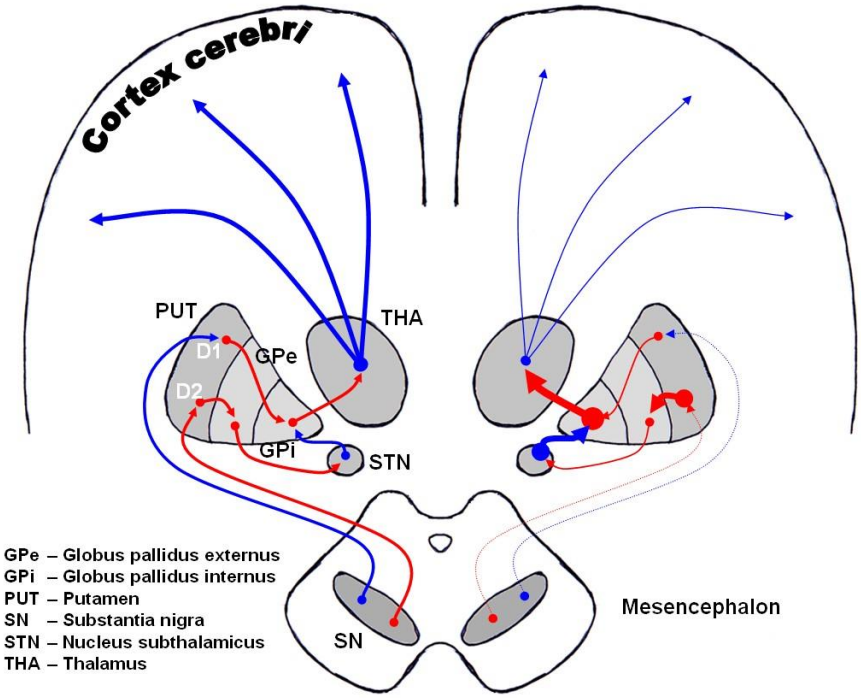
(FGATIR, FLAIR) (classic Leksell's pallidotomy target): +2 / -4 / 21

- axial plane of commissures, 3-4 mm line perpendicular to the pallidocapsular border at the junction of its posterior one-third and anterior two-thirds:



PD - Įsisiautėję stimuliacinis STN → inhibicinis GPi → nebestimuliuojamas cortex

Dopaminergic pathways in **normal condition** (left) and **Parkinson's Disease** (right).



For DBS need > 30% improvement in **UPDRS motor score** with levodopa challenge

DBS stimulates axons (not cell bodies).

Low (< 40 Hz) frequencies *stimulate*, high (> 100 Hz) frequencies *inhibit*

CT

Rule of thumb: blood remains ***denser*** than brain for 1 week, and ***less dense*** after 3 weeks.

- causes of ***hematoma density***↓: *severe anemia*, *hyperacute hematoma* (no clots at all).

Four questions before contrast:

1. Allergy to contrast
2. Nephropathy? (GFR)
3. Diabetic? (metformin – for CT)
4. Pregnant

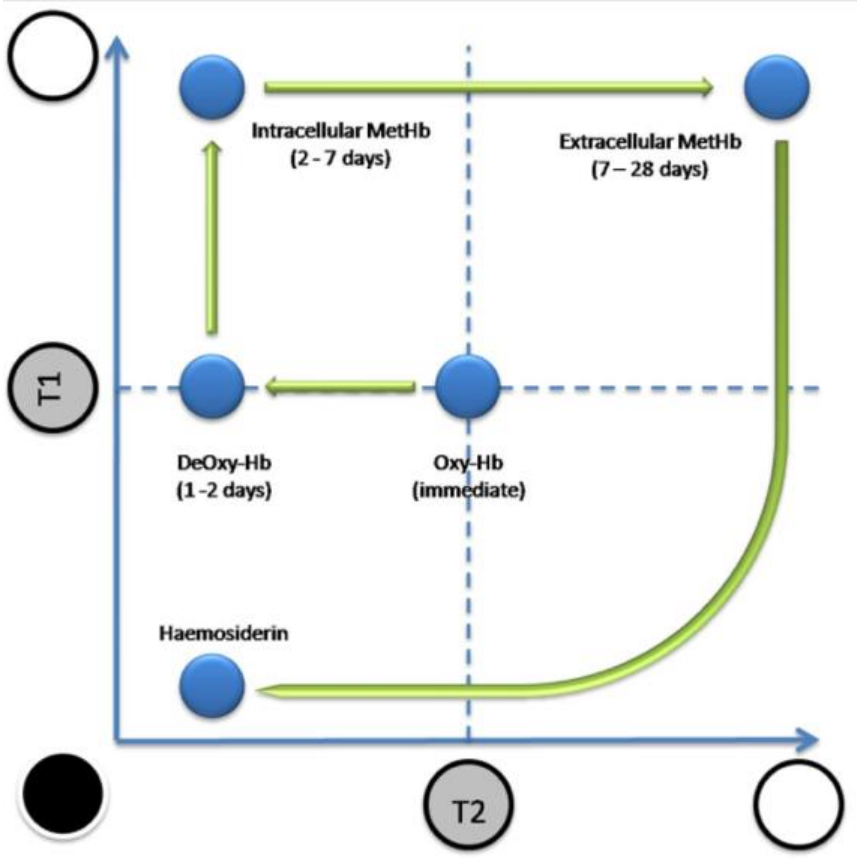
Plus, two questions for MRI – metallic foreign bodies, neuroimplants.

MRI

Only a few naturally occurring substances appear bright on T1:

1. **Lipid** (also bright on T2 and "empty area" on CT) – lipoma, dermoid cyst
2. **Methemoglobin**
3. **Melanin** (dark on T2) – **melanoma**!
4. **Protein** – colloid cyst, Rathke cleft cyst, cholesterol granuloma

BLOOD



INTRAVENOUS CONTRAST

Four questions before contrast:

1. Allergy to contrast
2. Nephropathy? (GFR)
3. Diabetic? (metformin – for CT)
4. Pregnant

Plus, two questions for MRI – metallic foreign bodies, neuroimplants.

maximum dose with normal renal function – 90 g/d of *IODINE* (CTA uses ≈ 21)

Tumors that **enhance strongly**: **benign** tumors (meningiomas, CN schwannomas, pilocytic astrocytoma, pituitary adenoma), **malignant** tumors (high-grade gliomas, metastases, lymphoma)

Beware of benign conditions that enhance: tumefactive MS, lymphocytic hypophysitis, sarcoid, subacute stroke, subacute ICH, abscess, toxoplasmosis. Always can biopsy if in doubt!

ALLERGY TO CONTRAST

(e.g. patient allergic to shellfish)

Premedication:

1. PREDNISONE (50 mg oral) – three doses: 13, 7, and 1 hour before study
2. DIPHENHYDRAMINE (50 mg oral) 1 hour before study

N.B. anesthesiologist should be present

KIDNEY FAILURE

After ***iodinated contrast*** – **hemodialysis** on patient's regular schedule / soon after study.
After ***gadolinium*** – **hemodialysis** for three consecutive days (start immediately after MRI).
GFR has to be:
> 45 for iodine, else risk of *CONTRAST NEPHROPATHY* (rise in serum [creatinine] ≥ 1 mg/dL within 48 h); prophylaxis – **good hydration (± bicarbonates, acetylcysteine)**

N.B. avoid of iodine in METFORMIN → **lactic acidosis**

Acute renal failure - absolute contraindication!

> 30 for gadolinium, else risk of *NEPHROGENIC SYSTEMIC FIBROSIS*

DWI

Abscess, stroke, lymphoma (high cellularity), radiation necrosis have ***diffusion restriction***, whereas gliomas and metastases do not restrict diffusion!
Same as epidermoid cyst (bright DWI) vs. arachnoid cyst (normal DWI)

MRS

- three PEAKS representing:
    1) creatine (CR) - cellular energy metabolism; present in much higher concentrations in glia than in neurons.
    2) choline (CHO) - cell membranes; present in much higher concentrations in glia than in neurons.
        CHO↑ - abnormal membrane metabolism: myelin breakdown, inflammation, neoplasia.
    3) *N*-acetyl aspartate (NAA) is neuronal marker - found primarily within neurons and precursor cells; NAA is marker of neuronal integrity.
        NAA↓ - neuron loss.
- additional peaks (not detectable in MRS of normal brain):
    4) lactate – products of anaerobic glycolysis: inflammation, infarction, abscess.
    5) lipids – products of brain destruction: radiation necrosis

Tumor – lots of membranes (choline) and anaerobic metabolism (lactate)
Necrosis – everything is down except dead lipids↑
Stroke – everything is down except anaerobic metabolism (lactate)↑
Abscess – atypical peaks
MS - normal

Tumor vs MS vs Stroke – check MRS!

DRUG DOSES

For pediatric patients – "weight-based dosage"
If don't know the dose → "Consult pharmacy"

Medications that are titrated **mcg/kg/time**:
1) nitroprusside
2) cisatracurium
3) propofol
4) Precedex

Medications that are titrated **/min**:
1) norepinephrine
2) phenylephrine
3) vasopressin

ONDANSETRON (Zofran) 4-16 mg q4hrs IV

STEROIDS

METHYLPREDNISOLONE

1) 1000 mg load
2) 160 mg/d
3) Bracken

ONCOLOGY

CABERGOLINE 0.25 mg PO 2x/week

AVASTIN 10 mg/kg every other week

5-ALA (Gleolan, aminolevulinic acid) 20 mg/kg PO 3 hours prior to anesthesia (works for 8 hrs)
→ no light exposure for 48 hrs
— PPV 99%, NPV only 37%

LOCAL ANESTHETICS

1-2% LIDOCAINE (medium-duration of action)
0.25-0.5% BUPIVACAINE (long-duration of action)

Lidocaine	**4.5 mg/kg q 90 min** **7.0 mg/kg q 90 min with epi**	1% lidocaine – max **30** mL 1% lidocaine with epi – max **50** mL
Bupivacaine	**Max 175 mg q 3 hrs** **Max 225 mg q 3 hrs with epi**	0.25% bupivacaine – max **70** mL 0.25% bupivacaine with epi – max **90** mL May produce cardiac arrest Pregnancy Category: C

BP

Antihypertensives

NICARDIPINE 5-15 mg/h

LABETALOL 5-20 mg q15min (max 300 mg/d)

HYDRALAZINE 5-20 mg q30min

NIMODIPINE 60 mg PO q4h or 30 mg PO q2hr

NITROPRUSSIDE 0.1-10 mcg/kg/min

PHENOXYBENZAMINE - alpha-blocker start 2 weeks preop for paraganglioma, pheochromocytoma (NF1, von Hippel-Lindau) but not with neuroblastoma.

N.B. *beta-blocker should never be started first*

Hypertensives

NOREPINEPHRINE **2-60 µg/min** (goal – MAP > 65 mmHg)

PHENYLEPHRINE **40-200 µg/min**

VASOPRESSIN **0.04 U/min** (no titration)

OPIOIDS / PAIN

NALOXONE 0.2 mg → repeat q2min (max 1-10 mg); in morphine-dependent patient, use *only 1/10-1/5 usual dose*.

FENTANYL **25-250 µg/h** (goal – Riker Sedation-Agitation scale 4)

KETOROLAC **15-30 mg q6h max 3 days**

10 mg parenteral morphine = 60 mg oral morphine

ANTIEPILEPTICS

LORAZEPAM (Ativan) for status: 0.1 mg/kg: wait 1 minute for response; if seizures continue → given additional doses up to max 9 mg

PHENYTOIN load 20 mg PE/kg → 300 mg/d (daily dosage for ER forms)

monitor [FREE phenytoin] (goal 1-2 mcg/ml; toxicity: confusion, ataxia, nystagmus) – after 3rd dose (or after 24 hrs), then again in 2-3 days. No other levels needed unless seizures occur.

Infuse no faster than 50 mg/min (fosphenytoin – 150 mg/min) - negative inotrope and can cause hypotension!

Reloading dose (in mg) = desired change in free conc x kg x 7

LEVETIRACETAM (Keppra) **20 mg/kg** IV (usually 1 g) / maintenance **500-1500 mg BID**

LEVETIRACETAM linear pharmacokinetics - ***no level monitoring needed***; ***no drug interactions***

BRIVARACETAM - psychiatric side effect profile is better than with LEV

LACOSAMIDE (Vimpat) **200 mg** or **3 mg/kg** (oral or injection) → **100 mg BID**

CARBAMAZEPINE: started 100 mg BID; max daily dose 1200 mg

CARBAMAZEPINE, OXCARBAZEPINE - LFT *potential for serious liver toxicity* & CBC *aplastic anemia*

LAMOTRIGINE - first-choice in elderly, pregnancy.

STATUS EPILEPTICUS

STEP 1 nasopharyngeal airway + prevent aspiration (turn head to side, suction secretions), 100% O_2 (via face mask) + IV line (send labs!)

Initial EEG has no role in management!

STEP 2 (5-20 minutes of seizure) – intravenous **ANTICONVULSANTS**

Seizure > 5 minutes: IV bolus of *rapid-acting* anticonvulsant:

a) LORAZEPAM 0.1 mg/kg (e.g. patient > 40 kg → 4 mg; if seizures continue after 1 minute → given additional up to max 9 mg) – **preferred agent**!

b) DIAZEPAM 0.1 mg/kg (q5min, up to 10 mg)

c) PHENOBARBITAL 20 mg/kg (max 1000 mg) - slower rate of administration, so it is a second choice to benzos

d) IM MIDAZOLAM 10 mg - first choice **if patient has no IV line**

Seizure > 20 minutes (practically, start at the same time as benzos) → loading dose of *long-acting* anticonvulsant (all equally effective at stopping SE):

a) LEV 60 mg/kg (max 4500 mg)

b) VPA 40 mg/kg (max 3000 mg) – platelet risk, esp. in neurosurgery!

c) FOSPHENYTOIN 20 mg PE/kg (max 1500 mg – i.e. 75 kg dose) – proconvulsant if overdosed!

If SE does not stop – it is RSE

STEP 3 – pharmacological COMA:

1. **Intubation** using RSI (considered full stomach).
2. **vEEG** – need to know if in nonconvulsive status (→ go to burst suppression).
3. Start **IVI** (be ready for hypotension!):
    a) **PENTOBARBITAL** 0.5 mg/kg/hr titrated to *burst-suppression*
    b) PROPOFOL 5 mcg/kg/min titrate to 50 mcg/kg/min (max 200 for fit patients)
    c) MIDAZOLAM IVI

STEP 4 – general anesthesia using inhaled anesthetic (ISOFLURANE).

STEP 5 – emergency surgery (seizure focus resection, VNS)

SEDATION / PARALYSIS

PROPOFOL 5 **µg**/kg/min titrate to 50 mcg/kg/min (max 200 for fit patients) – CI in pediatrics!

PRECEDEX **1 µg/kg/h start**

MIDAZOLAM **1 mg/h** titrate to **10 mg/h** (goal – Riker Sedation-Agitation scale 4) / (10 mg IM for epilepsy)

Flumazenil **0.2 mg → repeat q1min** (≈ naloxone)

CISATRACURIUM **2 mcg/kg/min**; maintenance **0.5-10 mcg/kg/min** (titrate up if patient respiratory rate > ventilator set rate for ≥ 10 minutes (goal – both rates equal)

PENTOBARBITAL **0.5-5 mg/kg/h** titrate as needed for 10-20 seconds of burst suppression [3-6 bursts/min]; Dr. Simmonds uses loading dose 10 mg/kg

Riker Scale

1. **Unarousable** - No response
2. **Very Sedated** - Arouses but does not communicate
3. **Sedated** - Follows simple commands
4. **Calm and Cooperative** - Calm, easily arousable, follows commands
5. **Agitated** - Calms to verbal instruction.
6. **Very Agitated** - Requiring restraint

7. **Dangerous Agitation** - Pulling at ET tube

BACLOFEN (20-240 mg/d in divided doses q8hrs*) *i.e. single oral max dose is 80 mg

DANTROLENE 2.5 mg/kg daily

CYPROHEPTADINE 6 mg q6h

OSMOTHERAPY

20% MANNITOL 1.0 (0.25-2.0) g/kg IV bolus over 15 minutes q3-6 h

practically, one bag of 20% 500 mL = 100 g of MANNITOL; renal losses must be replaced with isotonic saline

maximum action starts after 30 minutes and lasts several hours

23.4% NACL 30 mL via central line over 15 minutes

3% NACL (100 mL over 15 minutes) → 1 mL/kg/hr

ACETAZOLAMIDE 500 mg x2/d PO → increase by 250 mg/week (max 4 g/d)

HEMOSTASIS

normal fibrinogen 150-400

Abnormal parameters for surgery:

INR > 1.4, aPTT > 36.5 → FFP
fibrinogen < 200 mg/dL → cryoprecipitate
platelets < 100 → thrombocyte transfusion

PLAVIX® **300-600 mg** load → 75 mg/d

VerifyNow P2Y12 (therapeutic < 194)

ASPIRIN 81-325 mg/d

VerifyNow Aspirin Test (therapeutic < 550)

Preop stop:
Aspirin – 6-7 days
NSAIDs (except COX-2 inhibitors – no need to stop!), oral anticoagulants – 5 half-lives

Antiplatelet reversal:
PLATELET TRANSFUSION - 2 doses (3 doses if on dual antiplatelet; 1 dose for aspirin only and only if goes to surgery, otherwise - DDAVP)

DESMOPRESSIN (DDAVP):

ASA reversal: 10-20 mcg (0.4 μg/kg) IV

DI: 1-2 mcg BID IV

ABCIXIMAB (ReoPro) – short T1/2 – no reversal needed!

Heparins

HEPARIN IV: optional 80 U/kg (e.g. 5000 U) **bolus** → 15 U/kg/h (e.g. 1000 U/h) **maintenance**

aPTT q6h (heparin lasts 6 hrs) until reaches therapeutic 1.5-2 times control value (70-100 sec)

Prophylaxis: 5000 units subQ q8h (head problems)

ENOXAPARIN

Prophylaxis: 30 mg q12 h (SCI, trauma with long bone fx) / 40 mg qd (ischemic stroke)

Full anticoagulation: 1 mg/kg q12h (faster than heparin to achieve therapeutic levels but less reliable in CKD)

Heparins reversal:

PROTAMINE SULFATE: 1 mg/100 U **heparin** in past 3 hours
1 mg/1 mg **enoxaparin** in past 8 hours

if protamine N/A – use RECOMBINANT FACTOR VIIA 90 µg/kg

FRESH-FROZEN PLASMA 20 mL/kg – fluid overload (so use less)

Warfarin reversal:

Vit. K 10 mg once

KCENTRA 4-FACTOR PROTHROMBIN COMPLEX CONCENTRATE (preferred over FFP)

25 units/kg (max: 2500 units) for INR 2-4
35 units/kg (max: 3500 units) for INR 4-6
50 units/kg (max: 5000 units) for INR > 6

Direct Thrombin (Factor IIa) inhibitor reversal aPTT provides rough approximation

1. Praxbind (idarucizumab) 5 g IV - **FDA approved for dabigatran** "Consult hematology"
2. If drug was ingested within past 2 h → ACTIVATED CHARCOAL 50 g
3. **Hemodialysis** for patients with ESRD (PCC ineffective)

Factor Xa inhibitor reversal

1. Andexxa® (andexanet) low dose (400 mg) or high dose (800 mg) IV - **FDA approved for apixaban, rivaroxaban** "Consult hematology"
2. If drug was ingested within past 2 h → ACTIVATED CHARCOAL 50 g
3. KCENTRA

TRANEXAMIC ACID (TXA): 10 mg/kg (1 gm) → 5 mg/kg/hour for 24 hours after surgery.

Hemostasis disorders (may say "Consult hematology")

hemophilia → FACTOR VIII, FEIBA (Anti-Inhibitor Coagulant Complex)

thrombocytopenia → PLATELETS

N.B. platelet transfusions in TBI are controversial

Thrombolysis (may say "Consult stroke neurology")

ALTEPLASE (tPA): cleared by liver with T1/2 = 5 minutes (terminal half-life 72 minutes); onset of action: 30 minutes (maximum of action – 60 minutes)

1 mg intraventricular q8-12hrs

IV (0.9 mg/kg maximum total dose - 90 mg):
- 10% (0.09 mg/kg) IV push over 1 min
- the rest IVI over 60 minutes

thrombolysis reversal (if need surgery or if hemorrhagic transformation):
1) 10 U of **cryoprecipitate** (containing Factor VIII)
2) 1 g of **TXA**
3) 6-8 units of **platelets**
4) if emergent procedure is needed, give **Factor VIIa**

ANTIBIOTICS

CEFAZOLIN Preop prophylaxis – 2 g (25-30 mg/kg) IV
1 g for patients < 60 kg; 3 g for patients > 120 kg
Redose q4hrs

NAFCILLIN 2 g q4h IV

CEFEPIME, MEROPENEM 2 g q8hr IV

CEFTRIAXONE 2 g q12hr IV

VANCOMYCIN 1000 mg (15 mg/kg) loading over 2 hours → bid*

(check trough level after 3rd dose – target 15-20 mcg/mL); *dose adjustment necessary for Creatinine Clearance < 60 mL/min

Periop prophylaxis – 15 mg/kg 2 doses (redose intraop q6hrs)

10 mg/d IT

Shunt meds: 10 mg vancomycin + 4 mg gentamicin/tobramycin into valve reservoir

RIFAMPIN 600 mg q12h PO

CEPHALEXIN, METRONIDAZOLE 500 mg q6h

CLINDAMYCIN Periop prophylaxis: 900 mg IV

TRIMETHOPRIM AND SULFAMETHOXAZOLE (Bactrim) 1 DS tab PO bid (tab. DS = 160/800)

DOXYCYCLINE First day: 100 mg every 12 hours → maintenance 100 mg once a day

Toxoplasma treatment: **PYRIMETHAMINE** (+ **LEUCOVORIN**) plus **SULFADIAZINE**

> 1 enhancing lesion *OR* positive toxoplasma serology in AIDS patient = presumptive diagnosis of *TOXOPLASMA ENCEPHALITIS* → 2 week **trial of antitoxoplasma therapy** (objective response must be seen on imaging)

Treatment of *CRYPTOCOCCAL* meningitis – **AMPHOTERICIN B** + **FLUCYTOSINE** for 2 weeks → **FLUCONAZOLE** lifelong.

INFECTIONS

GRADENIGO'S syndrome – ***apical petrositis***
TOLOSA-HUNT - lateral wall of cavernous sinus.
RAMSAY-HUNT - **herpes zoster** of geniculate ganglion.
HEUBNER arteritis – arteritis of *circle of Willis* due to basal meningitis (syphilis, tbc, fungi).

N.B. if focal seizure / mass lesion, be sure there is no ***papilledema*** or ***midline shift*** before doing LP!

procalcitonin norm [0.1 ng/mL]; > 0.25 ng/mL can indicate infection

MENINGITIS

DEXAMETHASONE **10q6** IV - for 4 days of bacterial meningitis (3 weeks in TBC).
First dose of DEXAMETHASONE should be administered 20 min before first antimicrobial dose.
N.B. VANCOMYCIN effect may be adversely affected - use **higher doses** of VANCOMYCIN (15 mg/kg q6h) or **intrathecal** VANCOMYCIN.

CEFEPIME* 2 g q8h + VANCOMYCIN 15mg/kg q12h (goal trough: 15 – 20 mg/L) for 14 days

*for type I penicillin hypersensitivity (i.e. anaphylaxis) substitute with AZTREONAM or CIPROFLOXACIN

ABSCESS

Blood cx and biopsy first!!! → abx:

- neurosurgical patient: **VANCOMYCIN** + **CEFEPIME** + **METRONIDAZOLE** for 6-8 weeks (→ oral for additional 4-8 weeks) - until abscess cavity resolves completely (neovascularity persists!)
  alternative to CEFEPIME + METRONIDAZOLE - **MEROPENEM**

Practically, every patient needs at least biopsy (abscess ≥ 1 cm) for culture & stain (Gram, acid-fast, fungal)!!!

– if organism is known, indications for just decompression:
  1) significant **mass effect**
     Abscess > 2.5 cm should go to OR! Must be mature (symptoms > 7 days) – avoid operating on cerebritis (→ bleeding)

Profound cerebral edema with impending herniation - add **corticosteroids** (same for spinal cord abscess)

2) proximity **to ventricles** (risk of catastrophic rupture → ventriculitis → hydrocephalus)
3) **failure** to demonstrate abscess **shrinkage** in 4 weeks (antibiotic failure)

CJD

EEG - **periodic** **triphasic spiking** activity (resembles ECG).
CSF immunoassay - protein 14-3-3.

HSV ENCEPHALITIS

Major diagnostic impetus is to distinguish HSV from other viruses!

ACYCLOVIR right away *before definitive diagnosis*! 10-15 mg/kg IV q8h for 10-21 days
Periodic lateralizing epileptiform discharges (PLEDs) in temporal lobe
CSF – PCR, red cells

- if clinical deterioration occurs over next 48-72 hours with ACYCLOVIR → ***brain biopsy***.
- if **steroids** are inadequate → ***decompressive craniectomy.***

SPINAL OSTEODISCITIS

2015 IDSA Guidelines for the treatment of Native Vertebral Osteomyelitis in adults:

- blood cultures x2, ESR and CRP
  - fungal blood cultures if at risk for fungal infection
  - if blood cultures are negative → IR biopsy
- hold off on antibiotics in a neurologically normal / hemodynamically stable until diagnosis is established.

Surgical intervention is indicated in:

a) recurrent/persistent bacteremia
b) progressive neurologic deficits
c) progressive spinal deformity/instability (with or without pain)
d) worsening pain despite appropriate antimicrobial therapy

- just pain, including radicular pain (tends to get better with abx) are not surgical indications.
- Pott's - highly aerobic bacteria - discs are spared until later in course – "skip" lesions.

NEUROCYSTICERCOSIS

- ingesting eggs of *Taenia solium* → **larvae** in tissues, incl. brain

- test of choice is serum **serology**; **eosinophilia**; **biopsy** - sometimes needed.

N.B. steroids and aggressive management of hydrocephalus →ALBENDAZOLE, symptomatic cyst resection.

PAIN

HYPERALGESIA - stimuli that would *normally cause only minor pain* produce exaggerated response.

ALLODYNIA - *normally innocuous stimuli* (such as touch) cause pain.
PARESTHESIA - SPONTANEOUS abnormal sensation
DYSESTHESIA - abnormal sensations WHEN AREA IS TOUCHED

Opioid receptors in analgesia:

brain stem RF – mainly **μ receptors** (site of morphine action): *activation of periaqueductal gray* (midbrain) → *raphe magnus nucleus* (rostral medulla) → descending SEROTONERGIC fibers → inhibition at dorsal horn "gate"

spinal cord - dorsal horn "gate" – mainly **κ receptors**

PNS, at injury site – mainly **δ receptors**

σ receptor activation - *dysphoria*

EDX cannot diagnose pain (positive phenomenon)!

Always use MULTIMODAL treatment + PT + psychological support (treatment of depression, anxiety!)

Local - ice (acute pain) / heat (chronic pain) applications, CAPSAICIN ointment, LIDOCAINE patches / **EMLA cream**, US, diathermy, massage, acupuncture, TENS

Regional – sympathetic blocks

Systemic drug classes (9): NSAIDs, gabapentinoids, TCA antidepressants, SNRIs (duloxetine), muscle relaxants, steroids, opioids*, NMDA-receptor antagonists (KETAMINE), medical marijuana

*add NALOXONE Rx (esp. if > 50 MME/d, co-Rx benzos, hx of opioid abuse/overdose)

N.B. use SSEP for asleep **SCS** cases!!!!!!!! (for Boards) – must become symmetric flat during test stim; also cord damage monitoring.

Budapest criteria

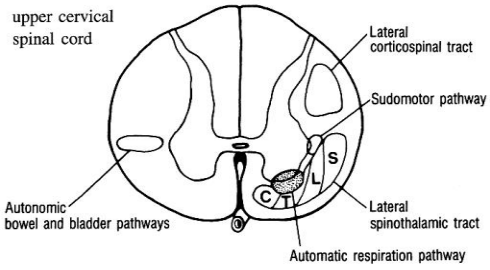
CRPS type 1 (reflex sympathetic dystrophy).

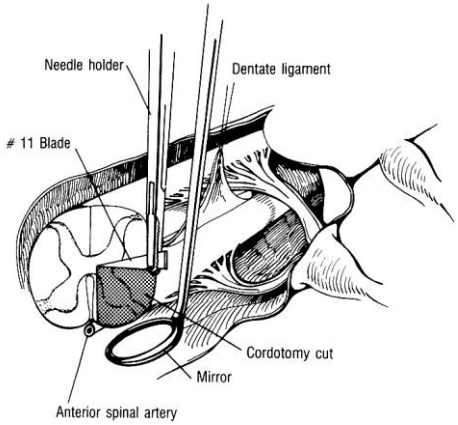
CRPS type 2 (causalgia) – if named nerve is involved (apparent TRAUMATIC nerve lesion)

- **selective sympathetic blockade → sympathectomy**
- **dorsal root ganglion stimulation**, SCS
- ***for type II* → nerve repair**

Cordotomy (anterior to T2-4 dentate ligament; pain recurs in 6-12 months) - for contralateral multisegmental pain.

bilateral cordotomy – only for below C5 [Ondine's curse] (alt – myelotomy) – awake procedure!





Myelotomy (split at level of pain) – for bilateral visceral **cancer** pain below neck.

DREZ (Dorsal Root Entry Zone) Myelotomy – for deafferentation pain:

brachial plexus avulsion pain – 60-80% improvement
phantom limb pain
postherpetic neuralgia does not respond (better – SCS, IT pump)

- **RF lesions** - Nashold electrode at 30 degrees oblique of coronal plane; lesions are made 1 mm apart with 75ºC for 15 seconds per lesion.

IT CATHETER TIP GRANULOMA

a) **asymptomatic** – decrease drug dose / stop pump.
b) **myelopathy, loss of effect** – open subtotal resection (± duraplasty).

EPILEPSY

Dyscognitive seizures: aphasic, akinetic, amnestic, dialeptic (= alteration of consciousness – synonyms: absence, petit mal)
Annual **SUDEP** risk 1:1000 in ***general epileptic population*** ***(much lower in children)***

2015 ILAE task force definition of status epilepticus:

a) seizure lasting **> 5 min** for generalized tonic-clonic seizures (t2 = 30 mins)
b) seizure lasting **> 10 min** for focal seizures (t2 = 60 mins)

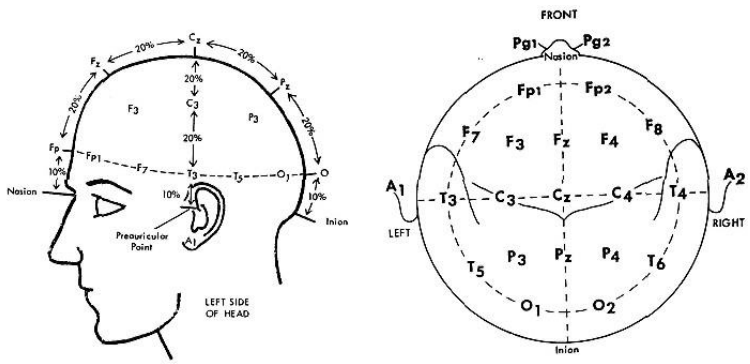
Seizures beyond t2 (despite treatment) = refractory SE (super-refractory > 24 hrs)

First seizure:

1. **MRI**
2. **Blood** (CBC, BMP), tox screen**,** serum prolactin
3. Fever → add **lumbar puncture**.
4. **ECG** (incl. Holter monitoring), **echocardiography**
5. If above are negative then **EEG**

locked-in syndrome simulating unconsciousness - EEG is normal

- **10-20 system**:



Right-sided placements - **even numbers**, *left-sided placements* - **odd numbers**, *midline placements* - **Z**.

VALPROIC ACID and PHENYTOIN interfere with **platelet** function!

replace with another medication 3 weeks preop

VALPROATE - highest risk for major congenital malformations of all antiepileptics - most critical period is first 5 weeks of gestation.

WADA - **4-vessel DSA:** no *cross flow*, no *persistent trigeminal artery*

N.B. fetal PComA is not contraindication but will cause cortical blindness.

Rasmussen syndrome - CHRONIC FOCAL ENCEPHALITIS - stimulating autoantibodies against GLUTAMATE receptors; H: **rituximab, RNS**

Temporal lobectomy minimum – MRI, PET, vEEG, neuropsych, fMRI (dominant side – always consider WADA testing)

- identify temporal horn early — *do not resect above TH* - prevents injuring temporal stem.
- amygdala is resected inferior to line between velum terminale (inferior choroidal point) and genu of MCA - prevents injuring basal ganglia and crus cerebri. N.B. never retract above choroid plexus!

SAH choice algorithm

- domain-specific memory decline - SAH acceptable
- in absence of domain-specific memory decline referable to side of ablation:

  MTS+: SAH acceptable (but if there is domain-specific memory loss on contralateral side → Wada test)

  MTS-:

  – nondominant side - SAH is acceptable, i.e. absence of visuospatial memory decline is acceptable for nondominant SAH, however, *maintain a low threshold for SEEG in MTS- cases* – be careful it is not a mimicker (epilepsy and normal lobe function are hardly compatible!)

  dominant side – consider RNS (i.e. normal verbal memory is incompatible with dominant-side SAH)

Rephrasing:

damaged hippocampus (either MTS+ or ipsilateral [domain-specific] memory decline*) is acceptable for ablation.

*if ipsilateral memory is normal but contralateral memory is declined, do WADA (if fails WADA, do RNS instead of SAH); if ipsilateral and contralateral memories are normal, assume that contralateral hippocampus took over (WADA test may give reassurance before proceeding with SAH)

intact (visuospatial memory, MRI-) nondominant hippocampus is acceptable for ablation.

intact (verbal memory, MRI-) dominant hippocampus – do RNS (or VNS) instead of SAH.

N.B. electroclinically typical temporal lobe epilepsy but intact (verbal memory, MRI-) hippocampus – be careful it is not a mimicker (epilepsy and normal lobe function are hardly compatible) – consider SEEG!

ONCOLOGY

KARNOFSKY performance scale - objective measurement of ***functional ability***:
100 – Normal (no evidence of disease)
70 – Unable to carry on normal activity (cares for self)
10 – Moribund

Metastatic workup:

1. **Skin and thyroid examination**
2. **Chest-abdomen-pelvis CT**
3. **Whole-body FDG PET**

+ **multiple myeloma**: laboratory diagnosis + skeletal survey + bone marrow biopsy
+ **PSA**

Syndrome	Nervous Tumor	Other tumors
Neurofibromatosis type 1	**Neurofibroma**, **malignant peripheral nerve sheath tumor (MPNST)**, **optic nerve glioma**	pheochromocytoma
Neurofibromatosis type 2	**Bilateral vestibular schwannoma**, **meningiomas**, peripheral **schwannoma**	
von Hippel–Lindau syndrome	**Hemangioblastoma**	Retinal hemangioblastoma, **renal cell carcinoma**, pheochromocytoma
Tuberous sclerosis	**Subependymal giant cell astrocytoma (SEGA)** Hamartomas - cortical tubers and subependymal nodules	Cardiac rhabdomyoma

Li-Fraumeni syndrome	**GBM**, **medulloblastoma**	
Turcot syndrome		Colorectal polyps
Multiple endocrine neoplasia 1	**pituitary** adenomas, malignant **schwannoma**	
Retinoblastoma	retinoblastoma, **pinealoblastoma**	
Werner's syndrome	**meningioma**	
Cowden disease	Dysplastic gangliocytoma of cerebellum (**Lhermitte-Duclos**)	
GORLIN syndrome (nevoid basal cell carcinoma syndrome)	**Medulloblastoma**	

BRAIN

CHEMODECTOMA – nonchromaffin paraganglioma

Gliadel® - carmustine (BCNU) wafer
GammaTile® - ^{131}Cs seeds in collagen matrix tile

Homer-Wright rosettes = -blastomas (incl. **medullo**)
Ependymoma – perivascular pseudorosettes, ependymal rosettes.

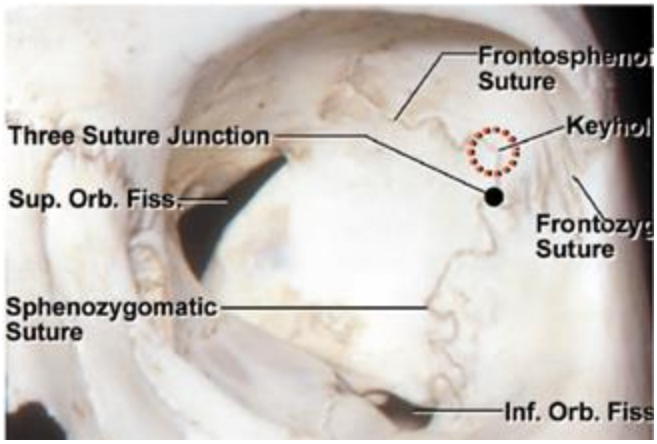
Nonoperative tumors – 1) diffuse **pontine** glioma* 2) optic pathway glioma** 3) germ cell tumors
*vs. **midbrain tectum**, **medulla** (esp. focal or exophytic) → surgery
**except optic nerve in already blind eye

- most hypervascular tumors - *CHOROID PLEXUS PAPILLOMAS*, *HEMANGIOBLASTOMAS* + *MENINGIOMAS*

Telovelar approach – between **tonsil** and **uvula**

MCCARTY KEYHOLE

- touch above where three sutures meet - 7 mm superior and 5 mm posterior to frontozygomatic suture; drill shaft is held at a 45 degree angle from plane of temporal bone
- access to orbita and frontal dura! (vs. pterional Dandy keyhole – made higher and directed superiorly – only access to frontal dura)



RING-ENHANCING MASS

1) high grade glioma
2) mts
3) lymphoma
4) radiation necrosis
5) benign conditions - resolving intracerebral hematoma, recent infarct, MS plaque, brain abscess.

Benign conditions that enhance: tumefactive MS, sarcoid, subacute stroke, subacute ICH, abscess, toxoplasmosis

Cyst + mural nodule

1) pilocytic astrocytoma
2) pleomorphic xanthoastrocytoma (PXA)
3) hemangioblastoma
4) ganglioglioma
5) metastasis
6) neurocysticercosis

TUMORS THAT SPREAD VIA CSF

HIGH-GRADE GLIOMAS (10-25%)
MEDULLOBLASTOMAS (10-20%)
EPENDYMOMAS (12%)
CHOROID PLEXUS CARCINOMAS
OLIGODENDROGLIOMAS (1%)
PINEAL GERMINOMAS (rare), *PINEOBLASTOMAS*!!!

Spine MRI preop, then 2 weeks postop! (or LP at 2 weeks postop)

TUMORS THAT TEND TO BLEED

1) oligodendrogliomas, high-grade astrocytomas
2) some metastatic tumors (melanoma!!!, renal cell carcinoma, choriocarcinoma, testicular carcinomas).
3) WNT among medulloblastomas

POSTERIOR FOSSA

Always open cisterna magna to drain CSF

HEMANGIOBLASTOMA – VEGF activation, polycythemia, nodule and nonenhancing cyst, VHL (pheochromocytoma)

Pediatric tumor:
Ependymoma – aim for GTR (still majority need postop XRT; chemo has no role)
Medulloblastoma, Astrocytoma – aim for near-total resection (no need for GTR at expense of complications)
Pilocytic astrocytoma – curative even with incomplete resection (resect recurrences)
Craniopharyngioma – aim for GTR or subtotal+XRT

Posterior fossa tumor (ependymo, medullo) → neuraxis MRI, CSF, screen for pheo** → embolization (**hemangio**) → OR: pacing electrodes, IONM → protect 4th floor: GTR (**ependymo**) vs > 75% STR (**medullo**) → postop intubated, BP control, may need PEG/trach → 2-wk LP, XRT for all (even kids < 3 yo); [**ependymo** - never chemotherapy vs **medullo**] → 3-month neuraxis MRI, geneticist (**hemangio, medullo**)

**hemangioblastoma – CT, plasma and urine [meta]catecholamines

Medullo:

MYC-amplified group 3 - worst prognosis.
SHH and group 4 - intermediate prognosis.
Wingless (WNT) - prognostically most favorable

GRADE 2 GLIOMAS

(oligo, diffuse astrocytoma, oligo-astrocytoma):

- GTR → **annual MRI** (i.e. hold off on adjuvant therapy, esp. in < 40 yo, oligo) vs. other experts add **radiotherapy*** (esp. > 40 yo or subtotally resected or IDH-wildtype)
  *Lower dose immediate (or delayed – for recurrence) radiotherapy (45–50.4 Gy)
- recurrence – **surgery** → **chemo** Temodar (for astro), PCV (for oligo).

OLIGODENDROGLIOMA – most chemosensitive of gliomas → PCV

Seizures, **hemorrhage**, and **calcifications** are more common with oligodendrogliomas than other gliomas!

HIGH-GRADE ASTROCYTOMA

F/U - **MD Anderson protocol:**
During chemotherapy - MRIs q2 months.
After completion of chemotherapy - MRIs q2 months for 1 yr → q3 months for 1 year → q4 months for 1 year → q6 months indefinitely.

AWAKE CRANI

Preop fMRI or MEG or TMS
Motor must be > 3/5, language errors < 25%
Load AED one day preop
Low dose REMIFENTANIL
PRECEDEX / PROPOFOL **LMA**, **neuroanesthesiologist**
MANNITOL IV - maximum 0.5 g/kg → nausea and vomiting

- patient comfort + airway access.
- lidocaine on dura
- *dura is not opened until the patient is completely awake and calm*.
- **60** Hz at 1 msec pulses for 2-3 seconds, *current 1-2 mA below AD threshold* - each cortical site is checked 3 times

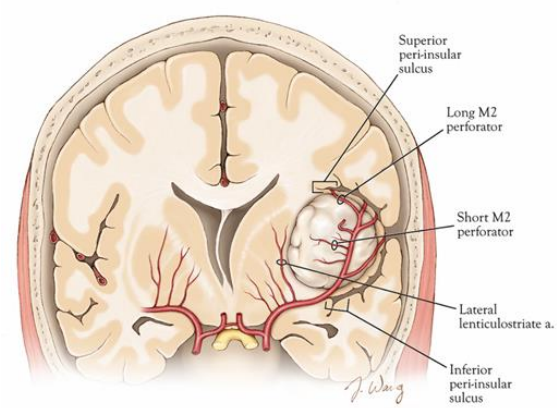
  Dr. Komotar uses 5 mA bipolar for **cortical**, 5 mA monopolar for **subcortical** mapping
- stimulation sequence: face motor → Broca (speech arrest without any movement in oropharynx) → Wernicke.
- resection just anterior to motor cortex → transient SMA syndrome, thus, when resecting in motor area, resect lesion in motor cortex → SMA.
- seizure during cortical mapping: stop mapping, ice cold irrigation, ↑oxygen, small doses of PROPOFOL, load with PHENYTOIN
- resections are kept a minimum of 1 cm from positive language sites.

INSULA

high-grade gliomas are treated conservatively (unless located along the lateral aspect of the nondominant insula in a young highly functional patient)

> N.B. modern approach for LGG – maximal safe resection; if unlikely to resect > 50% of tumor then biopsy is warranted instead

- **fMRI + DTI + navigation + awake mapping** (sensory, motor; if dominant side – add language mapping)
- **striatum (putamen) + lateral lenticulostriate arteries** determine the most medial extent of resection
- short M2 perforators supply the tumor.
- long M2 perforators supply corona radiata and must be preserved.



A) **Trans-Sylvian approach (Yasargil)** – split fissure widely, mapping.
B) **Trans-Cortical approach** – utilizing opercula (better preserves Sylvian veins, lower risk of MCA spasm); recognize medial border of insula by identifying lenticulostriate vessels.

N.B. vascular injury in insular region can be devastating! (immediate neurological deficits respond to steroids and typically resolve in 3 mos)

LATERAL VENTRICLE

Tumor	Typical site
COLLOID CYST	Foramen of Monro / 3rd ventricle
SEGA	Foramen of Monro
MENINGIOMA	Trigone of lateral ventricle
CHOROID PLEXUS PAPILLOMA	
EPENDYMOMA	
SUBEPENDYMOMA	#1 differential of nonenhancing intraventricular mass
NEUROCYTOMA	Lateral ventricles (involving septum pellucidum), most common lateral ventricle tumor in young adults
METASTASES	Lateral ventricles, ependyma and choroid plexus

Differentials: Neurocysticercosis

Preop embolization + EVD + navigation + monitoring!!!!

- secure vascular feeders as early as possible (DSA dictates approach – transcortical vs transcallosal) → tumor decompression → capsule mobilization (ventricle walls often do not adhere to tumor!)

Only two major choices:

A. **Transcortical** - parasagittal veins are not a concern, tedious interhemispheric arachnoid dissection is not required, but projection fibers in the frontal lobe are disrupted + ↑risk of postop seizures
B. **Transcallosal** - access only to frontal horn and body + 3rd ventricle!

Lesion Location	Suggested Approaches
Frontal horn	Anterior interhemispheric **transcallosal** **Transcortical** (via middle frontal gyrus)
Body	Anterior lesions - same as frontal horn. Posterior lesions: Posterior interhemispheric **transcallosal** **Transcortical** (via superior parietal lobule)
Atrium or trigone	*Ipsilateral* interhemispheric **transcortical** (via cingulate/precuneus) *Contralateral* interhemispheric **transcortical** (via falx → precuneus) **Transcortical** (via paramedian/superior parietal lobule) ***Trans-sulcal*** (intraparietal sulcus)
Temporal horn	**Transcortical** (anterior temporal neocortical resection) **Transcortical** (via middle temporal gyrus – map speech on Left side!) ***Trans-sulcal*** (via occipitotemporal sulcus) – avoid! **Transcortical** (via inferior parietal lobule) – CI on Left side **Transsylvian**
Occipital horn	Posterior interhemispheric **transcortical** **Transcortical** (occipital neocortical resection) Lesions around calcar avis - ***supracerebellar transtentorial***

TUMORS THAT CALCIFY

Oligodendrogliomas (90%), **meningiomas**, **craniopharyngioma**, ependymomas, choroid plexus tumors, teratoma, chordoma, central neurocytoma.

medullo, hemangioblastoma – never calcifications (vs. ependymoma, choroid plexus tumors)
medullo – also restricts on DWI

MARKERS

Tumor type	IDH	ATRX	1p/19q	p53 mutation
astrocytic	mutant	mutant	intact	secondary GBM
oligodendroglial	mutant	wildtype	co-deleted	no

- if histology looks like oligo, but IDH-wild type – call astrocytoma!
- p53 mutation goes "hand to hand" with IDH mutation.

IDH mutation, 1p/19q co-deletion, and MGMT promoter methylation – better prognosis!

All tumor samples should be sent for next generation sequencing (e.g. Tempus company)

Alcian blue – stain for mucin (e.g. myxopapillary ependymoma)

α-fetoprotein – embryonal carcinoma, endodermal sinus (yolk sac) tumor.

Anti-Leu 7 antibody – schwannomas.
N.B. uniformly negative in meningiomas

ATRX (Alpha-Thalassemia/mental Retardation syndrome X-linked) gene

- ATRX is present in every cell!
- loss of ATRX = astrocytic lineage (grade II/III astrocytomas and secondary GBM).

Brachyury (protein encoded by the TBXT gene, transcription factor within the T-box family of genes**)**

- early mutational event in chordoma evolution (discriminates chordoma from chondrosarcoma).
- present in majority of hemangioblastomas (helps to differentiate from clear cell renal cell carcinoma metastases in von Hippel-Lindau syndrome).

BRAF-V600E mutation:

1) metastases - melanoma, papillary thyroid
2) PXA
3) craniopharyngioma (papillary)
4) glioblastoma (epithelioid)
5) ganglioglioma (also reported in some DNETs and pilocytic astrocytomas)

CD3 – T-cell lymphoma.

CD68 (monocyte lineage: microglia, histiocytes) – differentiates histiocytosis from lymphoma.

Desmin – tumors containing muscle (rhabdomyosarcoma, teratoma, etc), primitive neuroectodermal tumor.

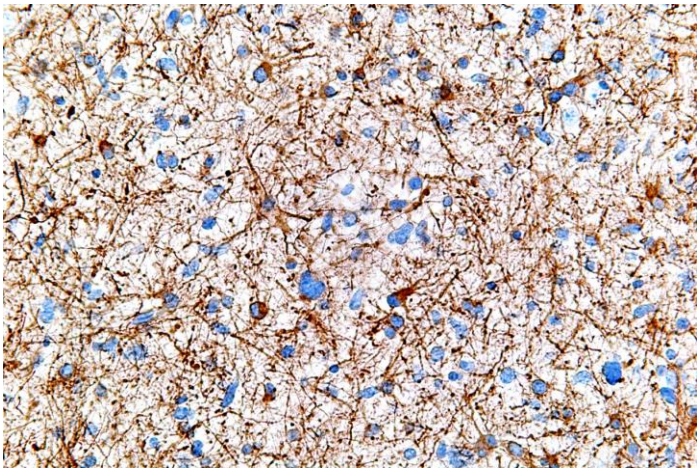
EGFR (epidermal-derived growth factor receptor) – aberrantly expressed (usually amplified*) in many gliomas.

*poor prognostic factor!

EMA (epithelial membrane antigen) – epithelia marker (ependymoma, meningioma).

N.B. not present in melanoma!

GFAP (glial fibrillary acidic protein) – expressed in astrocytes - marker for glial tumors; e.g. anaplastic astrocytoma:



Human chorionic gonadotropin – germinoma, choriocarcinoma

Ki-67 antibody (recognizes histone protein expressed in proliferating but not quiescent cells).

Luxol fast blue dye - myelin fibers appear blue.

OLIG-2 expression = diffuse gliomas
(astrocytomas, oligodendrogliomas and oligoastrocytomas); may also be expressed in other cancers (esp. some leukemias).

p53 mutation = astrocytic tumors (vs. oligo)
Li-Fraumeni syndrome (inherited p53 mutation) – strong predisposition to astrocytomas!

- p53 mutation goes "hand to hand" with IDH mutation.
- *progression from low-grade astrocytoma to glioblastoma* strongly correlates with loss of *p53* gene; *GLIOBLASTOMAS* that show p53 mutation are termed *secondary glioblastomas* (type 1) - occur in younger patients whose tumors have progressed from lower grade astrocytoma.

PD-1 (programmed cell death protein 1) - immune checkpoint protein on the surface of T and B cells that down-regulates immune system and promoting self-tolerance by suppressing T cell inflammatory activity (promotes apoptosis of antigen-specific T cells, reduces apoptosis in suppressive T cells) - prevents autoimmune diseases, but it can also prevent immune system from killing cancer cells.

- *PD-1 expression* – consider anti-PD-1 inhibitor. see p. Onc3 >>

Placental alkaline phosphatase (PLAP) – germ cell tumors esp. germinoma

Rosenthal fibers:

1) *JUVENILE PILOCYTIC ASTROCYTOMAS*
2) *CRANIOPHARYNGIOMAS*
3) around *EPENDYMOMAS*
4) *ALEXANDER DISEASE* (Rosenthal fibers radiate from vessels)

S-100 – present in cells derived from neural crest (Schwann cells, melanocytes) - markers for certain **melanomas, schwannomas** (100%), neurofibromas (weaker than schwannomas), malignant peripheral nerve sheath tumors (50%, may be weak and/or focal).

SSTR2 (somatostatin receptor type 2)

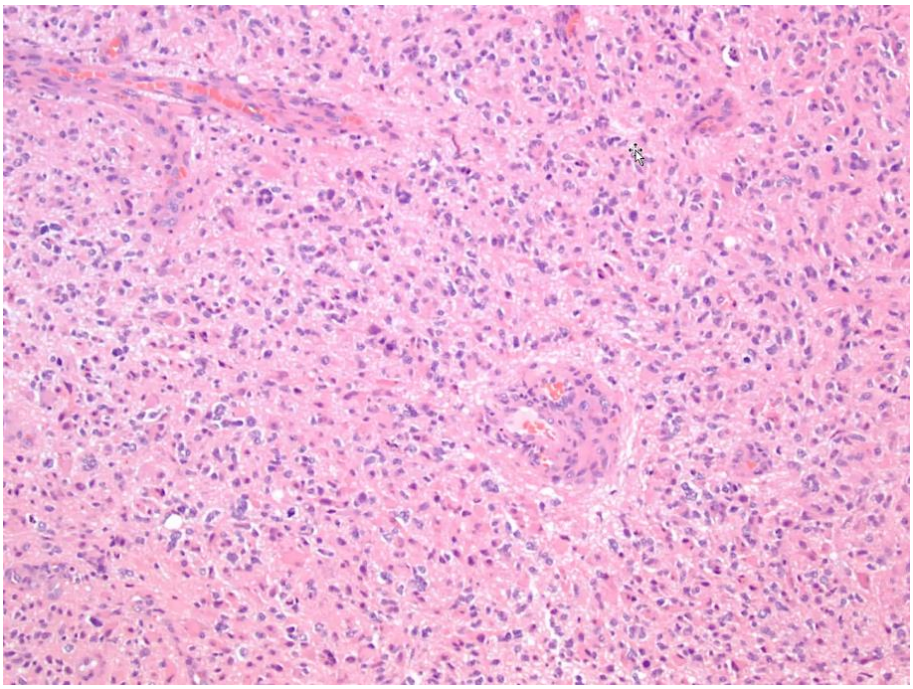
- most sensitive marker for meningiomas (present in 100%).

STAT6 – hemangiopericytoma (solitary fibrous tumor).

Synaptophysin – glioneuronal tumors

Vascular (endothelial) proliferation:

a) astrocytic lineage = grade 4
b) 1p/19q co-deletion = anaplastic oligo (grade 3)



SELLAR AND PARASELLAR TUMORS

1. **Tumors**:
    1) pituitary adenoma, pituitary carcinoma, craniopharyngioma
    2) meningioma, metastatic tumors
    3) cranial nerves - optic glioma, CN5 schwannoma
    4) bone - chordoma, chondrosarcoma
    5) epidermoid, dermoid, teratoma, germ cell tumors (← treated with radiation)

    H: surgery with *histological diagnosis*.

2. **Not tumors**: hemorrhage, aneurysm (supraclinoid carotid / superior hypophyseal artery, basilar tip), empty sella, Rathke's cleft cyst, tuber cinereum hamartoma, granulomas (e.g. tuberculosis, neurosarcoid, eosinophilic), lymphocytic hypophysitis.
   H: *neuroradiological imaging*, possibly *biopsy*.

- most important endocrine tests – 5 axes:
  1) prolactin
  2) TSH&fT4
  3) IGF-I
  4) fasting morning cortisol & ACTH
  5) LSH, FSH, testosterone / estradiol

↑[prolactin] < 200 may be due to stalk compression

MTS

RADIATION THERAPY ONCOLOGY GROUP (RTOG) classes for predicting outcome in brain metastases after whole brain radiotherapy:

Class	Karnofsky score	Systemic Disease	Median Survival (mo)
1 (age ≤ 65 yrs)	≥ 70	Controlled primary disease, no extracranial metastases	7.1 (13.5 for single metastasis, 6.0 for multiple metastases)
2		Not group 1 or 3	4.2 (8.1 for single metastasis, 4.1 for multiple metastases)
3	< 70		2.3

Aim for en bloc resection (to minimize leptomeningeal spread), with 5 mm brain margin

CP ANGLE

1. *VESTIBULAR SCHWANNOMA* (80%)
2. *MENINGIOMA* (20%)
3. Other rare cases:
   1) *EPIDERMOIDS* (!!!)
   2) *OTHER SCHWANNOMA*s - *TRIGEMINAL* (< 8% of intracranial schwannomas), *FACIAL NERVE* (extremely rare)
   3) *VASCULAR TUMOR*
   4) *LIPOMA*
   5) *METASTASES*
   6) *AT/RT*

EPIDERMOID - similar to CSF – hypointense on T1 and hyperintense on T2 (epidermoid has diffusion restriction vs arachnoid cyst)
DERMOID - similar to fat – hyperintense on both T1 and T2 – unique tumor.

- *cyst rupture and spillage* → acute chemical meningitis (maybe fatal) irrigation with dexamethasone intraop + 2 weeks of DEXAMETHASONE

MENINGIOMA

- preoperative CT - extent of bony involvement! (have titanium mesh ready)
- DSA (even if not anticipating embolization – to see feeders) – embolize?
- **lumbar drain** (even for olfactory groove meningiomas).
- harvest pericranium! – for dura resection (**cut dura** 2 cm away from tumor)
- devascularize → debulk → dissect

  Imaging role: SSS involvement + configuration of parasagittal bridging veins + intradiploic veins around the tumor! *veins in the region that will limit access?*
  If MRV shows occluded SSS, confirm it with DSA!
- prepare for venous blood loss + air embolism!
- recommend a clinoidectomy for all clinoid region meningiomas (extradural Dolenc clinoidectomy, optic canal unroofing and optic nerve sheath opening).

WHO Classification of Meningiomas:

Grade
Grade I - **(benign) meningioma**
Grade II - **atypical meningioma** ≥ 4 mitoses per 10 high-power fields
Grade III - **anaplastic meningioma** ≥ 20 mitoses per 10 high-power fields

Degree of Resection	Recurrence rate
Complete resection with dural margin	9%
Complete resection with coagulation of dura	19 %
Complete resection (no treatment of dura)	29 %
Partial removal leaving tumor *in situ*	40 %
Decompression	NA

a) ADJUVANT therapy - for grade II-III / recurrent grade I tumors → IMRT

RTOG 0539: phase II study

Risk Group	Grade	Surgery/Recurrence	
Low	I	GTR (Simpson I-III)	Observation
	I	STR (Simpson IV-V)	
Intermediate	I	Recurrent	54 Gy to GTV + 1 cm (0.5 cm at natural barriers)
	II	GTR	
High	II	Recurrent or STR	54 Gy to GTV + 2 cm →60 Gy to GTV + 1 cm
	III	Any	

*GTV includes tumor bed and any residual nodular enhancement

Atypical meningioma post GTR: IMRT 54 Gy in 30fx with 1 cm margin (SRS/SRT is mostly from retrospective study).

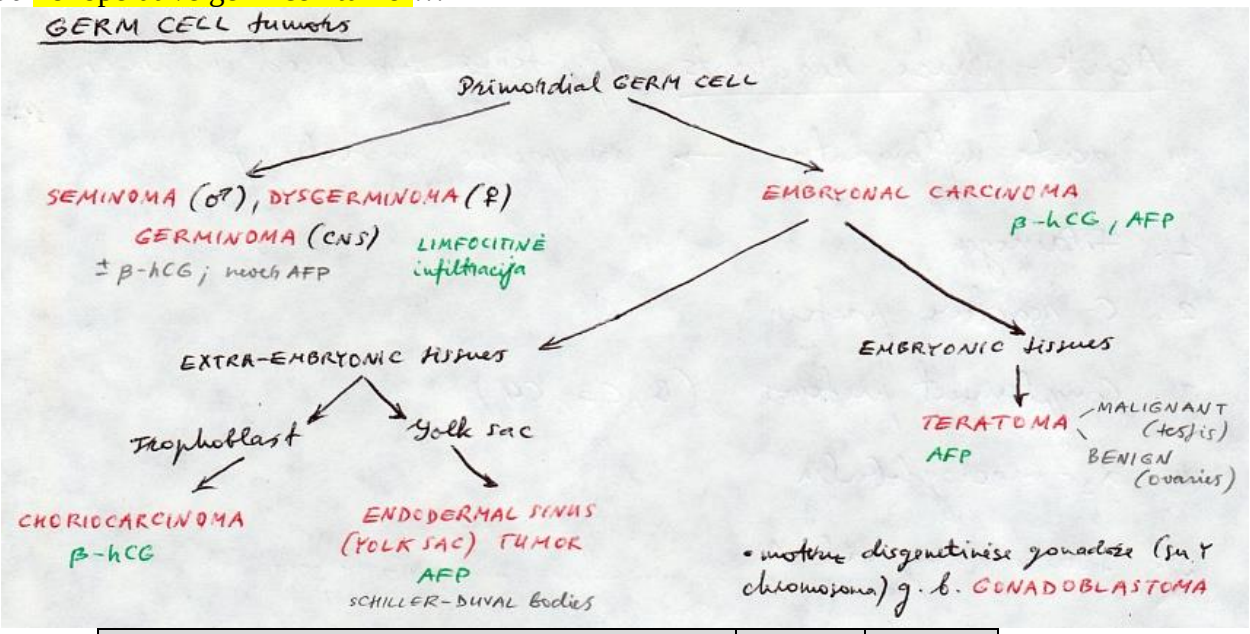
Anaplastic meningioma (or STR or recurrent atypical): IMRT 60 Gy in 30fx with 2 CM margin is standard care (SRS is not commonly used)

If SRS is used - margin is 1-2 mm

b) PRIMARY treatment – when surgery is not feasible: elderly patients, skull base, parasaggital, some unresectable tumors; used less frequently in convexity or optic nerve sheath tumors → SRS **15** Gy to margin
   - SRS as PRIMARY treatment - equivalent to a Simpson grade I resection

PINEAL REGION TUMORS

pineal calcification in child < 7 yrs - neoplasm
rule out a nonoperative germ cell tumor!!!

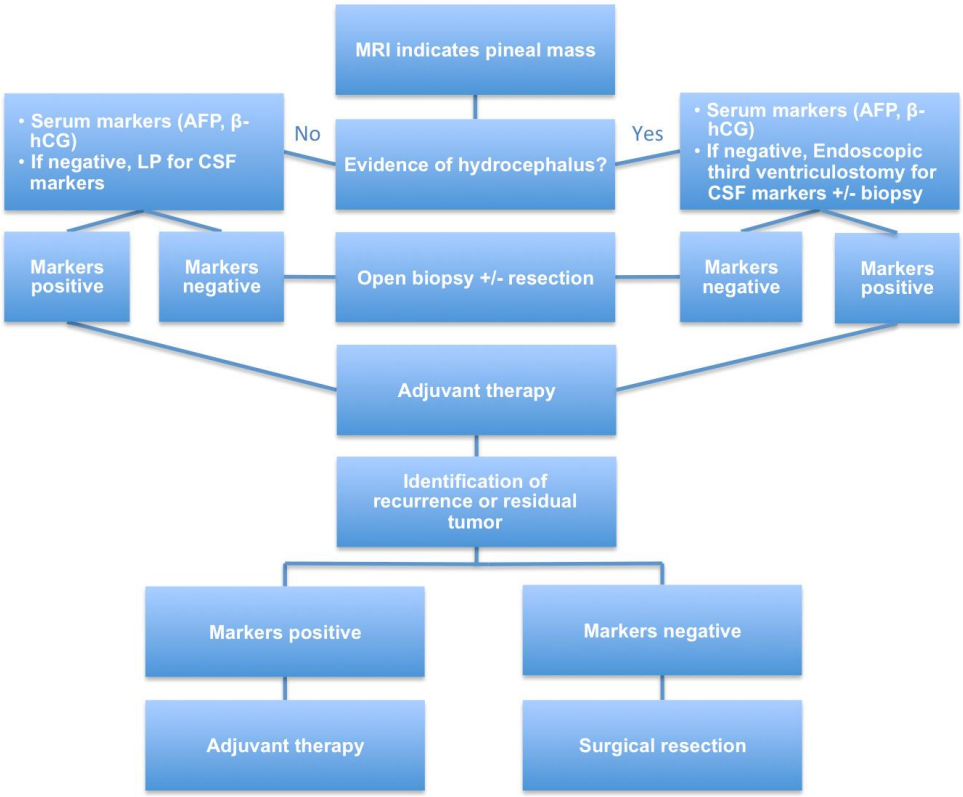


Tumor	AFP	β-hCG
*pure germinoma**		
mature teratomas		
immature teratomas	±	
endodermal sinus tumors	+	
choriocarcinomas		+
embryonal cell carcinomas	+	+

**GERMINOMAS* secrete LDH, PLAP, CEA – but useful only on immunohistochemical slides; some use also for follow up in serum!

Neuraxis MRI + MRV, tumor markers (serum → CSF*) → CSF cytology*
ETV → biopsy! (skip if AFP/ β-hCG ↑↑↑)
LP only if no HCP (otherwise, get CSF during ETV)!
Treat hydrocephalus prior to biopsy or resection! (ETV with biopsy with flexible endoscope / separate more frontal bur hole and rigid endoscope)

wait for frozen sections on biopsy before proceeding with tumor resection!



MRV → approach: **occipital-transtentorial** vs. **supracerebellar-infratentorial**

LYMPHOMA

DWI, LP, hold steroids → biopsy
Administer systemic MTX before XRT (else *necrotizing leukoencephalopathy*)

SKULL

Malignant tumors – single large or multiple lesions, irregular poorly defined borders, no periosteal reaction (no sclerosis).
Benign tumors – single, small, grossly round / oval lesion, with peripheral sclerosis, intralesional calcifications, peripheral bone vascularity.

Skeletal survey, MRI, FDG-PET → needle biopsy, but solitary lesions - resection ± preop embolization

- if other means cannot control tumor expansion, surgery is still option in metastatic disease (esp. for solitary lesions)

SPINE

Dex + brace

SPINAL INSTABILITY NEOPLASTIC SCORE (SINS)

1. **Pain**:
   - mechanical pain: 3 points
   - occasional pain but not mechanical: 1 point
   - painless: 0 points
2. **Bone lesion** (on CT):
   - lytic: 2 points
   - mixed: 1 points
   - blastic: 0 points
3. **Location**:
   - junctional (occiput-C2, C7-T2, T11-L1, L5-S1): 3 points
   - mobile spine (C3-C6, L2-L4): 2 points
   - semirigid (T3-T10): 1 point
   - rigid (S2-S5): 0 points
4. **Alignment**:
   - subluxation/translation: 4 points
   - deformity (kyphosis/scoliosis): 2 points
   - normal alignment: 0 points
5. **Vertebral body collapse** (**anterior** and **middle** columns):
   - > 50% collapse: 3 points
   - < 50% collapse: 2 points
   - no collapse but > 50% vertebral body involved: 1 point
   - none of the above: 0 points
6. **Posterior spinal element involvement** (pedicles, facets, costovertebral joints):
   - bilateral: 3 points
   - unilateral: 1 point
   - none: 0 points

Treatment and prognosis:
score 0-6: stable → radiotherapy / thermal ablation+cement
score 7-12: potentially unstable (warrant surgical consultation) → surgery, radiotherapy / thermal ablation+cement
score 13-18: unstable → surgery before radiotherapy

METASTASES

Metastatic work up, panspine MRI → biopsy → embolization

contrast-enhanced fat-suppressed T1-MRI + ***STIR***

Management Algorithm (NOMS)

Neurologic (Cord compression)	Oncologic (Is the tumor radiosensitive (cEBRT)?)	Mechanical (Is the spine stable?)	Systemic (Can the patient tolerate surgery?)	Treatment Decision
Low-grade	Yes	Yes		External beam radiation (cEBR)
		No		Surgical stabilization -> cEBR
	No	Yes		Stereotactic radiosurgery (SRS)
		No		Stabilization ->SRS
High-grade	Yes	Yes		cEBR
		No		Stabilization -> cEBR
	No	Yes	Yes	Separation surgery -> SRS
			No	cEBR
		No	Yes	Stabilization & Sep surgery ->SRS
			No	Stabilization (cement) -> cEBR

Modified from Laufer, I et al. The Oncologist 2013

Radiation is mainstay of treatment based on NOMS concept (unless need separation or stabilization*)

*for sick patients – just cement

Boards: avoid big surgeries*; only palliative actions to treat symptoms – multidisciplinary approach!
Isolated vertebral body mass, neuro stable – obtain biopsy.

*if still contemplating corpectomy (e.g. to restore anterior support and alignment), always consider preop embolization (+ have TXA, blood ready, tamponade locally)

SS is not just a simple laminectomy – also need (bilateral) pediculectomy, PLL section/resection, removal of ventral epidural tumor without significant vertebral body resection – thus, need **instrumentation** for stability.

- check with **intraop US** - need 2-3 mm of CSF.

spondylectomy / en bloc resections are not anymore indicated
if needed for structural support in solitary metastasis → corpectomy with cage / cement

radiosensitive - lymphoma, myeloma, seminoma, breast cancer, prostate cancer, small cell lung cancer;
radioresistant - sarcomas, melanomas, renal cell carcinomas, GI carcinoma, non-small cell lung cancer (NSCLC).

vascular tumors (need embolization before resection) - *METASTATIC* (renal cell, thyroid, hepatocellular, germ cell, neuroendocrine), *MULTIPLE MYELOMA* and *PLASMACYTOMA*, *HEMANGIOMA*, *HEMANGIOBLASTOMA*, *ANEURYSMAL BONE CYST*

- embolize, use TXA; avoid CellSaver (ok for en bloc resections - use leukocyte-trap)

Primary tumors that benefit from neoadjuvant therapy (thus, need biopsy):

1. Osteosarcoma – preop chemo
2. Chordoma – preop proton beam
3. Ewing sarcoma – may be cured with neoadjuvant!

- most common tumors with predilection to metastasize to vertebrae:
  - prostate
  - breast
  - lung
- osteoblastic (osteosclerotic) changes:
  1) prostate cancer
  2) breast cancer
  3) osteomas
  4) sarcomas
  5) occasionally - lymphoma, hemangioma
- isolated epidural involvement - lymphoma and renal cell carcinoma.

Multiple Myeloma

1) anemia, Ca↑, renal failure, serum and urine protein electrophoresis (Bence Jones monoclonal antibody protein in urine)
2) skeletal survey
3) bone marrow biopsy

N.B. ***hematological tumors*** (lymphoma, MM) – treatment is **medical**; surgery indications are rare:

1) acute / progressive neurological deficit esp. due to bone fragments (need preop embo)
2) intractable pain without neurological deficits → vertebral augmentation → XRT

Eosinophilic granuloma

- classic "*vertebra plana*".
- ***curettage*** → low-dose ***radiotherapy***; ***chemotherapy*** for systemic disease.

Hemangioma

– usually T1 bright (vs. metastases are T1 dark)

- treatment
  - asymptomatic hemangiomas are left untreated!
  - ***vertebroplasty***, low-dose ***radiotherapy*** and ***bracing***
  - ***only for*** spinal cord compression → preop embo → ***decompression, stabilization***.

BILSKY CLASSIFICATION

- epidural spinal cord compression (ESCC) scoring system:

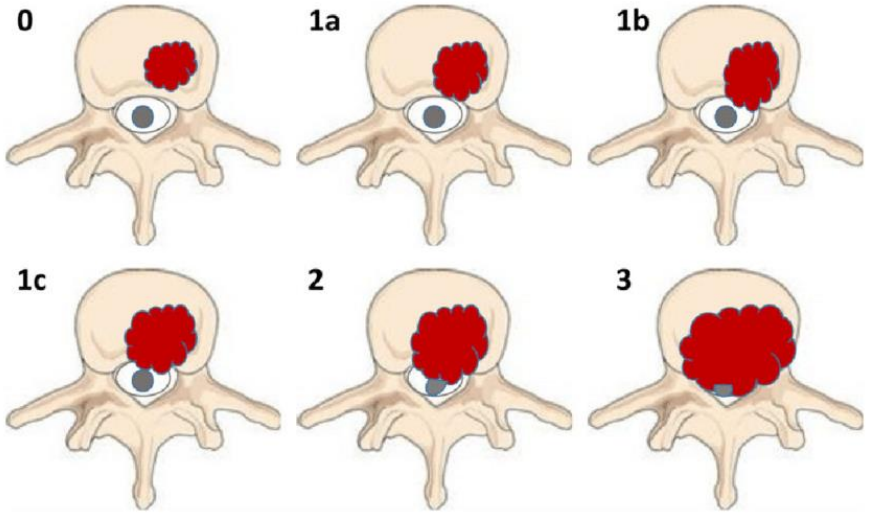
Low grade – no cord deformation

(A) **Grade 0** - bone-only disease.
(B) **Grade 1a** - epidural impingement, without deformation of the thecal sac.

(C) **Grade 1b** - deformation of the thecal sac, without spinal cord abutment.
(D) **Grade 1c** - deformation of the thecal sac with cord abutment, but without cord compression.

High grade – cord compression - require separation surgery before radiation!

(E) **Grade 2** - spinal cord compression, but with CSF visible around the cord.
(F) **Grade 3** - spinal cord compression, no CSF visible around the cord.



Biopsy (transpedicular) is important step in **PRIMARY** tumors:

1) not all primary tumors need aggressive resection
2) chordomas – neoadjuvant proton beam
3) osteosarcomas – neoadjuvant chemo.

N.B. CSF studies always go after MRI ruled out spinal block!

INTRAMEDULLARY

- baseline ***urodynamic studies***!
  Always use US to guide durotomy!
- for vascular tumors (e.g. hemangioblastoma) surgical principles similar to AVMs - first need to control* feeders – bipolar them first, then resect tumor en bloc.
  *ICG angiography to find feeding vessels
  N.B. wait for frozen pathology before proceeding with resection (astrocytoma – do not do aggressive resection!)
- find **cleavage plane** to dissect (Rhoton dissectors) tumor around.

N.B. T2 lesion in spinal cord (esp. with little or no swelling and no enough stenosis to explain it) – ask for MRI with contrast! (MS lesions are < 2 vertebral segments, occupy < ½ of cord cross-section - peripherally located in dorsal and lateral columns; Devic, transverse myelitis – long segments, large central cord involvement) → CSF study* for MS + serum aquaporin-4 antibodies

*normal IgG index is < 0.7

MS, Devic, ADEM, TM: 1000 mg METHYLPREDNISOLONE → beta-IFN (for MS only)

- no diffusion restriction ← main dif from cord infarct!

vs. Rapidly ascending weakness + areflexia = Guillain-Barre. Rx: plasmapheresis or IVIG
Steroids are harmful (GBS is the only autoimmune nerve disorder that steroids are contraindicated!)

SRS

Conformality ratio (ability to conform dose to the target) =
= entire volume getting the prescribed dose / target volume getting the prescribed dose
Has to be ≤ 2 (except for very small targets); for perfect plan, ≤ 1.5

Inhomogeneity ratio IR = maximum dose MD / prescribed dose PD

Dose Homogeneity – the consistency of dose within the treated volume

- IR has to be ≤ 2
- MD/PD = 100% IDL / 50% IDL = 2.0 ← don't prescribe to < 50% IDL (prescribe to 80%)

Gross tumor volume (GTV) - all known disease visible on CT / MRI.

Clinical tumor volume (CTV) - GTV plus surrounding tissue that presumably harbors microscopic disease

Planning target volume (PTV) - provides margin around CTV to allow for movement and treatment setup variation.

Methotrexate with radiotherapy, whether synchronously or at separate times → *necrotizing leukoencephalopathy*.
Children < 3 years are more susceptible (dose reductions of 20-25% vs chemotherapy).

Gamma Knife	LINAC
Steepest gradient index is around 50% isodose line	Steepest gradient index is around 80-90% isodose line
Dose rate 3 Gy/min	Up to 24 Gy/min – faster treatment

10 mg of DEXAMETHASONE before treatment
N.B. SRS decreases peritumoral edema with brain mts but increases with meningiomas (esp. single fraction SRS)

RADIATION NECROSIS

Rad necrosis manifests 6-24 months after radiotherapy, lasts 18 months

- incidence with **SRS is 7-15%.**
- **T1w-TRAM**, **pMRI** (rCBV cutoff value is 2.1), **MRS** → **biopsy**.
  < 2.1 – necrosis; > 2.1 – tumor recurrence
- steroids, Trental, Avastin, LITT, surgery

Algorithm:

a) small, minimally symptomatic lesions → medical treatment
b) lesions grow on 2 scans → LITT
c) significant mass effect → debulking
d) Avastin – for inaccessible lesions

RADIATION DOSES

Parkinsonism, OCD targets: 130 Gy at 100% isodose
Trigeminal neuralgia - 86 Gy at 100% isodose (or 43 Gy at 50% isodose)
High-grade glioma (Stupp protocol) - standard of care for GBM (start 2-5 weeks postop)

6 weeks of combination treatment:

XRT 60 Gy in 30 fx in 6 weeks, to contrast-enhancing lesion + 2–3 cm margin

PLUS

TEMOZOLOMIDE, 7 days per week from first to last day of XRT, i.e. for 42 days

↓

6 months of chemo:

6 cycles of TEMOZOLOMIDE for 5 days during each month

N.B. SRS is not recommended for newly diagnosed GBM! vs. recurrent GBM (consider LITT over SRS in recurrent GBM)

Ependymoma: 50-55 Gy
Low-grade glioma: 45-50 Gy
Lymphoma – WBRT: 40-45 Gy in 20-25 fractions
Metastases – WBRT: 30 Gy in 10 fractions over 2 weeks
Metastases – SRS (max total tumor volume 10 mL): No margin needed!

Tumor size	MTD (Gy, Tumor Margin)
< 2 cm	24
2 – 3 cm	18
> 3 cm	15 (better 8 Gy x3)

AVM: 16-25 Gy single-dose SRS
Hypothalamic hamartoma: 16-20 Gy
Paraganglioma: 14-16 Gy
Meningioma:

primary treatment - 15 Gy (at 50% isodose, 1-2 mm brain margin)
adjuvant for atypical – IMRT 54 Gy (60 Gy for anaplastic) in 30 fx with 1 cm margin (2 cm for anaplastic)

Pituitary adenoma: 12-16 Gy (double [30-35 Gy] for functioning)
Vestibular schwannoma: 12-13 Gy
Craniopharyngioma: 11-12 Gy

Spine mts:

SRS: 16-24 Gy (or 8-10 Gy x3 or 6 Gy x5) similar as SRS for brain mts
cEBRT (conformal external beam RT): 3 Gy x 10 same as WBRT for brain mts

MAXIMUM SAFE SINGLE XRT DOSE

Lateral wall of cavernous sinus:

N.B. CN 2 and CN 8 are very sensitive – safe doses < 8 Gy.

cochlear nerve is much more sensitive than vestibular and facial nerves.

N.B. CN 3, 4, 6 are rather resistant – safe doses < 16 Gy.

Cochlea

≤ 4 Gy

Lens (eyes)

- shield eyes when doing **functional/benign cases** to block beams transiting lenses.

Anterior visual pathway (optic nerve, optic chiasm)

≤ 10 Gy (to ≤ 1% of optic nerve) - 0-2% risk of optic neuropathy.

≤ 8 Gy – if had previous XRT, previous compression and prior surgery

- if the goal is close to zero, consider 8 Gy.
- 1 mm distance between tumor and optic chiasm is enough.

Pituitary

- gland and hypothalamus is < 15 Gy, to stalk < 17 Gy (endocrine F/U for 3 yrs)

Brainstem

≤ 8-10 Gy

Pyramidal (corticospinal) tract

≤ 20 Gy

Major arteries (e.g. carotid)

- no need to segment as "organ at risk" but keep hotspot < 25 Gy

Spinal cord

- 10 Gy to 10% volume of spinal cord (or absolute volume of < 0.35 mL), defined as 5-6 mm above and below the target.

PNS

PNS tumor – check for NF stigmata & family history!
Do not resect every nerve mass (it can be neuroma, cyst, hamartoma, intraneural ganglion [extending from neighboring joint], etc)! – only large / enlarging / symptomatic / uncertain pathology
If going to OR – request **US + stimulator**! (involved nerve fascicles are nonfunctional – always can sacrifice, but for Boards – always use stimulator!)

PET – if uptake is high, suspect malignant peripheral nerve sheath tumor

Schwannoma – only sensory nerves, never malignant;

a) resection
b) SRS – for intracranial

Malignant tumor

- pain at rest, rapidly enlarging immobile mass, early progressive motor loss – two tests:
  - MRI cannot differentiate malignant vs benign (unless gross *local invasion*, irregular borders, irregular enhancement, necrosis)
  - PET (> 7) is diagnostic in dif from benign tumors (< 2).
- **resection with wide margins → chemotherapy** ± radiotherapy

N.B. practically – need biopsy and staging in preparation for large surgery:

A. If highly suspected preop → **open biopsy** or **percutaneous needle*** **biopsy → further work up****

*Board's choice but risk of false negative

B. If became suspicious only during surgery (firm, no planes) → **open biopsy** and send frozen:

a) if pathologist certain it is benign → **simple resection**
b) if frozen uncertain / malignant (frozen can be wrong!) → close → **further work up****

****staging** (PET, CT chest-abdomen-pelvis) + **final path** → **tumor board**

VESTIBULAR SCHWANNOMA

Don't jump to treat; first test CN 5,7,8:

if big, test CORNEAL REFLEX → EYE PROTECTION
House-Brackman score
50/50 rule (> 50 dB pure tone audiogram / < 50% speech discrimination = nonserviceable hearing)

KOOS grading:

stage I – intracanalicular tumor
stage II – protrusion into cerebellopontine angle
stage III – occupying cerebellopontine cistern with no brainstem displacement
stage IV – brainstem and cranial nerve displacement

observation only for elderly / poor treatment candidates.

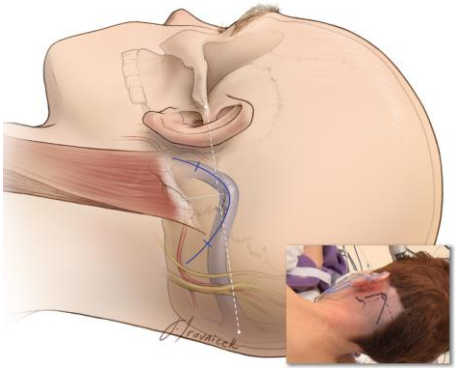
SRS is for Koos I-III; SRS may be used even for > 4 cm tumors if minimally symptomatic (KOOS grade 4) but recommend debulking first.

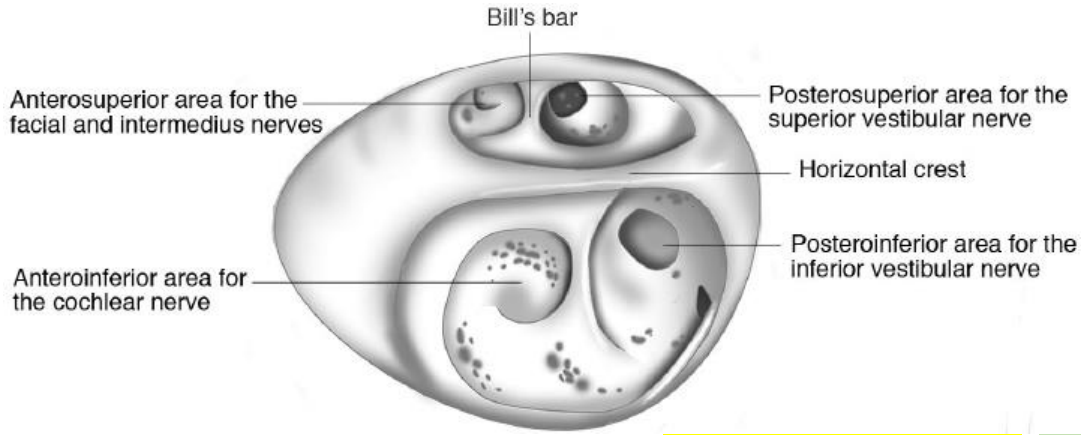
N.B. *brainstem compression* is not improved by radiation – use surgery instead!

park-bench position
MEP, SSEP + CN 5, 7, 8, 11 – monitoring
Steroids!

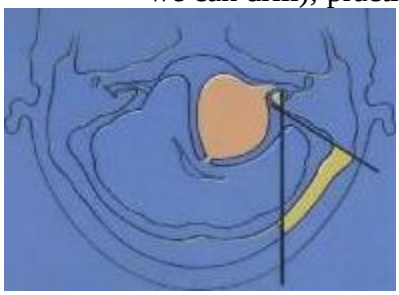
Do LP and drain 35-40 mL of CSF – significantly facilitates safety!
Be prepared to sinus injury and air embolism!
Wax mastoid cells x2
Valsalva at every step of closure – make sure no CSF leak!
Headache postop → CT → LP: steroids
hypertension postop should be avoided at all costs to prevent bleeding!

may leave 1 mm "tumor carpet" on CN7 to avoid nerve injury → SRS

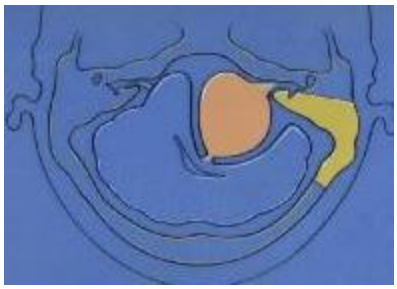




A. ***Retrosigmoid*** approach - for small tumors with minimal extension into IAC; hearing preservation; best view of posterior fossa
    - drill off posterior wall of IAC (endolymphatic sac is the landmark how posteriorly we can drill); practically *can be applied to all acoustic tumors*



B. ***Translabyrinthine*** approach – preferred if deaf by 50/50 rule; best view of brainstem and CN7; *hearing sacrifice* is unavoidable



C. ***Middle cranial fossa*** approach - for small intrameatal tumors ≤ 1.5 cm; better hearing preservation than retrosigmoid!

NF2:

b) surgical > 180 degree decompression + learn sign language
c) SRS
d) BEVACIZUMAB

HOUSE-BRACKMANN GRADING SCALE

Grade	Definition
I	Normal
II	Noticeable only on close inspection
III	Obvious weakness, but not disfiguring
IV	Incomplete eye closure
V	Motion barely perceptible
VI	**No movement**

TBI

Concussion – LOC < 6 hours (if > 6 hrs = DAI); ApoE-4 gene - risk for chronic problems
DAI → GRE / SWI (better), DTI

Goals

1. SBP 100-160 mmHg No albumin!
   Level III recommendation: Maintain SBP ≥ 100 mmHg (for 50-70 years old) or ≥ 110 mmHg (for < 50 or > 70 years old) to decrease mortality and improve outcomes.
2. CVP 5-15 cmH_2O
3. $PaCO_2$ 35-45 mm Hg

4. PaO2 > 60 mmHg or SaO2 > 94%.
5. Hb > 7
6. CPP 60-70 (children 40-50) – adjust goal based on "MAP Challenge" (↑MAP by 10 mmHg for 20 mins – if ICP↓ = autoregulation intact → increase MAP goal)
7. ICP < 22 (< 15 after DC) 15 mins (cumulative) within 1 hour
8. Brain tissue oxygenation (pbO2) > 20 mmHg
9. Jugular venous oxygen saturation (SjO_2) > 50%
10. Na < 155
11. Osmolarity < 320
12. No PEEP (increases ICP, lowers CPP), tidal volume 8 mL/kg (modern approach – OK to use PEEP and tidal volume 6-7 mL/kg)

Marshall Classification of Diffuse Brain Injury

Grade 1 = **normal** CT scan (10% mortality)
Grade 2 = **shift < 5 mm** (14% mortality)
Grade 3 = **cisterns** compressed (34% mortality)
Grade 4 = **shift > 5 mm** (56% mortality)

Harvard protocol - complicated **mild TBI** (nonfocal neurological examination + not operative lesion → ***does not need repeat CT*** * only 6 hrs observation in ED
*unless on "blood thinners" (except Aspirin) or there is EDH or SDH > 1 cm

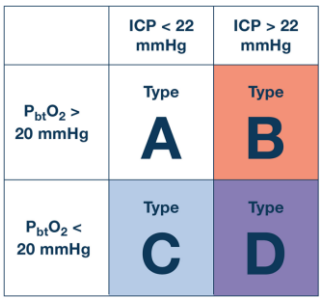
If mention "ortho injuries" – think fat embolism! (hypodense spots on CT, ARDS, petechial rash) H: steroids, hyperbaric oxygen with PEEP

Indications for ICP monitor:
A. ***GCS*** > ***8*** + significant mass lesions on CT scan (but often such patients need to go to OR)
B. ***Salvageable patient with GCS*** 3-***8*** plus:
   a) abnormal CT scan - ***mass lesions*** OR ***diffuse cerebral edema***.
   b) normal CT scan + any two of the following (on admission): SBP < 90 mmHg, age > 40 yrs, unilateral or bilateral motor posturing.

Preop

1. Hemostasis, Hb & type-and-cross
2. AED
3. abx + tetanus
4. mannitol & hyperventilate
5. check for fractures (skull & C-spine)
6. check for vascular issues - CTA

N.B. seizures within first 24 hours is not indication to extend AED beyond 7 days.
seizures after first 24 hours → AED is continued for 6 months



Type B - hyperventilation to hypocarbia 30-32

Type C – increase 4 parameters: oxygen (PaO2, Hb) + delivery (PaCO2, CPP)

Tier 1: increase FiO2 to 0.6

Tier 2:

1) increase CPP > 70
2) increase PaO2 to 150

Tier 3:

1) induce hypercarbia 45-50
2) increase PaO2 > 150 (normobaric hyperoxia)
3) if Hb < 9, transfuse 1 unit of pRBC

Type D – as Type C, except two things: keep normocarbia, CPP ↑ needs MAP challenge

HEMATOMAS

Indications for surgery

EDH/SDH/ICH:

a) thickness > 15 mm (EDH) or > 10 mm (SDH)
b) volume > 30 mL (EDH, SDH) or > 50 mL (ICH) (esp. in temporal or posterior fossa: > 30 mL).
c) midline shift > 5 mm.
d) neurodeficits (e.g. GCS < 9, GCS decrease by ≥ 2 points, focal neurologic signs)
e) refractory ICP > 22 mmHg, compressed basal cisterns, heterogenous clot on CT [indicates active bleeding].

N.B. in general, any neurodeficit due to extra-axial hematoma → surgery!

Other hematomas / contusions are managed nonoperatively with serial CT and close neurological observation in a neurosurgical ICU.

N.B. criteria for SDH are slightly different: in SDH, parenchymal injury plays bigger role, so it is ***managed by ICP criteria*** – even smaller SDH may contribute a lot to ICP: evacuate > 10 mm SDH or > 5 mm midline shift or refractory ICP (also, of course, anisocoria, GCS < 9 or drop ≥ 2 points)

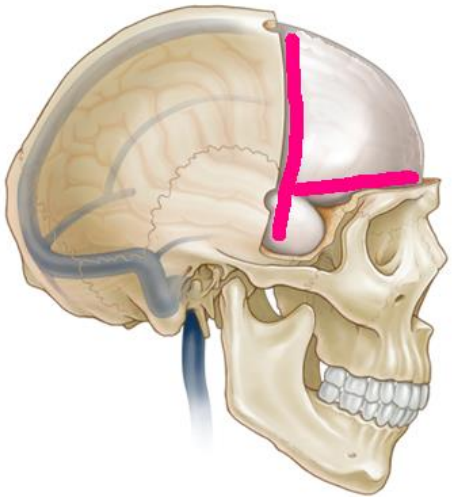
- *DELAYED TRAUMATIC ICH S.* ***BOLLINGER'S SPÄT-APOPLEXIE*** – new ICH where initial CT looked "normal".
- huge bleed with nonreactive pupils – either no surgery or osmotic load (if improves → DC)

"*OR says no room available for at least 2 hours*" – disagree as not acceptable – demand OR within minutes!
Mass casualty – no OR available, no CT available → do **bur holes in ED** – in orderly fashion based on **dilated pupils side** (if no EDH found, open dura – if no SDH → move to next bur hole):

1) at root of zygoma, ipsilateral to dilated pupil – to obviate uncal herniation!
2) at contralateral root of zygoma (in case of Kernohan's notch phenomenon)
3) parietal and frontal, ipsilateral to dilated pupil

DECOMPRESSIVE CRANI

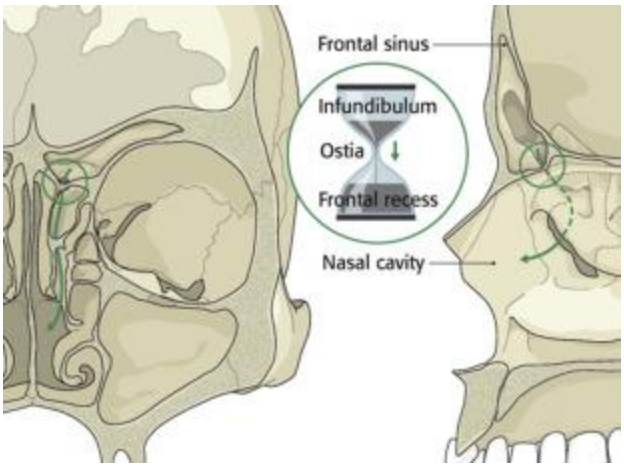
Hemi: bur holes at Dandy + root of zygoma
Kjellberg: add on both sides of SSS (2 cm posterior to coronal suture); no need to go low to enter frontal sinus; dura cut (division of anterior SSS and falx!!!):



CRANIOPLASTY

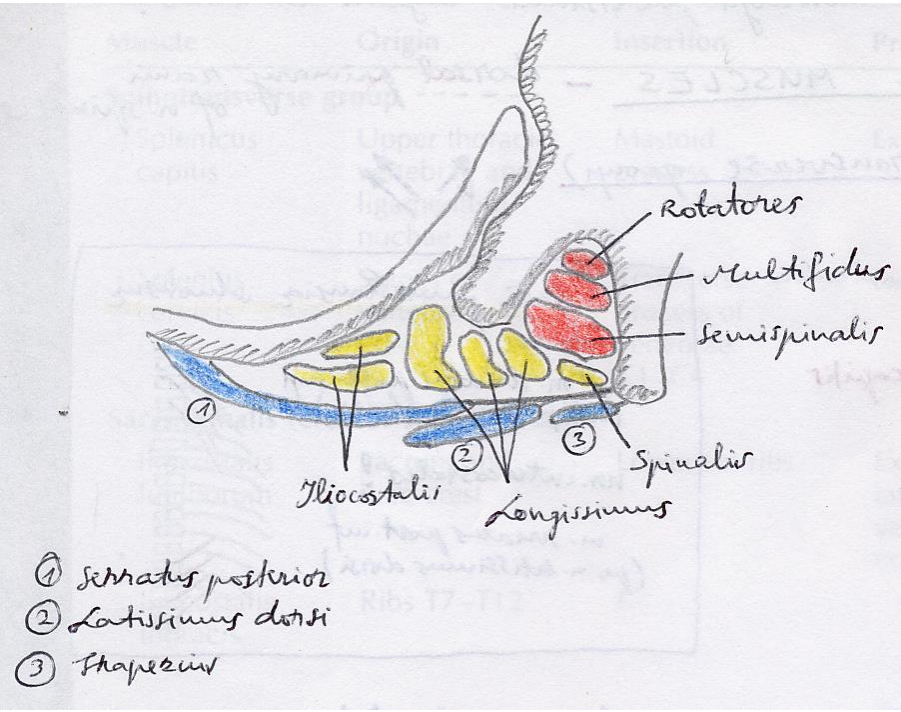
a) ***previous infection*** – 6 months after infection has cleared.
   - ***military penetrating injury*** – 12 months
b) ***no previous infection*** – after brain edema subsided (usually > 6 weeks – incision must be healed).

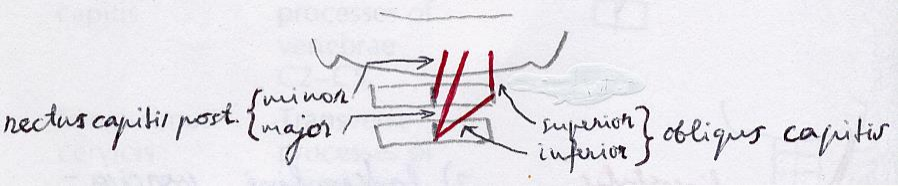
Frontal sinus drainage has hourglass configuration: infundibulum → ostium → frontal recess → small outflow tract into ethmoid sinus/nasal cavity:

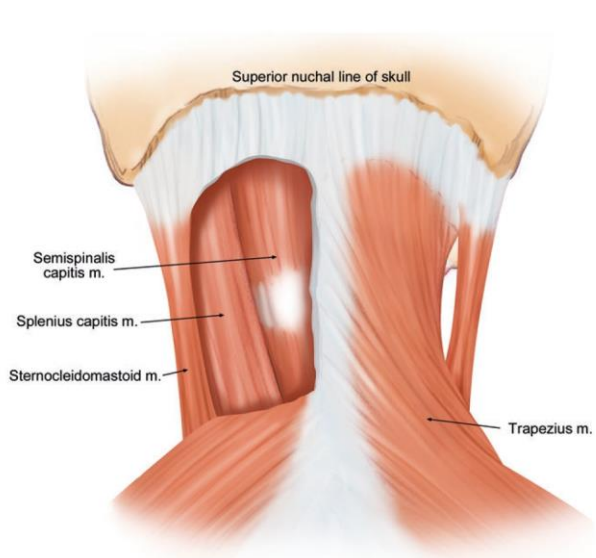


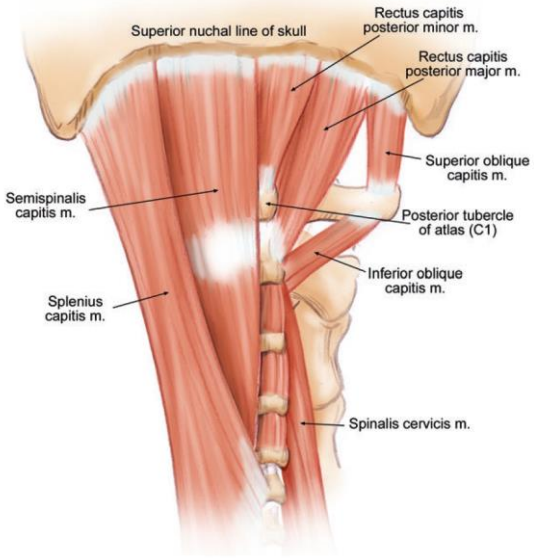
SPINE

Lesion Location	Pattern of Signs
Medial hemispheres	Spastic leg paraparesis with no sensory level
Thoracic spinal cord	Spastic leg paraparesis, thoracic sensory level
Lumbar spinal cord	Flaccid paraparesis, double incontinence (flaccid bladder and sphincters)









- suboccipital nerve and vertebral artery pass through **suboccipital triangle**.

CERVICAL (DEGENERATIVE)

Motion contribution

Flexion-extension: 50% at occiput-C1
Rotation: 50% at C1-2
Lateral bend: 90% at C3-7

- hyoid bone – C3
- C4-5—top of thyroid cartilage.
- C5-6—bottom of thyroid cartilage.

Slowly progressive symptoms (**spastic gait instability** + hand **numbness and loss of fine motor control** + **bladder dysfunction**) and signs (**hyperreflexia**, **weakness**, alteration of **proprioception**) in ***patient > 50 yrs*** = CERVICAL SPONDYLOTIC MYELOPATHY until proven otherwise.

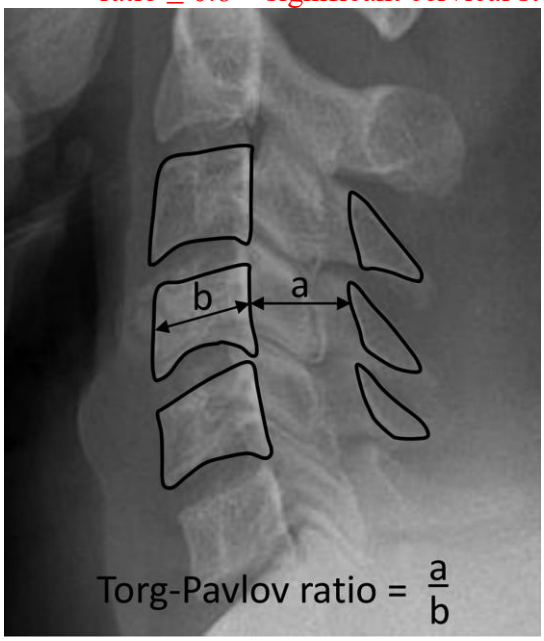
Jaw jerk ↑ - ALS?

sagittal dimension:
< 13 mm – *relative* stenosis
< 10 mm – *absolute* stenosis
≤ **7 mm**, 50% chances of myelopathy

surgical goal ≥ 12 mm

Torg-Pavlov ratio = a/b

ratio ≤ 0.8 = significant cervical stenosis



modified Japanese orthopedic association functional score (mJOA) – myelopathy severity:

≥ 15 – **mild**
12-14 – **moderate**
< 12 – **severe**

Nurick grades - disability from **cervical** spondylosis:

Grade 0 - radiculopathy
Grade 1 - myelopathy
Grade 2 - slight difficulty in walking
Grade 3 - unable to work full-time
Grade 4 - walk only with assistance or walker
Grade 5 - bedridden

Neck Disability Index (NDI) – for mechanical neck pain ± radiculopathy

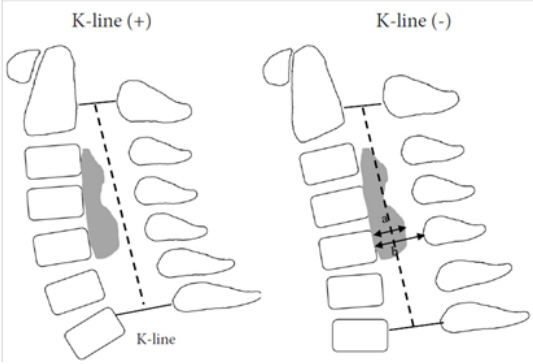
0–8% no disability
10–28% mild disability
30–48% moderate disability
> 50% severe disability
> 70–100% complete disability

DISH VS. OPLL VS. ANKYLOSING SPONDYLITIS

DISH: ≥ 4 levels of ALL
OPLL: PLL (adherent to dura!)

- risk of cord injury during intubation H: awake nasotracheal intubation, IONM.

C2–7 line ("K-line"): K-line (-) – only anterior approach!



AS – SI joints, ALL, PLL, osteoporosis, disc calcification. Chalk-stick fracture: C2-T2 PCF.

OSTEOPOROTIC SPINE

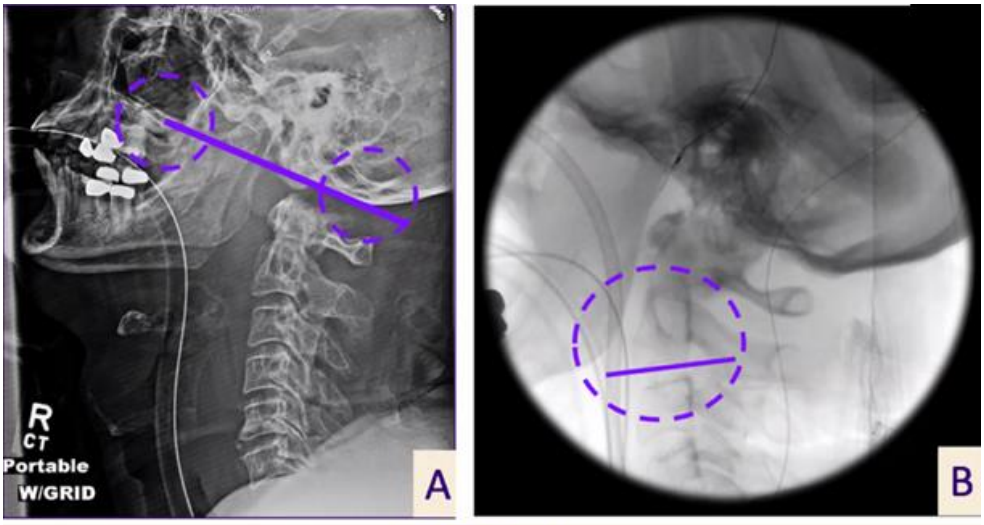
- *avoid hardware / avoid fusion*; if still needed:
  - use more constrained screws – less wobble, less loosening.
  - *do not tap!*
  - choose PEEK graft, titanium rod.
  - ***increasing points of fixation***.
  - cement augmentation
- ***rigid external orthotics***.

Grade B recommendation: **DEXA scan** (T-score ≤ 2.5), **CT** (Hounsfield units < 97.9), **serum vitamin D3 level** (< 20 ng/mL) - predicts increased risk of osteoporosis-related adverse events.
Grade B recommendation: treatment with TERIPARATIDE (6 mos preop + 18 mos postop) increases BMD, induces more robust fusion.

C-O JUNCTION

1. **BASILAR INVAGINATION** – congenital upward displacement of dens into a normal foramen magnum with normal bone.
2. **BASILAR IMPRESSION** – similar upward displacement of dens, however, due to acquired softening of skull base bones.
   - **PLATYBASIA** - abnormal flattening of skull base.
   - **CONVEXOBASIA** (more extreme form).

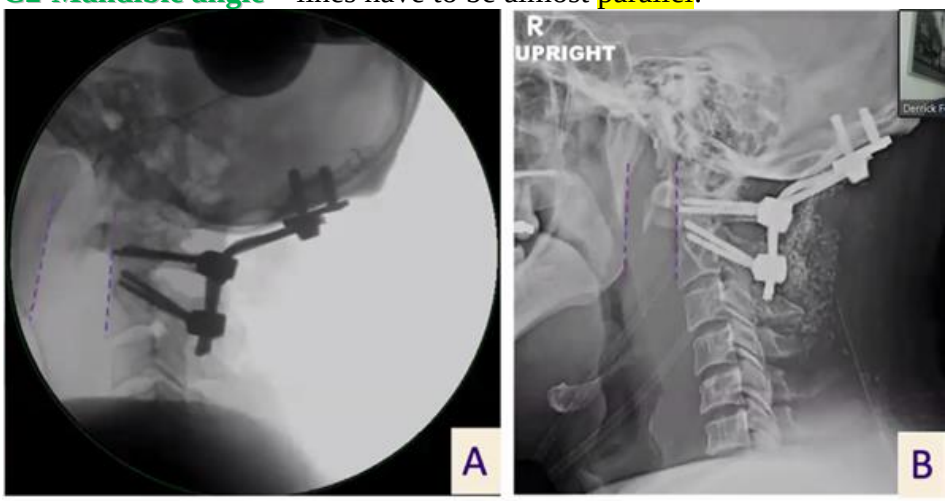
Occipito-cervical angle (OCCa) - gold standard; ideally, 14 degrees



OCC Angle

The OCC angle is measured between the McGregor line (A) and a line parallel to the inferior endplate of C2 (B).

C2-Mandible angle – lines have to be almost parallel:



C2-Mandible Angle

Fig 2: The C2 M angle is defined as the angle measured between a line parallel to the anterior C2-body/dens complex and a line parallel to the posterior mandible line of the mandibular ramus.

SPINOPELVIC HARMONY

SVA < 50 mm

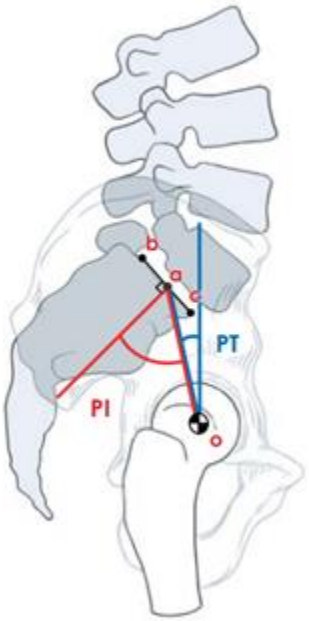
Age-related goals:

Age 50 yrs - SVA < 50 mm
Age 60 yrs - SVA < 60 mm
Age 70 yrs - SVA < 70 mm

Lumbar lordosis 55-65 degrees

PI – smaller the better; PI-LL mismatch < 9-10º

PT < 20 degrees



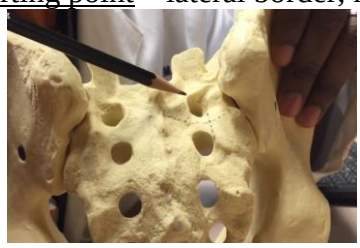
Coronal offset < 40 mm

Kyphosis correction: SPO – 10 degrees lordosis, PSO – 30-40 degrees lordosis

- safely can remove medial ½ of pars or lateral 1/3 of isthmus.

S2-alar-iliac (S2AI) screw

Starting point – lateral border, midway between S1 and S2 dorsal foramena:



Trajectory – crossing SI joint, just above greater sciatic notch, aiming at AIIS.

THORACIC

Posterolateral access: Costotransversectomy (may extend to lateral extracavitary approach) - can expose any thoracic level!

- paramedian incision (along lateral border of erector spinae muscles, at costo-transverse joint level), 2-level laminectomy, take pedicle and rib below disc, subperiosteal dissection along vertebral body + downward pleural retraction → diskectomy + drill small cavity into vertebral body → herniated disc removal → place rib fashioned into strut into vertebral cavity.
- for bilateral transpedicular corpectomy, contralateral screws and temporary rod should be placed to stabilize spine during corpectomy and cage placement.

- Valsalva maneuver under irrigation to evaluate for occult pneumothorax.

Anterior access to Thoracic Spine:

T1-2: Anterior neck suprasternal approach with or without sternotomy.
in majority of patients, T3 vertebra is above suprasternal notch (esp. in patients with long necks)

T3-4: Anterior neck dissection with partial **median sternotomy** and anterolateral thoracotomy "trap door" technique.
alternative - posterior lateral extracavitary approach

T5-10: thoracotomy:

a) **Transthoracic open**
b) **Thoracoscopic** – less postop pain!
c) **Extra/Retro-pleural** – does not open pleural space – may not need chest tube!

Preferable side:
upper thoracic – right (avoids heart, aortic arch, subclavian and carotid arteries)
middle, lower thoracic – left (avoids inferior vena cava, liver)
Double-lumen endotracheal tube
Incision along rib below disc (or one rib above, e.g. 9 rib for T10-11 discectomy)
Verify that the proper rib is being resected by AP X-ray.
Drill off rib head
Discectomy, 25% dorsal corpectomy → herniated disc removal → place rib fashioned into strut into vertebral cavity
Parietal pleura is closed over a thoracostomy tube (water seal for 24 hrs)

T11-L2: Combined thoracoabdominal approach (requires partial takedown of diaphragm) - retropleural retrodiaphragmatic retroperitoneal approach or transpleural transdiaphragmatic retroperitoneal approach.

By **nature and location of disc**:

a) **calcified (central) disk - anterior approach** (CT surgeon for approach with one lung ventilation)
b) **soft herniated discs, lateral calcified discs** – **posterolateral approach** (transpedicular ÷ transthoracic approach, best costotransversectomy) – semiblind procedure!

High-medical-risk patients - dorsolateral decompression (unless disc is midline, large, and densely calcified)

LUMBAR (DEGENERATIVE)

N.B. normal lumbar lateral recess is 3-5 mm
On Boards, ask for gait characteristics!
NEUROGENIC CLAUDICATION - discomfort persists if patient stops walking but does not flex spine; no loss of pulses, no trophic skin changes in feet – but do not hesitate get ABI

Stimulate all lumbar pedicle screws up to 30 mA (if cortical bone is intact, EMG response should occur at > 14 mA; threshold to suspect breach is 6 mA).

Oswestry Disability Index
level of function (disability) in activities of daily living from low back pain.
Range 0-100% (severe disability > 40)

Feature	Cauda Equina LMN ≥ 2 roots	Conus Medullaris UMN
Pain	*Severe **radicular** pain* (sciatica) & low back pain	***Back pain*** (less severe than radicular pain)
Sensory loss	Asymmetric *saddle anesthesia*	Bilateral *saddle anesthesia*
Motor deficits	Asymmetrical areflexic para- / mono-plegia	**Absent**!!! (or mild distal leg paresis)
Evacuation disorder	Late and mild – hypotonic bladder (*urinary retention*)	Early - atonic bladder (*urinary retention with overflow incontinence*), atonic anal sphincter (*constipation with incontinence*)
Impotence	±	+
Bulbocavernosus (S_{2-4}) & anal wink (S_{4-5}) reflexes	+	ABSENT

ALIF – place bilateral big toe Pulse-Ox, have CellSaver.

Long posterior instrumentation:
Standard stop upper levels – either T10 or T2-**4**.
Standard stop lower levels – see Scheuermann's kyphosis (wedging ≥ 5° in at least 3 adjacent vertebrae):
A. **Vertebra just below first lordotic disc (FLD)**
B. **Sagittal stable vertebra (SSV)** - most cranial vertebra touched by a vertical line from posterior superior corner of S1

SCOLIOSIS

Cobb angle > 10° (between vertebrae with the greatest angle relative to the horizontal plane)
- < 25° → serial XR, PT
- > 25° – add Boston brace for children
- > 50° - surgery is indicated
- > 90° → cardiopulmonary insufficiency.

Dextroscoliosis in child – suspect tumor! Levoscoliosis - Chiari
Dextroscoliosis = tumor

BONE ALLOGRAFTS

- allografts - **osteoconductive**.
- add patient's own marrow aspirate → *osteogenesis*
- BMP → *osteoinduction*.

Autografts have all 3 features.
Autografts:

A. **7th rib** - just caudal to scapula tip, lateral to trapezius border
B. **Posterior iliac crest** – maximum 8 cm from PSIS - superior cluneal nerves
C. **Anterior iliac crest** – 2-3 cm lateral to ASIS - avulsion/stress fracture, lateral femoral cutaneous nerve
D. **Midfibula** (7 cm above ankle, avoid head)

ADJACENT LEVEL DISEASE

- after ACDF, 3% / year for the next 10 years (operation rate for symptomatic ASD after ACDF at 10 years is 5-20%)
- after L4-5 fusion, 25% incidence at 10-yr (requiring reoperation); rostral > caudal 8-fold

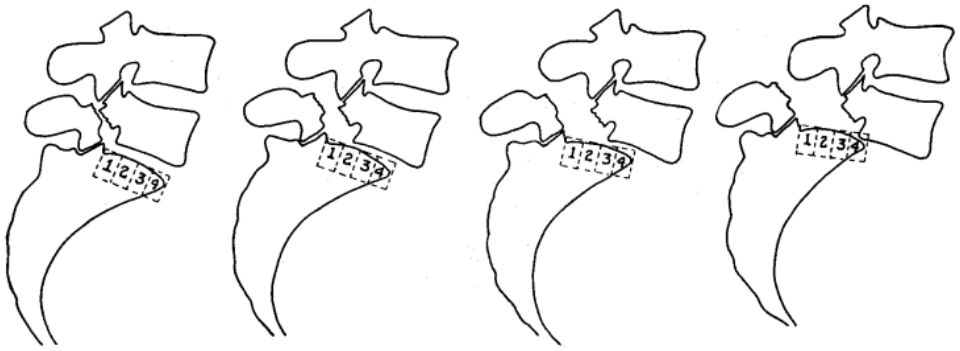
PJK - sagittal Cobb angle between inferior endplate of UIV and superior endplate of UIV+2 ≥ 10 degrees compared to preoperative angle.
PJF – clinical significance (pain, neurological symptoms, need for surgery):
PJK + fracture of UIV or UIV+1

SPONDYLOLYSIS

"Stork test" –stand on one leg and hyperextend back.
Spondy on XR → ask for oblique views (Scotty dog)
Traumatic spondylolysis – lesions with non-sclerotic edges / increased uptake on bone scan / STIR signal = potential for healing in **rigid** Boston **brace** for ≥ 3 months → **PT** (kids may resume sports but if symptoms recur → stop).
Congenital, stress fractures - lesions with sclerotic borders (little chance of healing with bracing)

- try **conservatives**: PT, injections, NSAIDs.
- indications for **fusion**:
  - isthmic spondylolisthesis slips to grades III and IV
  - pain does not respond to conservative measures
  - neurological symptoms appear.

SPONDY



Instability: translation ≥ 4 mm

SYRINX

Lysis of adhesions (for post-traumatic syrinx)!

SPINAL DAVF

Steroids!!!! Baseline urodynamic study!
Need DSA to find it (+ associated Adamkiewicz?) → a) **embolize** (before sacrifice, inject AMYTAL + LIDOCAINE and test patient) b) leave **localizing coil**
Surgery: ICG → clip vein → watch IONM → cut → remove clip → ICG again

SPINE (TRAUMA)

Indications for surgery in compression/burst fracture:

a) neurological deficits esp. with canal compromise (> 50%)
b) anterior column comminution
c) posterior element disruption (unstable burst) - **kyphosis > 30°**, height loss > 50%

Just pain – kyphoplasty (max 6 mos + STIR signal)

SCI

NEUROLOGIC LEVEL - most caudal spinal segment with *normal sensation* and *muscle strength of 3/5 or better* ← level is where you can move antigravity

- ***sacral sparing*** may be only evidence that paralysis may not be complete – always test perineum sensation, **voluntary** anal sphincter contraction and toe flexion!
  N.B. absent bulbocavernosus & anal wink **reflexes** = spinal shock is present (sacral sparing is not testable at this time)

ASIA Impairment Scale (only after return of bulbocavernosus & anal wink **reflexes)**

A = Complete SCI – loss of motor and sensory function in S4-S5 segments.
B = Incomplete SCI – sensory but not motor function is preserved.
C = Incomplete SCI – motor function is preserved (> ½ of key muscles below neurological level have muscle grade < 3/5 [unable to resist gravity]).
D = Incomplete SCI – motor function is preserved (> ½ of key muscles below neurological level have muscle grade > 3/5).

Goal MAP 85-90 mmHg for 7 days

IVI fluids + norepinephrine

Spinal cardiac sympathetic center is at T1-4; lesions:

a) below T6 – OK to use PHENYLEPHRINE
b) above T6 – need inotrope

operate early even complete SCI, especially if *ongoing cord compression*!

BRACKEN PROTOCOL

methylprednisolone ASAP (start no later than 8 hours after trauma) 30 mg/kg IV bolus (over 15 min), then after 45 min, start IVI 5.4 mg/kg/h over 23 h. Add PPI, AccuChecks and insulin on sliding scale.

CORD COMPRESSION

1) awake fiberoptic **intubation**
2) **position** patient awake (if in pins, scalp anesthesia)
3) **neuromonitoring** (prepositioning baseline and after positioning)
4) A-line - keep **MAP > 85**
5) prophylactic **steroids**

Hypotension: abdominal binder, MIDODRINE (first-line; alpha-agonist) or FLUDROCORTISONE.

DVT Prophylaxis:

1) *calf-compression devices* (for first two weeks)
2) *anticoagulation*: ENOXAPARIN (30 mg q 12 h) → WARFARIN (INR 2-3) for 3 months.

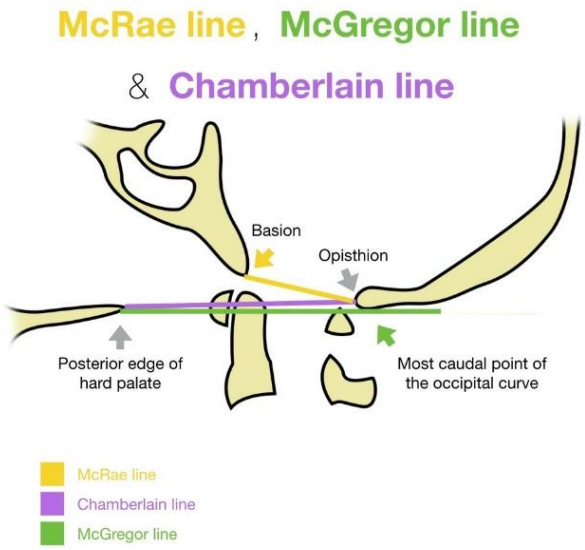
Neurogenic Bladder: Continue Foley and monitor I&O's → transition to intermittent catheterization.

Chest PT

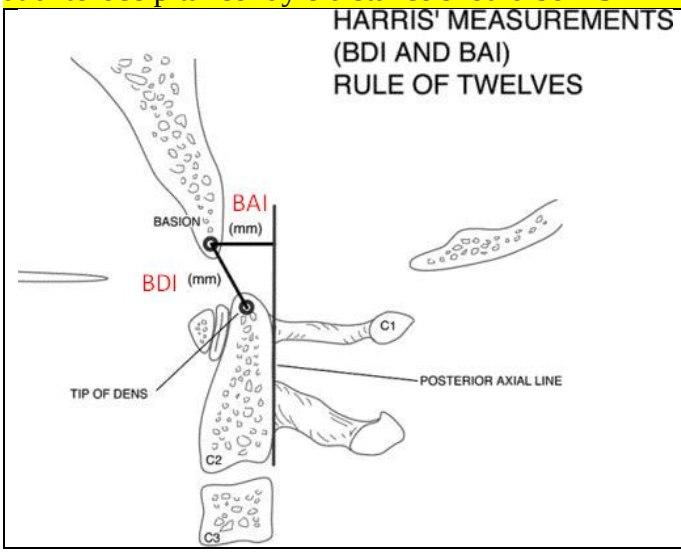
Psychology consult

Autonomic dysreflexia (Level T6 and above): sensory inputs activate massive reflex sympathetic activation below lesion → ***hypertension*** (up to 300 mmHg!!!) H: clonidine + treat cause (fecal impaction, UTI, pressure ulcer).

C-SPINE TRAUMA



atlanto-occipital condyle distance should be < 5 mm regardless of age!



basion dental interval (BDI) – distance between tip of dens and basion: < 12 mm on plain XR, < 9.0 mm on CT

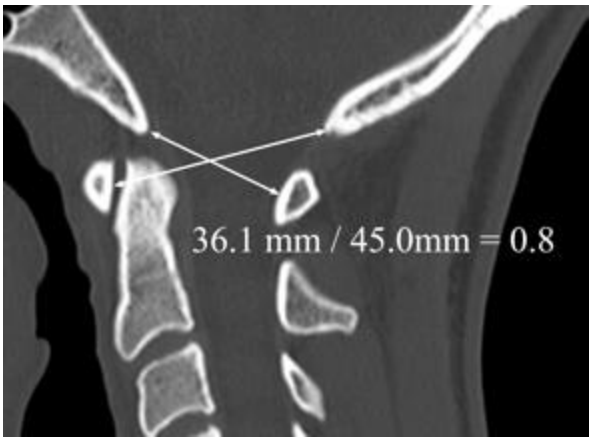
basion axial interval (BAI) – distance between line drawn along posterior cortex of axis body and basion: < 12 mm

WACHENHEIM'S line

POWERS ratio = BC/OA normal < 0.9 (> 1 = anterior subluxation)

BC - distance from basion to midvertical portion of posterior laminar line of atlas;

OA - distance from opisthion to midvertical portion of posterior surface of anterior C1 ring.



Classic **JEFFERSON fracture (s. C1 burst fracture)** – fracture of C1 ring in 4 places (Rx: halo) ± disruption of transverse ligament (Rx: occ-C2 fusion)

Diagnosis of TRANSVERSE ATLANTAL LIGAMENT RUPTURE – 3 criteria:

1) **MRI** – most sensitive test
2) **SPENCE'S rule**: ≥ 7 mm
3) ADI, s. predental space > 2 mm (or > 3 mm in men, > 5 mm in children)

Indication for surgery – also PADI < 14 mm

Indications for surgery in dens fractures (odontoid screw – only if < 6 weeks)

1. **Transverse ligament** disruption
2. Dens **comminution**
3. Type 2 or 3 fracture with **displacement ≥ 5 mm** or **> 5° angulation** (between supine and upright films)
4. Type 2 fracture in **> 50 yrs**

Type IIA - *horizontal* fracture → external immobilization
Type IIB - *oblique* → odontoid screw (if < 6 weeks and < 60 yo)
Type IIC - *oblique* → posterior C1-2 fusion

In kids < 7 yo – C2 synchondrosis fracture (H: orthosis for 3-6 months)

Indications for surgery in Hangman's fracture (anterior C2-3 or posterior C1-3 fusion)

a) C2-3 disc disruption - C2 translation > 3-5 mm over C3 / severe angulation (> 11 degrees) **Levine and Edwards type 2**
b) facet dislocations **Levine and Edwards type 3**

Occipital condyle fracture - **Anderson and Montesano types**
main question – alar ligament avulsion (AM type 3)

Denver Criteria for CTA:

1. Fractures involving C1-6 transverse foramina
2. Facet dislocations
3. C1-3 subluxations
4. Penetrating wounds to cervical zones I and III

Tongs application

- in vertical line of tragus, 1 fingerbreadth (or 1 cm) above ear
- **begin with:** 10 lbs for occiput; additional 5 lbs for each vertebra (start max 20 lbs) → added in 5 lbs increments, in 30 min intervals for max 3-6 hrs (max 80-90 pounds)

Halo: tighten to ≈ 8-10 lb and repeat in 24 hrs.

360º fusion for bilateral facet dislocations (alternative – after **ACDF**, flex neck and do XR – if spinous process space widens, add PCF; if not – keep in C-collar)

Grisel – 8 weeks of halo; recurs → C1-2 fusion.

SLIC (subaxial injury classification) + TLICS (thoracolumbar injury classification & severity score)

Characteristic	TLICS	SLIC
Injury morphology		
No abnormality	0	0
Compression	1	1
Burst component	2	2
Translation/rotation	3	3
Distraction	4	4
PLC integrity/DLC integrity		
Intact	0	0
Indeterminate	2	1
Disrupted	3	2
Neurological status		
Intact	0	0
Nerve Root Injury	2	1
Complete cord injury	2	2
Incomplete cord injury	3	3
Cauda equina injury	3	–

Cervical: Continuous cord compression with neurological deficit: +1

Signs of major disruption of anterior or posterior ligamentous complex:

1. Horizontal sagittal plane translation > 3.5 mm
2. Sagittal plane rotation (angulation) > 11 degrees

Facet joint disruption:

articular apposition < 50%
diastasis > 2 mm through facet joint

Total scores:
≤ 3 points = non operative
4 points = nonop vs op
≥ 5 points = surgery

N.B. cauda injury is same "weight" as incomplete SCI

AO CLASSIFICATIONS

UPPER CERVICAL SPINE

Injury site vertically (bone and subjacent articulation):

Type I - occipital and craniocervical region
Type II - atlas and C1-2 joints
Type III - axis and C2-3 joints

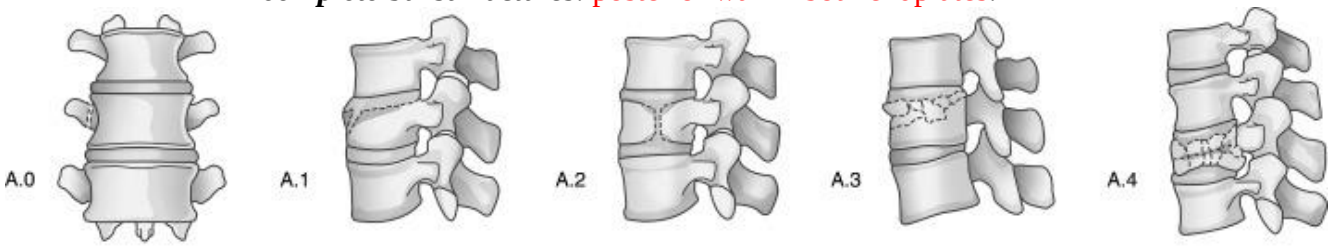
Injury type:

A – bone injury (clearly stable – brace)
B – ligamentous injury ± bone (potentially unstable – MRI is indicated)
C – translations, i.e. any significant displacements (clearly unstable – surgery)

TL SPINE

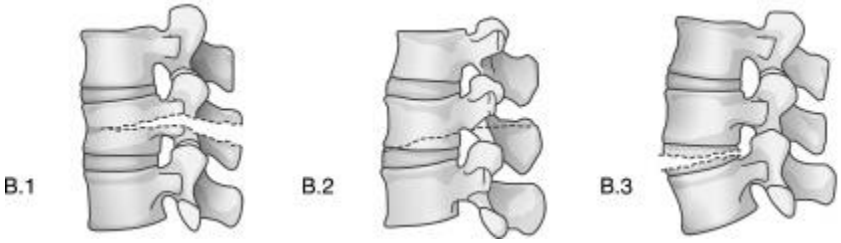
Type A injuries (compression) – failure of anterior elements + preservation of posterior ligamentous complex:

A0 - transverse or spinous process fractures
A1 - wedge compression fractures of 1 endplate
A2 - ***split (pincer)*** fractures: both endplates
A3 - ***incomplete burst*** fractures: posterior wall + only 1 endplate
A4 - ***complete burst*** fractures: posterior wall + both endplates.

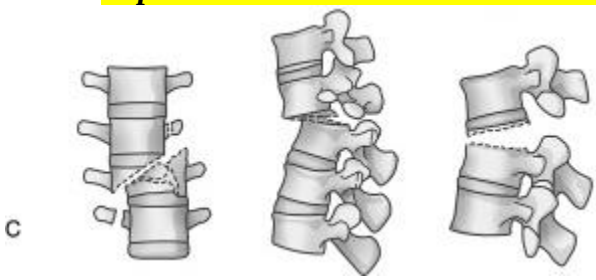


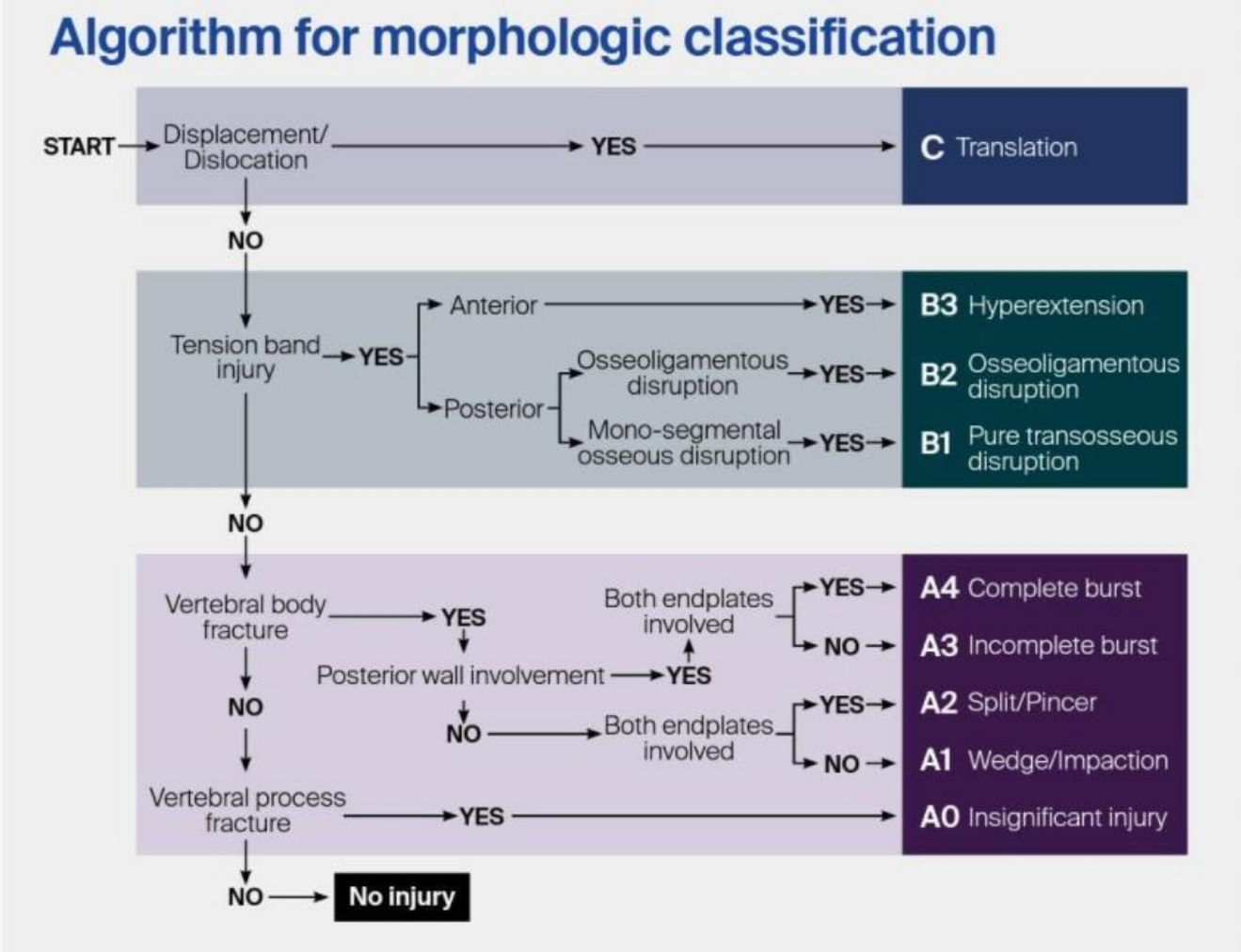
Type B injuries (distraction) – ***tension band injury***: failure of anterior or posterior elements:

B1 – **posterior osseus**: monosegmental.
B2 – **posterior osteoligamentous**: bony and/or ligamentous failure of the posterior tension band + fracture of vertebral body
B3 – **anterior**: hyperextension through disc space or bone - as commonly seen in ankylosing spondylitis.



Type C injuries (translation): axial torque leading to failure of all elements with ***displacement or dislocation*** of cranial spinal elements relative to caudal elements.





T/L BURST FRACTURE

- indications for surgery:
  a) deformity: height loss (> 50%), kyphosis (> 30% - predictor of long-term back pain)
  b) canal compromise (> 50%)
  c) **posterior osteoligamentous complex disruption** - unstable burst fractures
  d) **vertebral fragmentation**
  e) **neurologic deficit**

N.B. the entire goal of surgical treatment – to prevent neurological deficit; surgery or brace do not seem to affect residual pain / ability to return to vigorous work!

VASCULAR

Temporal artery biopsy – STA occlusion test

TRANSRADIAL ROUTE – **Allen's test** with pulse oximetry.

Allcock test (evaluates flow through PComA) - vertebral injection with simultaneous CCA compression in the neck.

- if STENT is left – HEPARIN for 24 hours, CLOPIDOGREL for **6 months** + lifelong ASPIRIN.
- test before embolization: either examine patient or EEG
    a) inject SODIUM AMOBARBITAL (AMYTAL®) (blocks neuronal activity) + LIDOCAINE (blocks axonal activity).
    b) **temporary balloon** occlusion
- femoral artery is *compressed* – total 10 minutes
- remain horizontal flat for 2 hours

BYPASS

- crossclamp time:
    M1, A1 – 5-10 minutes (due to nonforgiving perforators)
    Distal – up to 30 minutes
- arteriotomy for side anastomosis – 3 times vessel diameter.
- 10-0 Prolene

ANATOMY

Aorta bifurcates at lower level of L4

CCA bifurcates at C4 (C3-4 or C4-5 level) - upper level of thyroid cartilage

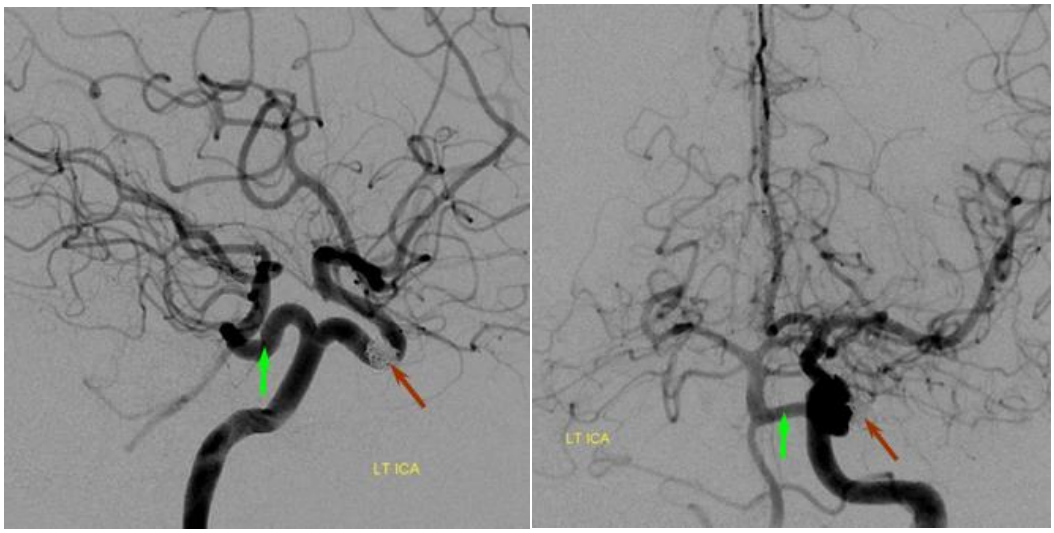
ARTERY OF ADAMKIEWICZ – T_8-L_2 džn. L_2 iš kairės pusės.

- left VA is dominant in 75% cases.
- 2% V2 prasideda nuo C7.
- tarp SCA ir PCA praeina CN3, tarp AICA ir A. LABYRINTHI praeina CN6.
- fetal PComA prevalence ≈ 25%

Carotico-vertebral anastomoses:

Artery	Origin	Termination	Route
Pro-atlantal intersegmental	Cervical ICA	VA	Via foramen magnum
Hypoglossal	ICA	VA	Via hypoglossal canal
Otic (exceptionally rare)	Petrous ICA	BA	Via internal auditory meatus
Trigeminal (< 1% normal people; some say it is 100% just below imaging resolution)	Cavernous ICA (meningohypophyseal trunk)	BA trunk (between AICA and SCA)	Transdural (follows the course of CN5)

Trigeminal artery (*green arrow*) connects MHT (ICA) and BA (PComA is hypoplastic):



STROKE

Approx. threshold for neuron death "< 20" – CBF, PaO2, glycemia

Fat embolism - large doses of **glucocorticoids**, **hyperbaric oxygenation with PEEP**; also early ortho stabilization of fractures!

Artery of Heubner stroke - classic triad: contralateral mild face and arm weakness without sensory loss, and aphasia (if stroke in dominant hemisphere).

AChA stroke – devastating triple **H**

1) posterior limb of internal capsule → contralateral **Hemiparesis** (face, arm, and leg)
2) posterolateral nucleus of thalamus → contralateral **Hemisensory loss**
3) lateral geniculate body / early geniculocalcarine tract → contralateral **homonymous Hemianopsia**

Angular gyrus injury:

dominant hemisphere → Gerstmann syndrome: agraphia, acalculia, finger agnosia, left-right confusion; also dyslexia, ideomotor apraxia

nondominant hemisphere → hemineglect, homonymous hemianopia, impaired visual memory - visual-spatial processing problems - construction deficits

Lateral MEDULLARY (s. **Wallenberg**) syndrome – PICA (or VA):

1. **Nucl. tractus solitarii** (CN7) → (ipsilateral) loss of taste.
2. **CN9**, **CN10** → dysphagia, dysarthria, etc.

\+ crossed hypalgesia-thermoanesthesia (ipsilateral face / contralateral body)

Absence of pyramidal tract findings + no change in mental status

- cortical / subcortical gyral pattern (aka "ribbon") ***enhancement***: not apparent for first 1-2 days → approaches 100% by 7 days → persist for 12 months (**neovascularity**).

rule of thumb: there should not be enhancement at the same time there is mass effect – dif from tumors

Stroke

Decreased CBF and prolonged MTT (Tmax) match decreased CBV

Decreased PWI mismatched with normal DWI = PENUMBRA

DWI-positive and FLAIR-negative (DPFN) findings mean stroke very fresh = in tPA window.

Tmax > 6.0 sec, CBF < 30%, CBV < 2.0, MTT > 145% are significantly abnormal

Ischemic penumbra (salvageable tissues)

Decreased CBF and prolonged MTT (Tmax) mismatched with normal or even increased CBV (autoregulatory vasodilation) = PENUMBRA

- **CBF < 30% (core) against Tmax > 6 (core + penumbra)** volume mismatch is best.

Penumbra –velocity is low but volume high → flow is OK (neurons surviving)

TABLE. BLOOD PRESSURE TARGETS DURING ACUTE STROKE TRIAGE

Treatment	Goal (mm Hg)
Intravenous (IV) thrombolysis	<185/110
Thrombectomy	≤185/110
Both IV thrombolysis and thrombectomy	<185/110
Neither IV thrombolysis nor thrombectomy	<220/120

Post-thrombectomy / Post-thrombolysis goal is 5 mmHg lower (< 180/105 mmHg) for 24 hrs

NO hemorrhage on CT – admit to **stroke unit**:

a) not candidate for intervention → ASPIRIN in ED (if unable to swallow – rectal suppository)
b) candidate for intervention → TPA → ASPIRIN after 24 hours (and negative repeat CT)

Thrombolysis criteria: ≤ 4.5 hrs, < 185/110 mmHg (otherwise, goal < 220/120), NIHSS ≥ 5, < 1/3 of MCA + absence of:

1) platelet count < 100
2) INR > 1.7
3) aPTT > 40

4) glucose < 50 or > 400

+ desirable ASPECTS > 7

CI:

1) ischemic stroke or serious head trauma or intracranial/spinal surgery within 3 months
2) prior ICH ever (except small number of cerebral microbleeds on MRI)
3) symptoms suggestive of SAH (even if CT is negative)
4) intra-axial neoplasm
5) GI malignancy, GI bleed < 21 days
6) LMWH within 24 hrs
7) direct thrombin inhibitors or direct factor Xa inhibitors unless laboratory tests are normal or dose was > 48 hours
8) infective endocarditis
9) aortic arch dissection

- ASA, Plavix, warfarin, pregnancy, meningioma/pit-adenoma, post-LP – all OK!
- "door-to-needle time" – 60 min

Thrombectomy criteria:

1) penumbra+core / core **> 1.8**
2) core **< 70 mL**

- NIHSS ≥ 6
- ASPECTS ≥ 6
- from onset < 24 hrs
- occlusion of major vessel (distal ICA, M1, BA); ok thrombectomy to BA without pCT if within 6-8 hrs?

TICI 0 – no perfusion
TICI 1 – does not fill entire territory
TICI 2A – filling 2/3 of territory
TICI 2B – filling slower than normal
TICI 3 – full perfusion

Malignant MCA stroke ≥ 50% MCA territory (mortality ≈ 80% without surgery) – indication for surgery within 48 hrs (no need to wait for decline!!!)

Continue ASA even if goes DHC

Cerebellar infarctions

- any of **brainstem (pons) compression** signs:

Suboccipital craniectomy with enlargement of foramen magnum **± evacuation** of infarcted tissues + **dural expansion** + **EVD**

CAROTID STENOSIS

Doppler

Stenosis	Peak Systolic Velocity (cm/s)	Peak Systolic Velocity Ratio

60-69	**200**-250	**2.5**-3.0

What is percentage of stenosis per radiology report?
If CTA is good quality, no need for Duplex or DSA
Boards: ask for all DSA runs – not to miss contralateral disease, "bad" aortic arch
Cardiac ECHO + **ECG** - high incidence of concomitant coronary artery disease.

Symptomatic* stenosis ≥ 50%** (North American Symptomatic Carotid Endarterectomy Trial **NASCET** 1991, European trial **ECST**)
Asymptomatic stenosis ≥ 60-70% (Asymptomatic Carotid Atherosclerosis Study **ACAS** 1995)
*TIAs or small strokes; if massive stroke – no salvageable tissue – do not treat (risk of hemorrhagic conversion)
**stenosis < 50% + failed medical therapy (ongoing symptoms), esp. with contralateral carotid occlusion → intervention
combined perioperative morbidity and mortality should not exceed 3% for *asymptomatic* and 6% for *symptomatic* patient

Do not jump on surgery - start ASA 325 + statin + BP control

Stenting has slightly higher periprocedural (30 days) stroke risk but **surgery** has a higher rate of cranial nerve palsy or myocardial infarction.
Best time window after stroke: 1-4 weeks
Boards: carotid intervention ASAP after "not massive" stroke

When stent is better (vs. CEA):
- high-risk patients:
  1. **Poor health** (esp. synchronous coronary artery disease)
  2. Difficult **access**:
     1) high bifurcation (above C2) / stenosis (would need mandibular splitting for CEA)
     2) previous radiotherapy to neck (stenosis may be not due to atherosclerosis)
     3) previous (any) surgery on neck
     4) significant obesity
  3. **Carotid** factors:
     1) prior CEA (postsurgical restenosis)
     2) contralateral carotid occlusion

- prior to application of tourniquets / clamps, IV heparin 100-150 U/kg (typical 5000-8000 units).
- "ICE" → watch EEG for 2 minutes for drop of amplitudes > 50% → increase BP → place shunt (place heparinized shunt into CCA first → allow to bleed → ICA → increase MAP 20%).
- *loose distal intimal flap* should be tacked with 6-0 double-arm polypropylene.
- close with 6-0 Prolene (consider saphenous / Dacron patch) → watch EEG 20 mins → palpate, Doppler (→ DSA PRN)

Postop maintain BP < 130 mmHg

Postoperative (CEA) neuro decline

a) ***within first 12 hours*** are result of ***thromboembolic*** *phenomena* → immediate heparinization & STAT DSA (vs. straight to surgical exploration).
b) ***beyond 12-24 hours*** - either due to *thromboembolic phenomena* or *hyperperfusion syndrome* → prompt CT → DSA.

After SAMMPRIS trial - Wingspan indications: ≥ 2 strokes (recovered with mRS ≤ 3) despite DAP-smoking-BP-cholesterol + 70-99% stenosis + > 7 days from stroke

VA-BA stenosis – DAP!!!

N.B. unilateral VA stenosis in asymptomatic patient is not indication for surgery!

DISSECTION

Denver dissection scale

Grade	Description	Risk of stroke with ICA injury*	Fate
I	luminal irregularity with < 25% stenosis	3%	70% heal 25% persist 5% progress to ↑ grade
II	≥ 25% luminal stenosis or intraluminal thrombus or raised intimal flap	11%	70% progress to ↑ grade
III	pseudoaneurysm	44%	most persist
IV	occlusion	lethal	
V	transection with free extravasation	lethal	

*risk of stroke increases with increasing grade for ICA injuries;

not true for VA injuries – depends on status of contralateral VA:

grade I – many cases probably just vasospasm or compression with external hematoma and not true intimal injury.

grade IV, if tolerated, has low risk of embolic stroke as flow supplied from contralateral side becomes retrograde to fill PICA.

grade II-III – risk of stroke is higher

treat **V1-3 injuries** with ASPIRIN (for grades II-III – higher risk of stroke – may consider HEPARIN) → CTA at 6 weeks

N.B. **V4 injuries** carry risk of SAH – ASPIRIN / ANTICOAGULATION may increase this risk further.

Most intradural dissections (and all with **SAH**) – treated with intervention.

ICH

ELDERLY PERSONS – hypertension, amyloid angiopathy, tumors, coagulopathies (incl. anticoagulants).

YOUNG PERSONS (spontaneous ICH or extra-axial bleed):

1. Vascular causes - AVM, aneurysm, cavernoma, venous thrombosis (judicious anticoagulation + hydration + observation), vasculitis
2. Bleeding disorders
3. ADEM
4. Tumor
5. Illicit drug (amphetamines, cocaine)

Treatment
ICU: BP control + reversal of coagulopathy

ICH SCORE

Feature	Finding	Points
GCS	3-4 5-12 13-15	2 1 0
Age	≥ 80 < 80	1 0
Location	infratentorial supratentorial	1 0
ICH volume	≥ 30 mL < 30 mL	1 0
Intraventricular blood	yes no	1 0

Score	30-day mortality
0	0%
1	13%
2	26%
3	72%
4	97%
5	100%
6	100%

SURGERY

US for ICH location – with surgery done between 48 and 72 hrs with residual clot < 30 mL

Preop CTA is a must! – attempt to secure distal aneurysms endovascularly prior to OR
Surgery – mainly for life-threatening ICH
No trials to date (STICH I-II, CLEAR up to III, MISTIE up to III) have demonstrated the benefit of surgery for ***non-life-threatening*** ICH

STICH II – lobar ICH with clot ≤ 1 cm of the cortical surface + **GCS 9-12** = better off with early surgery!

N.B. patients with deep ICH esp. with IVH do worse with surgery!

MISTIE III - **minimally invasive aspiration + 1 mg t-PA** through intraclot catheter vs. **medical therapy alone**

- death at 7 days: 1% in MISTIE group vs. 4% in standard group (p=0.02);
- death at 30 days: 9% in MISTIE group vs. 15% in standard group (p=0.07);
- mRS score of 0–3 at 365 days: 45% in MISTIE group vs. 41% in standard group.

Resume: mortality improved but not functional outcome!

CLEAR III – intraventricular tPA (e.g. 1.0 mg q 8-12 hrs) for small ICH (< 30 mL) but with IVH does not improve good functional outcome (mRS 0-3: 48% in alteplase group, 45% in saline group), but gives 10% reduction in mortality.

(RE)BLEED RATES

Cavernoma 0.1-1.0% annual

AVM 2-4% annual (main risk factors – deep location, deep drainage, intranidal aneurysm, **previous bleed**)

Boards: ask if IR saw "high risk" features (e.g. draining vein stenosis, intranidal / flow aneurysm)

risk of bleeding (at least once) ≈ 105 - age in years

- risk of immediate rebleeding is relatively low – ***DSA and treatment is delayed***
  Boards: do not send patient home after AVM bleed: keep in ICU → surgery in 7-14 days (time for hematoma to liquefy); SRS is not good option after AVM bled

DAVF:

Benign: Borden I, Cognard I-IIA
Malignant: annual risk of hemorrhage 8%

Aneurysm:

Rebleeding risk of untreated aneurysms
1st day – 4%
daily first 2 weeks – 1.5%
6 mos cumulative – 50%
after 6 months – bleeding risk returns to baseline

- overall MORTALITY is 45%
  50% deaths occur within 1 month
  rebleeding → mortality ≈ 50-85%

Life-threatening hematoma requires urgent evacuation surgery - decompress hematoma:

1) avoiding AVM (small superficial AVMs can be removed)
2) clip aneurysm

AVM

Supplemented Spetzler-Martin Grading System (SM-Supp)

= SM plus **LY (Lawton-Young) grading system**

TABLE 1. Comparison of the Spetzler-Martin and Supplementary Grading Systems

Spetzler-Martin Grading	Points	Supplementary Grading
Size, cm		Age, y
<3	1	<20
3-6	2	20-40
>6	3	>40
Venous drainage		Bleeding
Superficial	0	Yes
Deep	1	No
Eloquence		Compactness
No	0	Yes
Yes	1	No
Total	5	

Sum of two scores (SM-Supp) ≤ 6 – acceptably low surgical risks (0%-24%)
Sum of two scores (SM-Supp) > 6 – significant increase in surgical risk (39%-63%).

Eloquent brain (language, motor, sensory, or visual cortex, thalamus, hypothalamus, internal capsule, brain stem, cerebellar peduncles, deep cerebellar nuclei)

Spetzler-Martin grade I-II → **surgery** / **SRS** (staged if > 3 cm)

Boards: also acceptable to do solo embolization if symptomatic!

Spetzler-Martin grade III → add preprocedure **embolization**

Spetzler-Martin grade IV-V (not amenable to surgical treatment alone - high procedural risk):
observation + DSA every 5 yrs (treatment only for progressive neurologic deficit or identified aneurysms) → staged **SRS**.
indication for pre-SRS embolization - *palliative* (e.g. neurodeficits)

Boards: for ***unruptured*** AVMs always can choose **observation** based on ARUBA results (likely will get bleed);

- young patient with SM grade 1-2 – offer surgery! (if surgery is not feasible → SRS)
- ***unruptured*** SM grade 4-5 – observation!

Superselective WADA during embolization; embo max 1/3 → sx within 7 days

Preop pre-treat with PROPRANOLOL, type and cross, Keppra, **embolize** feeding vessels!!!!

- large crani to see vessels
- **IC green** - delineate *arterial feeders* and *draining veins*.
  - gold standard - complete with **DSA** (if some nidus is left – risk of postop ICH!)

- preserve "en passage" arteries! Test clip suspicious vessels!
- **aneurysms** are clipped surgically as well.

Postop/post-embo SBP < 120, MAP 70-80

After SRS – MRI q6mos: nidus not obliterated (on MRI or angiogram at 3 years) → **repeat SRS**

SAH

Hunt & Hess scale:

Grade	Clinical Findings	Survival Rate
1	asymptomatic *minimal HA, minimal meningismus*	70%
1A	+ *fixed neurologic deficit*	
2	headache and nuchal rigidity, no neurologic deficit other than CN palsy	60%
3	AMS: lethargy, confusion, mild focal deficit	50%
4	stupor, moderate ÷ severe hemiparesis / early decerebrate	30%
5	deep coma / moribund	10%

0 – unruptured
1 – asymptomatic
2 – HA + nuchal rigidity
3 – AMA
4 – hemiparesis, posturing
5 – deep coma

World Federation of Neurological Surgeons (WFNS) Scale:

Grade	GCS	Major focal deficit*	Mnemonics
I	15	-	normal
II	13-14	-	confused
III	13-14	+	aphasia or hemiparesis
IV	**7-12**	+/-	near coma
V	**3-6**		deep coma

*aphasia, hemiparesis / hemiplegia

MODIFIED FISHER SCALE (MF) - ***risk of vasospasm progressively increases with each grade***:

mF grade	Blood pattern	Incidence of symptomatic vasospasm
0	No SAH, no IVH	0%
1	Focal or diffuse, thin SAH, no IVH	20%
2	Focal or diffuse, thin SAH, **IVH present**	30%

3	Thick SAH, no IVH	30%
4	Thick SAH, **IVH present**	40%

Note: no specified measurement or criteria to define thick vs thin hemorrhage.
Note: Any intraventricular hemorrhage, no matter how small, is counted.

Boards – in (suspect) SAH: always ask CTA + DSA (i.e. DSA even if CTA/MRA-negative)

Benign perimesencephalic SAH – only one DSA → two CTAs

TREATMENT

Bed rest in ICU
A-line: BP < 130 (nicardipine) → up to 220
Keppra
Nimodipine
NS at 2 mL/kg/hr
EVD + LD

Daily TCD and clinical exam, ± vEEG

VASOSPASM

Doppler > 120 (esp. > 200 or ↑ 50 per day), Lindegaard > 3 (esp. > 6)
Treatment: drop EVD, norepinephrine (up to SBP 220), NS at 200/hr ± albumin (also fludrocortisone, DDAVP if UO > 200 mL/hr) – reversal of deficits within 1 h in 80%; if not → DSA

DOPPLER

GOSLING index = (systolic velocity – diastolic velocity) / mean velocity.

- in intracranial hypertension, Gosling index > 1.

LINDEGAARD index = mean velocity in MCA / mean velocity in extra-cranial ICA

Normal mean velocity in MCA ≈ 60 cm/s; in ICA 60-100 cm/s

- mean velocity in MCA > 100-120 cm/s:
  a) vasospasm (Lindegaard index↑).
  b) brain hyperemia (paraleliai didėja LKG tiek MCA, tiek ir ICA - Lindegaard index unchanged).

Mean **MCA** velocity	MCA:ICA (Lindegaard) ratio	Interpretation
< 120	< 3	Normal
120-200	3-6	120-160 Mild spasm 160-200 Moderate spasm
> 200	> 6	Severe vasospasm

  – increases of > 50 cm/sec/**d** suggest vasospasm

ANEURYSMS

Unruptured Aneurysms - **International Study of Unruptured Intracranial Aneurysms (ISUIA)** - natural history of unruptured aneurysms of different sizes: 5-year cumulative rupture rates.

5-yr rupture risk

Size	**Cavernous ICA**	**Anterior** (ICA, ACA, MCA)	**Posterior** (PComA, PCA, BA, VA)
< 7 mm	0	0 / 1.5	2 / 3
7-12 mm	0	3	15
12-25 mm	3	15	20
> 25 mm	6	40	50

N.B. prior SAH only matters in < 7 mm aneurysms

Annual rupture risk

Size	**No prior SAH**	**Prior unrelated SAH**
< 10 mm	< 0.05%	0.5%
> 10 mm	1%	1%

Overall 1-yr morbidity and mortality:

13% - clipping
10% - coiling.

Ruptured Aneurysms - four randomized controlled trials: ISAT, BRAT, Finnish, Chinese.

International Subarachnoid Aneurysm trial (ISAT)

- class 1 evidence.
- rates of rebleeding are higher after ***coiling*** but poor outcomes (mortality, dependence) are more common after ***clipping*** (coiling gives 23% relative risk reduction for poor outcome):

1-yr disability or death:	(vs. unruptured aneurysms from ISUIA)
30% – clipping	13%
24% – coiling	10%

  - ISAT investigators - surgery may be better in **< 40-50 yrs** group.
  - what happens after 1 year (rebleeding)?

3 angiograms still give 1-4% false-negatives

threshold to clip: 1 : 2 neck to corpus ratio or > 4 mm neck

avoid clipping during days 3-10 when maximal vasospasm is likely – better coiling

Infundibulum ≤ 3 mm

Mycotic aneurysms

- **antibiotics** for 4-6 weeks → MRA: failure to reduce in size → "deconstructing the vessel"; if in eloquent area, may use Amytal+lidocaine.

COILING

- complete patient immobilization (and thus general anesthesia).
- monitoring: MEP, SSEP, EEG, BAER
- HEPARIN bolus IV (100 U/kg) to achieve ACT > 250 seconds (in ruptured aneurysms, patients may not receive heparin until first coil is deployed); do not reverse postop.

- WEB - dual antiplatelet therapy is not required! – can use for ruptured aneurysms!
  vs
- Pipeline - start DAP before implantation → PLAVIX for 6 months + ASPIRIN indefinitely.
  Make sure patient agrees with compliance (or abort procedure or use WEB)!

  check P2Y12 on day of surgery:
  if < 60-90 – do not proceed (if bleeding happens it will be catastrophic);
  if > 194, proceed with ReoPro intraop, then prasugrel (Effient) or Brilinta postop

CRANI + PROXIMAL CONTROL

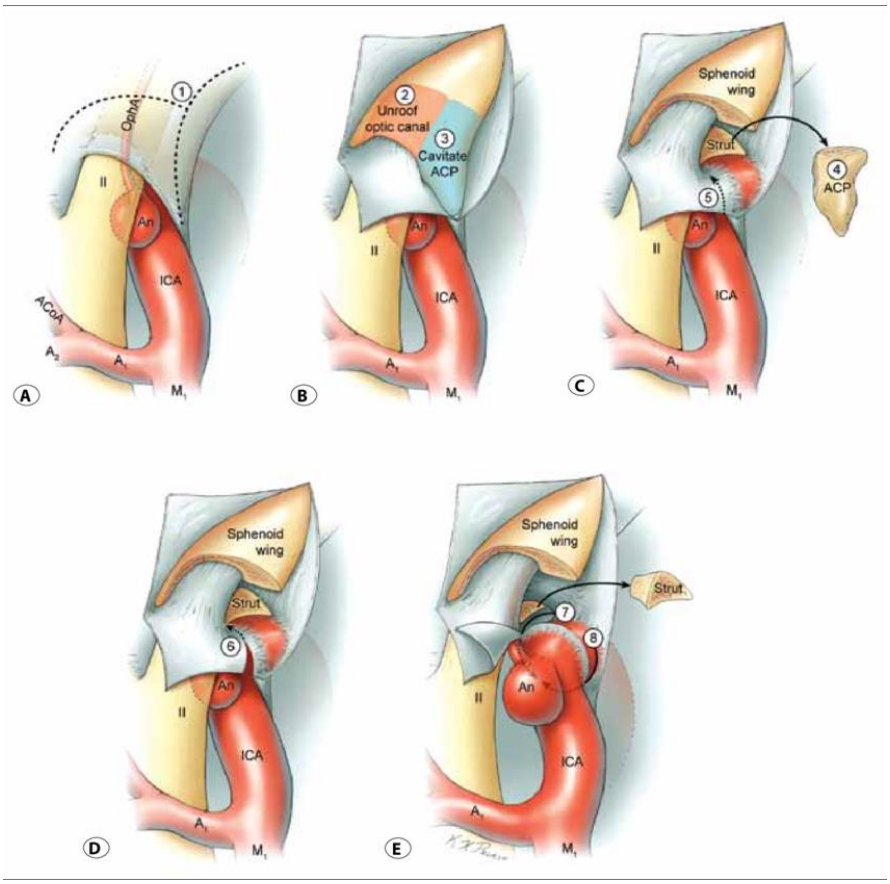
Prep neck ICA only for ICA aneurysms (± PComA), not even for ICA bifurcation

Plan approach so can access aneurysm neck before dome!
CSF drainage
Femoral sheath
KEPPRA
type and cross 2 U pRBC
Radiolucent head-holder (lidocaine at pin sites!)
Microscope
EEG, MEP, SSEP
Navigation
MANNITOL when opening dura
Wash clot off, open basal cisterns
Parent vessel preservation
Proximal vessel control!!! (prep neck)
Access aneurysm neck before dome! (i.e. check imaging - which direction aneurysm is pointing)
Temporary clip on parent vessel!!! - ***mobilize and inspect aneurysm in all directions*** - for perforating vessels
TIM (THIOPENTAL*-ISOFLURANE-MANNITOL) ± hypotension-hyperventilation-hypothermia
*up to burst suppression
Doppler → IC green angio → completion DSA

- use **micro Doppler** prior to clipping to gauge baseline flow for postclipping comparison.

if patient wakes up with new deficit → STAT DSA – gives much more reliable info than CTA (plus, CTA wastes more time)

Proximal ICA (ophthalmic) – dissect neck and put vascular loops on ICA in the neck + ***anterior clinoidectomy***:



<u>AComA</u> [fragile hypothalamic perforators - coiling is very preferred!!!; ***stent-assisted*** *if* wide neck]
Extended pterional craniotomy (head rotation 60 degrees, anterior edge of craniotomy extends lateral to the midpupillary line) - arachnoid bands tethering the frontal lobe to the chiasm are placed on stretch and sharply divided; no need to expose proximal carotid: only anterior aspect of Sylvian fissure is split and A1 is identified - proximal control on ipsilateral A1, then contralateral A1 (first temp clip is on dominant A1); usually need **fenestrated** clip.
Side of Approach (in order of importance):

1) ***contralateral to the direction of aneurysm dome***!
2) ipsilateral to ***isolated dominant A1***
3) ipsilateral to ***ICH*** - to avoid any injury to the only intact contralateral gyrus rectus
4) right-sided pterional approaches are technically easier

<u>MCA</u> (pterional craniotomy with head rotation 45 degrees): minimal subfrontal exposure; sylvian dissection proximally at the level of the carotid cisterns (major vector of retraction on temporal tip) → drain CSF to relax inflamed brain, gain proximal control on M1 (just distal to lenticulostriate vessels) →"inside-to-outside" dissection from M1 (along anterior-inferior aspect) toward bifurcation

- preserve STA for potential bypass
- avoid any significant retraction on temporal lobe!

- ICH (80% in temporal lobe) – need much larger craniotomy, *early proximal control* is especially important - start subfrontal dissection proximally near carotid cisterns (early proximal control at supraclinoid ICA) → **transcortical approach**: corticotomy over anterior superior or middle temporal gyrus → evacuate safe part of clot, find M1 and apply temporary clip on M1.

PComA (extended [lesser sphenoid wing, flatted orbit] pterional craniotomy with head rotation 30 degrees, sphenoid wing must be aggressively drilled, may need ***anterior clinoidectomy***) - **subfrontal corridor** (mobilization of the frontal lobe - dissection of arachnoidal attachments over chiasm and floor of frontal fossa; do not manipulate temporal lobe i.e. ***aneurysm must be exposed solely via frontal lobe retraction***) → proximal Sylvian fissure split → opening optico-carotid cistern → drain CSF + proximal control over supraclinoid ICA (proximal ICA at opticocarotid triangle) + prep neck.

N.B. if dissection exposes proximal neck of aneurysm without adequate space for temporary clip deployment, additional exposure of proximal ICA is mandatory. Ensure proximal control at all costs!!!

ICA bifurcation – endovascular:

a) stent-assisted in Y configuration
b) PulseRider, pCONus
c) WEB – does not need antiplatelets!

Basilar tip - approach depends on BA bifurcation height:

above dorsum sellae - modified pterional, right side preferred (transsylvian - Yasargil's approach through carotid-oculomotor triangle), subfrontal through 3rd ventricle via lamina terminalis

below dorsum sellae – subtemporal (classic Drake's approach) with splitting tentorium behind CN4 (do not cut it!)

N.B. aneurysm neck below posterior clinoid tip is difficult or impossible to reach even with a subtemporal approach!

proximal control – on BA

PICA (midline suboccipital or far lateral craniotomy without condylectomy [max 1/3 – condylar vein is a limit]) – segment of VA

VA - midline suboccipital

- brain relaxation - gentle elevation of anterior frontal lobe and opening arachnoid membranes over opticocarotid cisterns.
- indications for of sylvian splitting: MCA aneurysms, Yasargil approach to BA tip aneurysms, insular tumors
- amount of sylvian splitting:
    a) large insular tumors or giant MCA aneurysms → fissure must be dissected as widely as possible to the level of superior and inferior peri-insular sulci.

b) anterior skull base tumors, anterior circulation aneurysms → dissect only the anterior limb of the Sylvian fissure, exposing the cistern just anterior to the M1

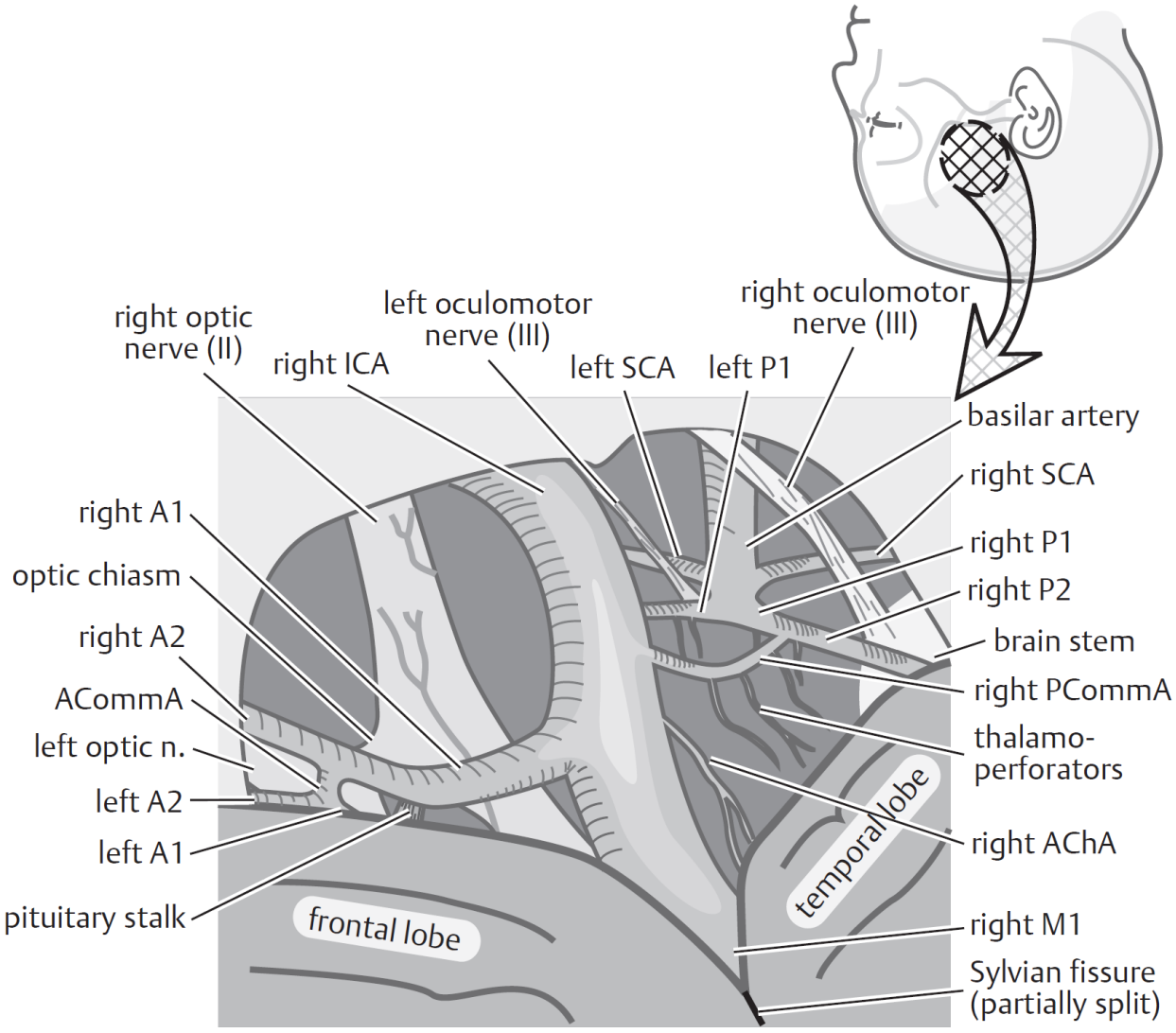
"Inside-to-outside" technique

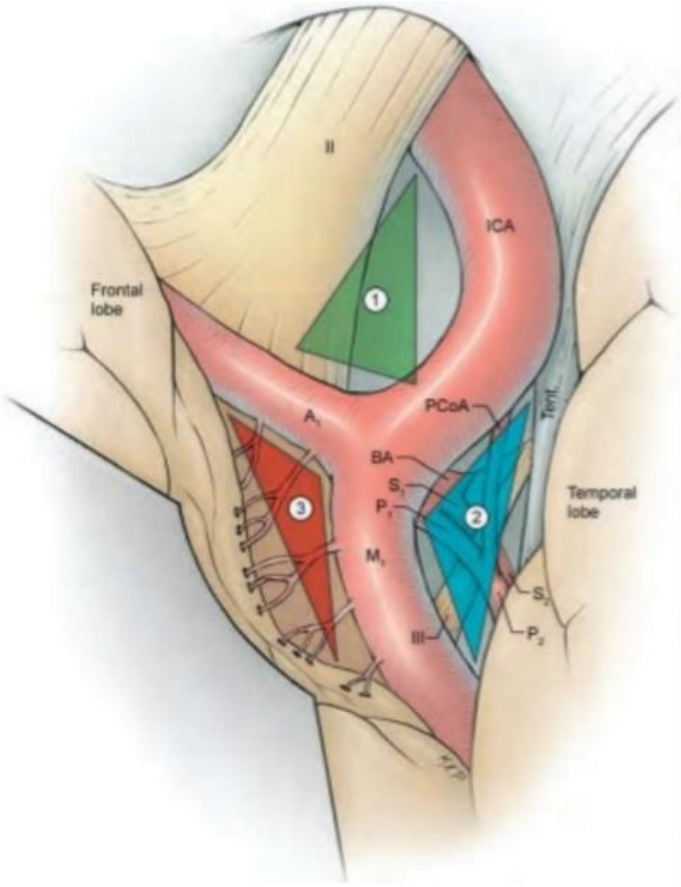
- round blade (beaver knife), using two micro pick-ups (e.g. jeweler's forceps with fine tips) tear arachnoid apart in **avascular spot** at Sylvian point → work with low power suction and Rhoton dissectors / microscissors → soft, moist, cotton pledgets or balls are gently glided.
- *dissection above* (rather than below) *superior Sylvian vein*
  - fissure should preferably be *opened on frontal side of veins* - veins will not cross the fissure when frontal lobe in elevated.
  - if > 1 superficial Sylvian vein is present, *dissect between two veins*.

  N.B. there are no arteries that cross Sylvian fissure - if correct plane is maintained, no arteries need to be sacrificed!
- divide **temporopolar vein** – untethers anterior temporal lobe.
- M1 may be used as a landmark to reach the opticocarotid cistern.
- open **opticocarotid cistern** (thick arachnoid band tethers frontal and temporal lobes to each other here).

Extended pterional approach = standard pterional craniotomy expanded by:

1) Osteotomy along the lateral sphenoid wing to the level of the superior orbital fissure
2) Drilling along the roof of orbit to flatten its surface.
3) If necessary, rongeur temporal squama towards the floor of middle fossa.


right optic nerve (II)
right ICA
left oculomotor nerve (III)
left SCA
left P1
right oculomotor nerve (III)
basilar artery
right SCA
right P1
right P2
brain stem
right PCommA
thalamo-perforators
right AChA
right M1
Sylvian fissure (partially split)
right A1
optic chiasm
right A2
ACommA
left optic n.
left A2
left A1
pituitary stalk
frontal lobe
temporal lobe



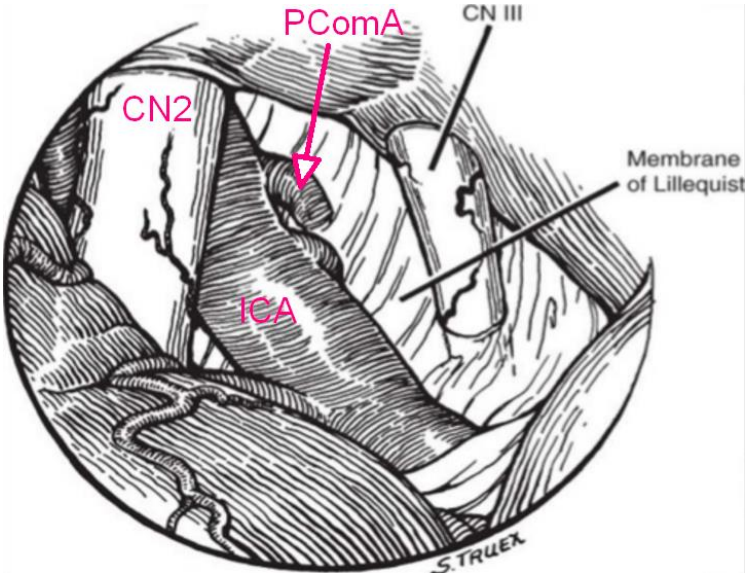
Anatomic triangles providing access to the basilar bifurcation:

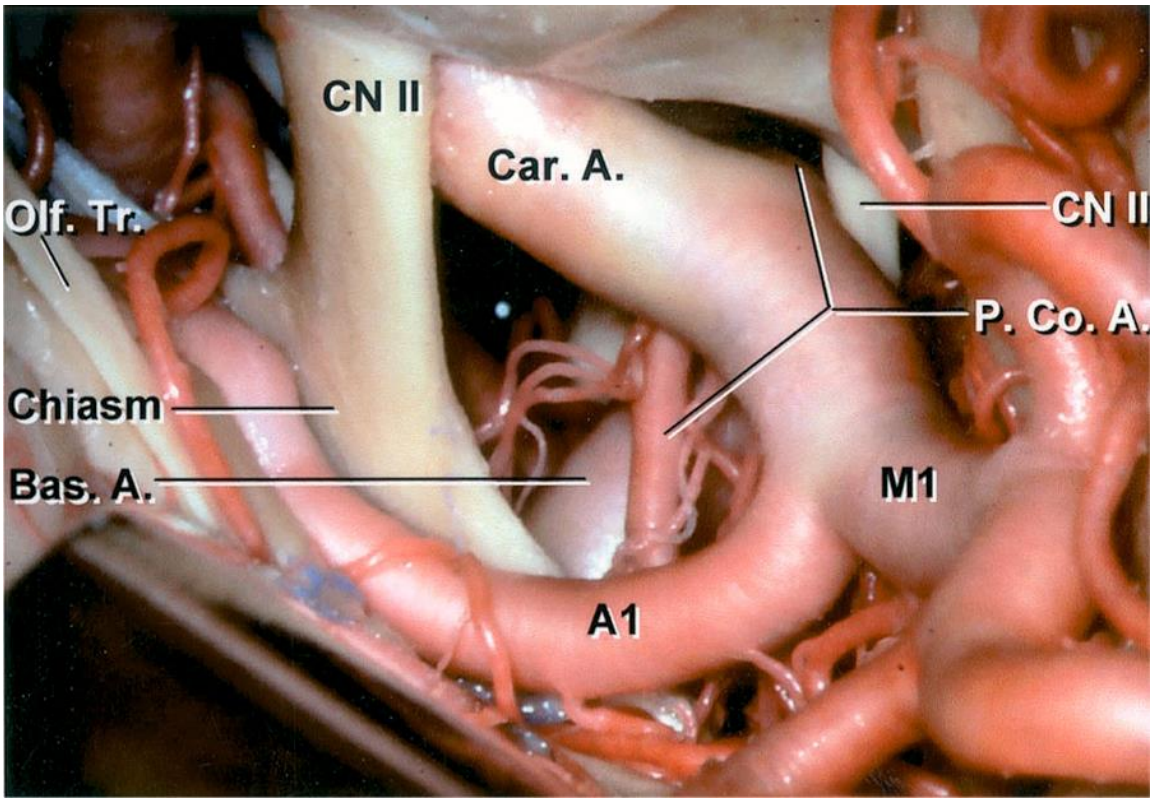
1 optic-carotid triangle

2 carotid-oculomotor triangle

3 supracarotid triangle

The carotid-oculomotor triangle is the one used most commonly for basilar bifurcation aneurysms.





After clipping – **CTA / MRI with gadolinium**

1 year
5 years
Every 10 years

CAROTID-CAVERNOUS FISTULA

Direct type (70-90%):

Type A fistula - direct connection between **intracavernous ICA**.

- high-flow and high-pressure fistulas → fast progression of clinical features!!!
- most commonly traumatic in *young males*.

Dural types:

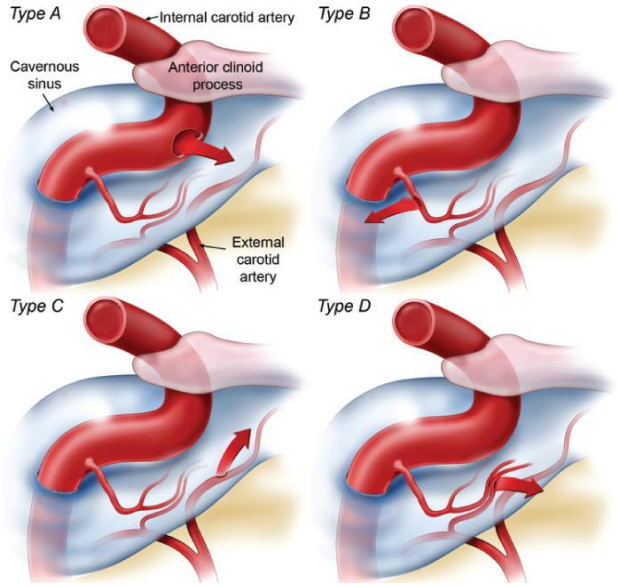
- low-flow.
- most commonly spontaneous in *women > 50 years*.
- **carotid self-compression** for 30 seconds x4/hour using contralateral hand; if fails → transvenous embolization.

Type B fistula - dural shunt between intracavernous branches of **ICA**.

Type C fistula - dural shunt between meningeal branches of **ECA**.

Type D fistula - **combination** of types B and C.

Diagrammatic representation of 4 types of fistulas:



All need DSA!
Ask ophthalmologist to evaluate and measure IOP!!! (emergent surgery if > 20) + DEXAMETHASONE, DIAMOX

DAVF

Need 6-vessel DSA (also in any SAH – to rule out DAVF as cause of bleed)
BORDEN classification
Type I: drains **anterograde** into sinus. Do not bleed but need clinical* observation (may convert into type II-III)! *new symptoms → CTA, DSA
Type II: drains into sinus with both **anterograde** + **retrograde** drainage (subarachnoid veins).
Type III: drains **retrograde** into subarachnoid veins (no sinus drainage).

Benign: Borden I, Cognard I-IIA – need CLINICAL observation
Malignant: annual risk of hemorrhage 8% - Rx: embolization / crani and disconnection (ICG!, apply temporary clip on vein – watch for brain swelling, monitoring signal change).

MOYAMOYA

Angiography

- patient well hydrated!!! (sickle cell – transfuse blood)
  Admit preop to hydrate x1.5 normal requirement

Symptomatic moyamoya – no other test is needed after DSA diagnosis → proceed to treatment: STA-MCA bypass, EDAS (suture STA to pia with **8-0 nylon**)
Aspirin (hold if bleed) + statin for life

- ***avoid hyperventilation*** - general anesthesia may cause stroke!

- ***mannitol*** is risky!!! (dehydration → hypotension)

Monitoring (EEG)
Postop SBP 120-140 (no more, no less)

Prompt treatment for everyone even asymptomatic cases! (use Diamox SPECT to select side for completely asymptomatic)

PERIPHERAL NERVES

ARM

Radial nerve – extension: elbow (C7), wrist (C6), fingers at MCP (C7)
N.B. finger extension at IP is ulnar (III-IV*, interossei) and median (I-II*) nerves
*lumbricals (C8-T1)
vs. wrist flexion is mainly C7
Hand grip (finger flexion) – C8
Best way to test T_1 - 5th finger abduction

LEG

One posterior calf muscle gets L5 – posterior tibial (still via "normal nerve" – *tibial n.*)

Femoral nerve (L2-4) = hip flexion + knee extension

Sciatic nerve (L4-S3) = knee flexion + all muscles bellow knee

Common peroneal n. (L4-S2)

Tibial n. (L4-S3)

Toe extension (*deep peroneal n.* L5-S1) = extensor hallucis longus + digitorum longus & brevis

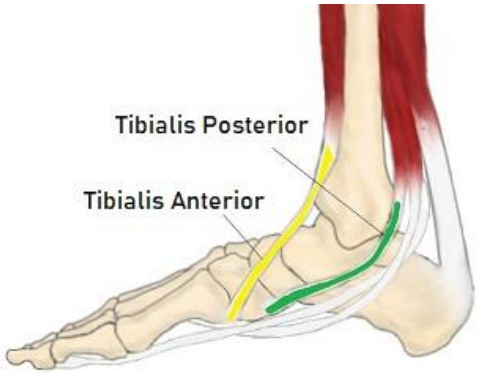
Toe flexion (*tibial n.* S1-2) = flexor hallucis longus + flexor digitorum longus & brevis

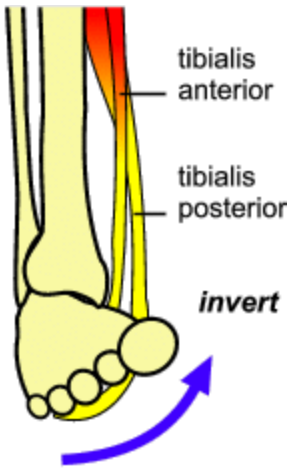
Foot plantarflexion (*tibial n.* L5-S2, mainly S1) = gastrocnemius + soleus + tibialis posterior

Foot dorsiflexion (*deep peroneal n.* L5 > L4) = tibialis anterior + EHL + extensor digitorum longus

N.B. foot drop is L5 / *deep peroneal n.* Foot drop → get **MRI** to rule out mass effect – either **L-spine** or **peroneal** ← decide clinically

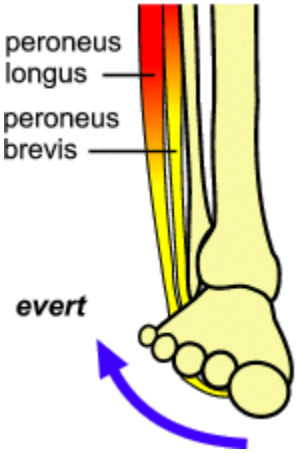
Foot inversion (L5) – tibialis anterior (*deep peroneal n.*) + tibialis posterior (*tibial n.*):





N.B. tibialis posterior is L5 (not S1) vs. gastroc and toe flexors are S1

Foot eversion (L5 – *superficial peroneal n.*) – three peronei:

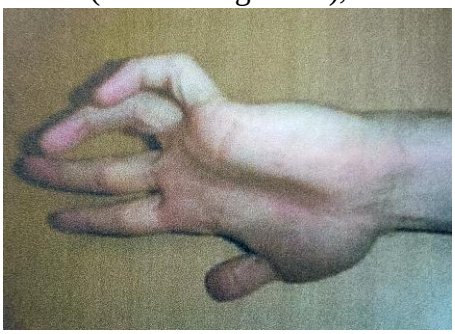


N.B. L5 affects both foot **inversion** and eversion (*deep peroneal n.* – only *partial inversion*; *superficial peroneal n.* – only eversion)
N.B. short head of biceps femoris is the only peroneal-innervated muscle proximal to peroneal tunnel!

C1 – no such dermatome!
C2 – angle of mandible
C4 – clavicle
C5-6 – **Biceps**
Pectoral reflex (C5)
Biceps reflex (C5-6)
Brachioradialis reflex (C5-7)
C6 - wrist extension (extensor carpi radialis C6 + extensor carpi ulnaris C7 [PIN])
C7 – wrist flexion
C7-8 – triceps reflex
C8 – grip (finger flexion)
C8-T1 – intrinsics

C6 – 1st finger
C7 – 3rd finger
C8 – 5th finger
L1 – inguinal (femoral pulse)
L2 – iliopsoas
L2-4 - knee jerk
S2 – popliteal fossa
S2-4 - anal sphincter
S2-Cx converge on coccyx (bull's eye) not anus!

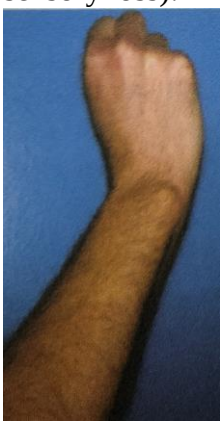
Proximal median neuropathy: ligament of Struthers, lacertus fibrosus, hypertrophied pronator teres, sublimis bridge.
Proximal ulnar neuropathy: medial intermuscular septum, arcade of Struthers, ulnar groove, cubital tunnel (Osborne ligament), FCU heads (Osborne fascia) ← all must be released!

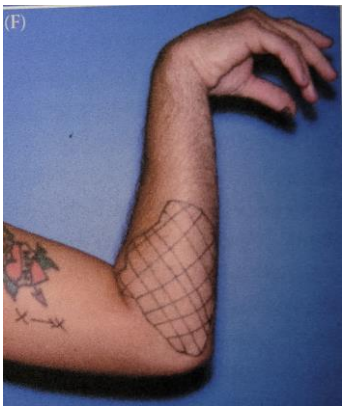


Wartenberg sign, **FROMENT prehensile thumb**

Boards: recurrence after neurolysis → submuscular transposition (bigger incision: 10 cm above, 10 cm below epicondyle) under *m. pronator teres* and *m. flexor carpi ulnaris* →cast at 45° flexion for 3 weeks

Radial neuropathy: spiral groove, leash of Henry arteries, arcade of Frohse (under supinator) → radial tunnel.
N.B. extensor carpi ulnaris – PIN; extensor carpi radialis – proximal radial nerve.
Radial nerve* – triceps*, wrist and MCP drop. PIN* – only MCP drop and radial wrist deviation
PIN palsy (no sensory loss): **Proximal Radial palsy** (sensory loss – hatched; x-x – Tinel):





Most common mimickers (of C5 radiculopathy):

1. **Rotator cuff tear** – also gives shoulder abduction weakness but starts from 0 degrees and no elbow flexion weakness + painful shoulder movement / significant tenderness; positive Neer and Hawkins' tests for impingement.
2. **Suprascapular nerve entrapment** - not associated with weakness of other C5 innervated muscles (such as deltoid, biceps).

Most common mimicker (of C6-7 radiculopathies):

1. **Carpal tunnel syndrome** - nocturnal dysesthesias, hypoesthesia is present distally, over the palmar side of the hand and over the first three to three and one half digits. Weakness and atrophy of the thenar and first two lumbrical muscles (← innervated by C8 and T1). Phalen's test + Tinel's sign + Durkan sign.
2. **Posterior interosseus nerve compression** – no sensory findings, does not affect triceps.

Most common mimickers (of C8 radiculopathy):

1. **Ulnar entrapment at the elbow** - tenderness along the medial aspect of the elbow; positive Tinel's sign, *sensory change does not extend proximal to wrist*.
2. **Anterior interosseus nerve entrapment** - no sensory loss, pain over proximal forearm.

	Hand intrinsics	Abductor pollicis brevis
C8 radiculopathy	+	+
Ulnar neuropathy	+	
Median neuropathy		+

Scapular winging (scapula alata)	**trapezius (spinal accessory n.)**	**serratus anterior (long thoracic n.)**	**rhomboids (dorsal scapular n.)**
degree	milder	more severe	
at rest	present	negligible	
becomes worse on	shoulder abduction	shoulder flexion	

Su rankos nykščiu galima pratestuoti visus tris nervus:

ekstenzija – N.RADIALIS (m. extensor pollicis longus et brevis).

opozicija – N.MEDIANUS (m. opponens pollicis).

addukcija – N.ULNARIS (m. adductor policis).

abdukcija – N.RADIALIS (m. abductor pollicis longus) + N.MEDIANUS (m. abductor pollicis brevis).

fleksija – N.ULNARIS (m. flexor pollicis brevis, deep head) + N.MEDIANUS (m. flexor pollicis longus et brevis, superficial head).

Lesion site	**Romberg test**		
	eyes-open	**eyes-closed**	**eyes-closed tandem**
fasc. gracilis et cuneatus			
cerebellar			
vestibular			

Mechanical nerve injuries:

	Sunderland	Myelin	Axon	Endo-	Peri-	Epi-	Recovery
Neurapraxia	1°	±					Within days-weeks
Axonotmesis	2°	+	+				1 mm / day (s. 1 in / mo)
Neurotmesis	3°	+	+	+			No spontaneous recovery
	4°	+	+	+	+		
	5°	+	+	+	+	+	

VEP – evaluates only **anterior visual pathways**

DIAGNOSTICS

5 things:
Main differential – peripheral nerve vs spine – use **provocative tests**:
Tinel, Phalen, thoracic outlet vs Spurling, Lasegue

1. **EDX**
2. **US / MRI (STIR, MRI neurography)** – image:
   For brachial plexus, add CXR – C7 rib, Pancoast
   1) surgical failures
   2) unusual sites of compression (e.g. localized with Tinel) to rule out a mass
   3) usual sites if strong clinical suspicion but EDX is (false)-negative
3. **Nerve blocks** – diagnostic, therapeutic (e.g. for meralgia paresthetica)
4. **Labs**:
   1. HgA1c (DM)
   2. BMP (uremic neuropathy)
   3. Thyroid hormone levels (myxedema).
   4. Vit. B12 levels
   5. Multiple myeloma: anemia, 24 hour urine for kappa Bence-Jones protein, SPEP, skeletal radiologic survey.

Radiculopathy – preserved SNAP (lesion before DRG) but abnormal EMG of paraspinal muscles. Also F and H responses ← test proximal axons and soma (F – only motor, H – motor and sensory)! prolonged H reflex with normal F latency - ***dorsal root pathology***
Neuropathy – affected SNAP but normal paraspinals.

axon-loss lesions - conduction **block** & amplitude **reduction**; EMG shows denervation
myelin-loss lesions - conduction **slowing***; normal EMG

*severe demyelination may cause conduction **block**!

Normal conduction velocity ≈ speed limit on highway (50-60)

PNS trauma: both EMG and NCS earliest that can be helpful is **≥ 3 weeks** after injury!
(only then 1º injury shows return of normal NCS vs. ≥ ***AXONOTMESIS*** – conduction block)
EDX after trauma – at 3 weeks and 3 months (ENoG for CN7 – 3 days)

SURGERY

Timing of Nerve Exploration (Repair) - **RULE OF 3'S + 1**	
Sharp clean lacerations	- (within) **3** days
Blunt or jagged / dirty lacerations	- **3** weeks
Closed, stretch, gunshot injuries in continuity	- **3** months
Tendon transfers, joint fusions	- **1** year

Surgery is indicated for ***NEUROTMESIS***! (i.e. anything > axonotmesis will need surgery)

Consent for cable graft (sural) donor site! (if gap > 2-3 cm)
US (to find nerve), stimulator (always stimulate before cutting!) + EMG (no local anesthetic!)
8-0 for epineurium tension-free (align fascicles as best as possible) → fibrin glue
Postop: immobilization in joint flexion for 3 weeks after any nerve repair → PT

Famous tendon transfer – tibialis posterior for foot drop (until then – AFO).

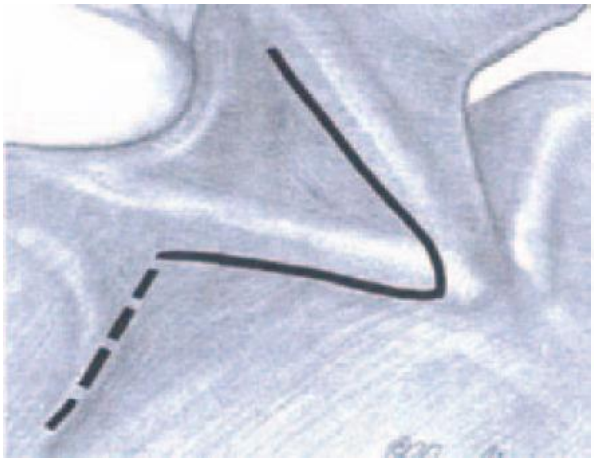
BRACHIAL PLEXUS

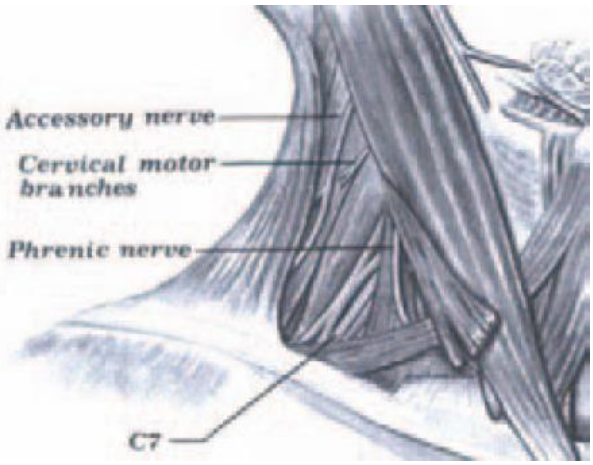
For ***brachial plexus STRETCH*** injuries, first NCS/EMG at 3 months, operate < 6 months from injury! (obstetric – at 3-9 mos old) (not for Dejerine-Klumpke)

Root avulsion (preganglionic injury) – Horner, pseudomeningoceles, EMG denervated paraspinals, sensory NCS (SNAP) is normal! + no Tinel's sign at Erb's point
Rx: DREZ + neurotization:

Priorities: elbow flexion (intercostal nerves → musculocutaneus) > shoulder abduction (CN11 → suprascapular)

For post-ganglionic Duchene-Erb could add: Oberlin transfer, radial branch of triceps → axillary





- ***phrenic nerve*** (located anterior to anterior scalene muscle) traces to C5 nerve
- trunks of plexus between **anterior and middle scalene muscles**, subclavian artery is caudad to lower trunk; divide anterior scalene to reach plexus.

- identify *neuroma-in-continuity* → **external neurolysis (circumferential dissection around nerve)**
- **stimulate** (proximally).
  a) recorded NAPs distally – good prognosis (nothing more surgically is needed) as proximal muscles (above elbow) have 90% chances of recovery within 2 years.
  b) no NAP distally → **neuroma resection & nerve cable grafting** (sural nerve) or **nerve transfer**

Parsonage-Turner

- corticosteroids have no proven benefit.
- clinical recovery takes 2 months ÷ 3 years (so don't rush to operate!!!); if no improvement by 2 yrs → **tendon transfer surgery**.

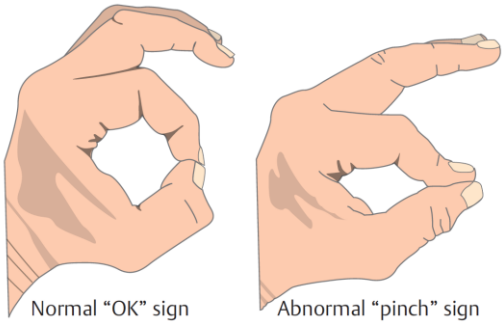
Proximal long nerve injuries (Dejerine-Klumpke, ulnar in axilla, peroneal above midthigh) – nonsurgical (no chance of recovery); vs other – return of protective crude sensation is worthwhile to try!

AIN

No sensory loss + weakness of 3 forearm muscles:

1) flexor digitorum profundus radial edge - flexion of distal phalanx of digits 2 & 3
2) flexor pollicis longus - flexion of distal phalanx of thumb
3) pronator quadratus (in the distal forearm): H: EMG

Summary – distal phalanx of I-III digits → abnormal "OK" sign:



CTS

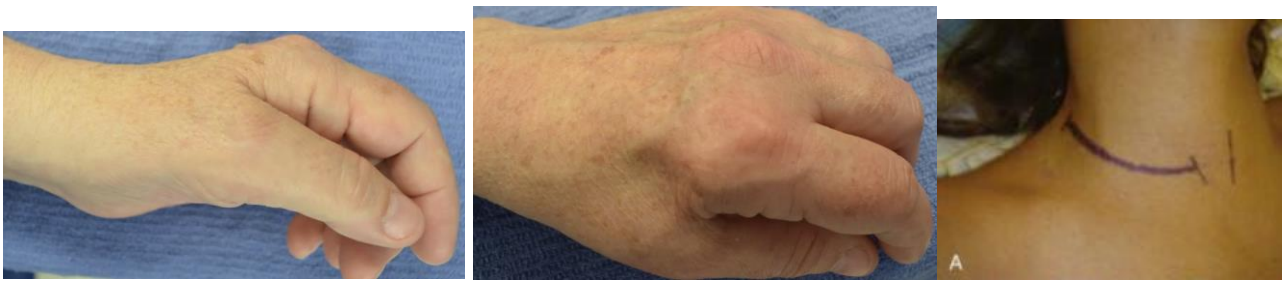
Recurrent motor branch (median n.) – "LOAF muscles" (**Riche-Cannieu anastomosis**).

Kaplan's line: from base of thumb web space to hook of hamate

Cut TCL over Penfield 4 to protect nerve! - make sure see palmar fat

TRUE (CLASSIC) NEUROGENIC TOS

- Tinel sign over supraclavicular brachial plexus, **Gilliatt-Sumner hand** (ulnar + median):



PT + scalene Botox → surgical release (scalenotomy at insertion while carefully protecting phrenic nerve, transection of aberrant bundle, removal of cervical rib) via *anterior* ***supraclavicular*** *approach*

TRIGEMINAL NEURALGIA

RF thermocoagulation - **patient awake** (N.B. may cause HTN!) - curved Tew electrode 60º x 60 sec (may need a few lesions to cover area); lowest recurrence
Glycerol rhizotomy – patient sitting - anhydrous **GLYCEROL** to Meckel's cave volume 0.4 cm^3 for **2** hours
Balloon compression → **4F Fogarty** 1.4 atm pressure held for 1-2 minutes bradycardia occurs regularly! lowest risk of corneal anesthesia, best for MS

PEDIATRICS

Genetics consult!!!!

N.B. **palpate anterior fontanelle before proceeding with any other part of physical examination on acutely ill baby**!

Folate supplementation 4 mg/day (0.4 mg/d if no neural tube history)
previous fetus with neural tube defect → risk increases 10-fold – genetics consult!!!

SYNOSTOSIS

- 90% of adult head size is achieved by age 1 yr; 95% by age 6 yrs.
- growth essentially ceases at age 7 yrs.

Anterior fontanelle: closes by age 2.5 yrs.
Posterior fontanelle, sphenoid and mastoid fontanelles: close by 2.5 months (mastoid by 1 year)

- suture closure occurs by age ≈ 12 years.
- coronal synostosis → **BRACHYCEPHALY** → **HARLEQUIN** eye → amblyopia
- coronal + sagittal sutures → **OXYCEPHALY** - high, conical head with sharp bossing of anterior fontanelle
- coronal + sagittal + lambdoid sutures → **TRIPHYLLOCEPHALY, S. KLEEBLATTSCHÄDEL** e.g. **CROUZON'S**
- **APERT'S** – **syndactyly**. **PFEIFFER** – **polydactyly**

Surgery timing best is – **3÷18 months** → custom-made **molding helmet** for 6-18 months

Blood loss + air embolism

EBL OK < 1/3 of circulating blood volume (70 mL/kg)
+ type and cross 1 unit, A-line, two large bore IVs, wax bone edges
+ precordial Doppler, end-tidal CO2 monitor

- chlorhexidine is contraindicated at age < 2 months (use Betadine).
- corneal protectors!
- follow at 6 mos of age – if recurrence, reoperate!

SPLIT CORD

Type I SCM – bony → diplomyelia
Type II SCM – fibrous → diastematomyelia

PVH

N.B. germinal matrix is present only in < 32 weeks!

INDOMETHACIN- ***accelerates maturation*** of germinal matrix;

reduce systemic BP fluctuations + **PANCURONIUM** paralysis while infant is **ventilated**

Grade III- IV

- daily ventricular punctures (10 ml CSF /kg).
- if head growth is double normal rate over 2 weeks or ICP↑ persist → **ventriculosubgaleal (VSG) shunt**; head circumference > 1.5 cm above 97th percentile → **VPS** (when ≥ 2 kg); modern alternative – **ETV with CPC** (choroid plexus coagulation).

TETHERED

Conus below L2-3 at any age is abnormal!
Filum terminale is abnormal if the diameter is > 1 mm at L5-S1

- **surgical release**: EMG (± SSEP, MEP - not routine for a simple sectioning of filum)
- **urinary bladder** may worsen in adults postop – if lower motoneuron type **urodynamic study** (detrusor weakness) → 3 months of bladder rehab preop

MMC

defects above L_3 - deficits preclude ambulation (wheelchair dependent)

SERUM α-fetoprotein (AFP)↑ → amniocentesis:

Amniotic fluid **AFP↑** + amniotic fluid **AChE↑** - sensitivity for open defects ≈ 100% → **detailed (level II) ultrasound** → (in utero MMC closure) → **near-term C-section**

Close within 24 hrs.
Preop ***weight-based*** naf+genta + prone with Telfa (saline 3 mL/hr) + **head** US (HCP, Chari II), **renal** US (anephria), **spine** XR (scoliosis, kyphosis)
Close placode with 8-0 Prolene

N.B. shunting is not needed at time of MMC repair; if HCP is large – shunt it during MMC repair! fixed medium pressure or programmable valve

FCD

Type I - ***no abnormal cells***.
Type IA - isolated architectural abnormalities, usually laminar or columnar disorganization.
Type IB - + giant cells or immature neurons.
Type II - ***abnormal neurons*** (brain feels firmer on palpation)
Type IIA - dysmorphic cells.
Type IIB - + balloon cells.
Type III – ***associated pathology*** is present.

Surgical extirpation of epileptogenic lesion **guided by icEEG**!

CHIARI

Chiari I - displacement of cerebellar TONSILS (> 5 mm below McCrae's basion-opisthion line) over cervical spinal cord ± *syringomyelia*

- manifests in younger adults

Chiari II (s. Arnold-Chiari) – *myelomeningocele* → pull on brainstem → small posterior fossa → downward displacement of brain stem and cerebellum (VERMIS and inferior poles of HEMISPHERES) → *hydrocephalus*; prenatal US – lemon and banana signs.

- manifest in first few months of life; *dysphagia*, *vocal cord paralysis / stridor*, *life-threatening apneic spells*
- levoscoliosis!
- preop - **swallow** study, **vocal cord** visualization by ENT, assessment of **pulmonary function** + **neuraxis MRI**
- post-op respiratory monitoring

Chiari III - encephalocele (foramen magnum / high cervical) – ininencephaly?

Chiari IV - cerebellar hypoplasia / aplasia

Associated anomaly	Chiari 0	Chiari I	Chiari 1.5	Chiari II
Hydrocephalus		7-9%	±	+
Supratentorial anomalies*				+
Cerebellar herniation		Tonsills	Tonsills	Vermis, hemispheres
Brainstem herniation			+	+ *"Z" kinking*
Syringomyelia	100%	30-75%	+	40-95%
Myelomeningocele				+

*callosal agenesis, enlarged massa intermedia, *beaked tectum of midbrain, craniolacunia*

BRACHIAL PLEXUS

– hand support, passive ROM exercises.

observe for 3 months → MRI to determine extent of injury → surgical exploration & repair (aim at 3-9 months of age).
N.B. if found neuroma, just excise it (nerve stimulation does not work in babies; same EDX)

SHAKEN BABY

Retinal hemorrhages + SDH + skeletal survey.
Daily **subdural taps** (10-20 mL) needle with stylet; if > 10 taps needed → subduro-subgaleal shunt for 6 months.

NEUROLOGY

GUILLAIN-BARRÉ SYNDROME (GBS)

CSF – protein↑ with normal cell count (***albuminocytological dissociation***).
EDX – segmental demyelination
MRI - ***enhancement of roots***

Rx: plasmapheresis or IVIG

- steroids are contraindicated!

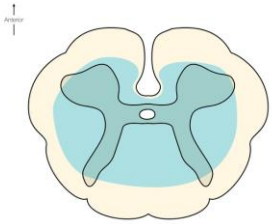
ACUTE DISSEMINATED ENCEPHALOMYELITIS

Rx: METHYLPREDNISOLONE / plasmapheresis / IVIG

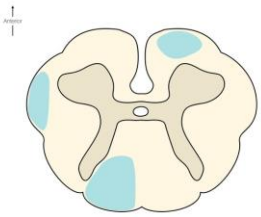
MS

N.B. T2 lesion in spinal cord – check MRI with contrast! (syrinx does not enhance vs. demyelinating lesion or tumor) → CSF study for MS + serum aquaporin-4 antibodies

Rx: **attacks** - high-dose METHYLPREDNISOLONE or high-dose PREDNISONE



NMO



Multiple sclerosis

ALS

CKP → MRI → EDX

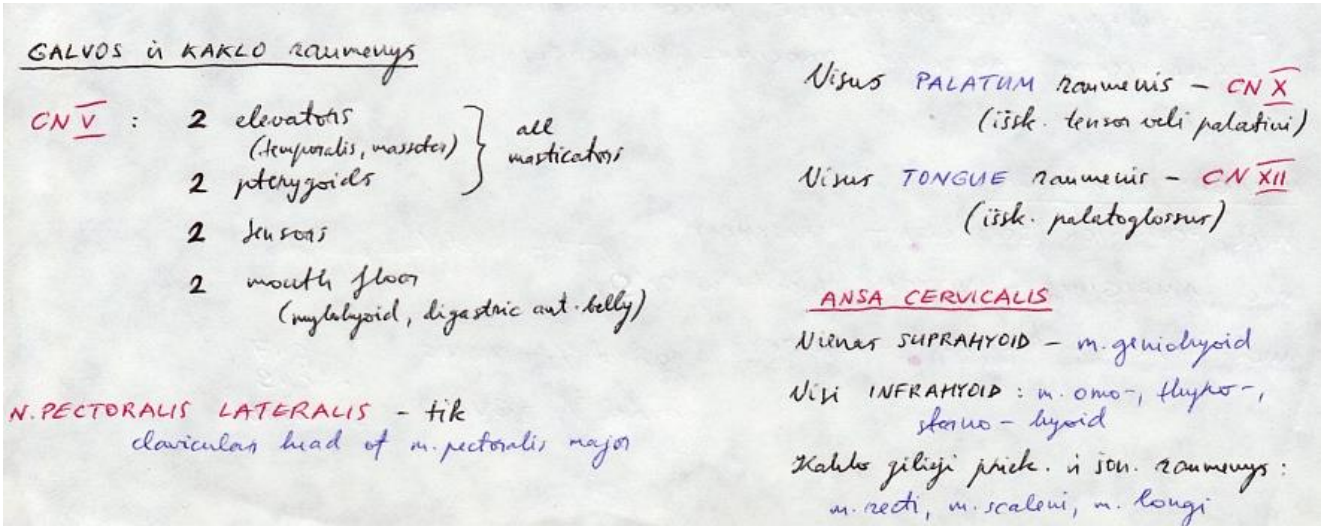
TEMPORAL ARTERITIS

never at age < 50 yrs

True jaw claudication.
Vision loss can be quick
1. ESR↑, CRP↑
2. Temporal artery biopsy – do within 5 days (up to 2 weeks) of steroid initiation.
   Before temporal artery biopsy, try to occlude artery – make sure no neuro deficits (e.g. ICA occlusion → STA-ophthalmic artery anastomosis for collateral flow).

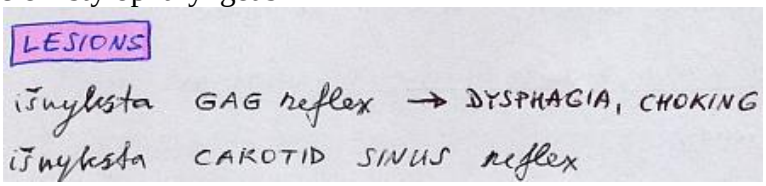
METHYLPREDNISOLONE 1000 mg IV → 160 mg/d

ANATOMY



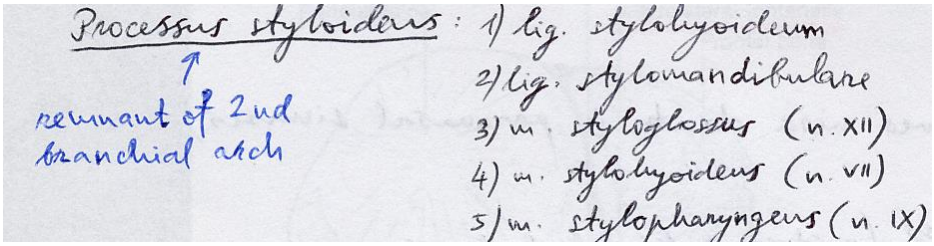
uvula, palatoglossus – CN X

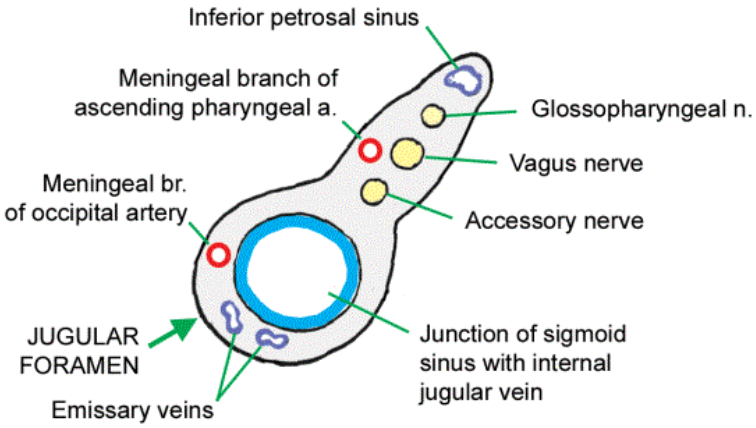
CN9 only muscle – stylopharyngeus



N.B. fibers to motor neurons of **CN7 (lower face)** and **CN12** are primarily crossed!
N.B. fibers to motor neurons of **CN11** (for sternocleido, not trapezius) are primarily ipsilateral!
vs. fibers to other motor neurons are equally distributed bilaterally

pterygopalatine ganglion = **sphenopalatine** ganglion





Sylvian point – skull point on nearest the Sylvian fissure and is located about 30 mm behind zygomatic process of frontal bone

CN7 frontalis branch(es) are located in the superficial fascia of the fat pad (not within the fat pad).