ABNS vignettes

Last updated: May 20, 2023

OPEN VASCULAR

Moyamoya – see P5 >>

CASE V1 – aSAH

35 yo F with explosive HA during intercourse. Hx – smokes, had HA 3 weeks ago (if no mention, ask about "sentinel bleeds").
Exam: 170/85, opens eyes to stim, nuchal rigidity, disoriented to year and location = H&H 3, WFNS 4
Remember – ABC, labs
Next – think about GCS (important for scoring!)

Head CT (fig. 6.1 – p. 44): basal SAH (more on L side with thick clot), mild↑ of ventricles = modified Fisher grade 3.
N.B. ***if CT negative for SAH (esp. after > 5 days) → LP***: RBC, xantho, OP – drain minimal CFS to avoid rebleed!
If LP negative (esp. after > 2-3 weeks), MRI (FLAIR, GRE, SWI, DWI) may show SAH
CTA – "poor bolus timing".
N.B. CTA may miss ≤ 3 mm aneurysm!
DSA (fig. 6.2 – p. 44): Left ophthalmic and MCA aneurysms (MCA slightly larger and lobulated)

Treatment
ICU
NICARDIPINE 5-15 mg/h to lower BP to < 140 (if poor grade HH ≥ 3 may use < 160)
EVD ± LD
NIMODIPINE for 21 days
KEPPRA until aneurysm is secured
Secure aneurysm ASAP after stabilization: likely MCA → clipping both aneurysms – Left pterional approach

- mention only if familiar and know rationale: IONM, navigation, ICG or fluorescein videoangiography, micro-Doppler, DSA.
- **proximal control** - expose carotid artery in the neck!!!
- mannitol when opening dura
- anterior clinoidectomy (intra or extra-dural)
- CSF drainage
- intra-operative rupture: temporary occlusion or trapping to facilitate controlled dissection
  consider adenosine IV bolus 30 mg (gives 5-15 sec asystole, 30 sec bradycardia = 60 sec of hypotension)
- base of MCA aneurysm incorporates M2 branch; clip slips down onto base (occludes parent vessel and/or branch) H: add second tandem clip above it, then remove first clip.
- verify patent flow in vessels + no flow in aneurysm (ICG or fluorescein videoangiography, micro-Doppler, DSA)

CASE V2 – AVM

20 yo had grand mal seizure; exam normal in ED, tox screen negative.
CT – R frontal hyperdensity.
MRI (fig. 6.3 – p. 48) – AVM without bleed.

Management
KEPPRA
Elective DSA (fig. 6.4 – p. 48): compact nidus, drains to deep veins
Craniotomy: wide crani flap to expose vessels:

- take feeding arteries
- dissect nidus circumferentially
- draining veins: smaller can be taken to facilitate dissection, major taken only after dissection is finished and nidus is devascularized.
  N.B. intraop IC green helps to distinguish between arteries and veins!
- complete with DSA (if some nidus is left – risk of postop ICH!)

Postop – normal perfusion pressure breakthrough – keep SBP < 130.

CASE V3 – spontaneous ICH

53 yo F (on anti-HTN meds and warfarin) found AMS: GCS 7t, BP 210/100, Left pupil dilated and sluggish, Right withdrawal
INR 3.4
CT (fig. 6.5 – p. 50) – large ICH with IVH
N.B. only typical hypertensive ICH in basal ganglia may skip CTA, others need CTA
CTA negative (fig 6.6 – p. 51)
N.B. FACTOR VII is not recommended (can prevent ICH growth but does not improve outcome!)

Management
SBP goal < 160 (AHA goal < 140 may be deleterious)
VITAMIN K
PCC (better than FFP)
Prophylactic Keppra is not recommended!
ICH score 3 and ICH is life-threatening – discuss with family neurological outcome prognosis! Family wants surgery → **craniotomy, evacuation** (role of DHC is not clear)

CASE V4 – spinal DAVF

72 yo with progressing walking difficulty, dull LBP radiating to legs along with paresthesias – symptoms worsen with walking, improve with rest. Takes tamsulosin for "urinary difficulty".
Did not improve with PT, ESI, NSAIDs.
L-spine XR, MRI – mild L3-4 spondy (no significant stenosis) – referred by PCP for "decompression".
On exam: distal legs motor 4/5, patchy diminished hypesthesia in legs, no Babinski but several beats of clonus.

Management
T-spine MRI (fig. 6.8 – p. 53): engorged dorsal perimedullary veins, distal cord and conus edema.
Spinal DSA (fig. 6.9 – p. 54): DAVF (type 1 malformation) at L3 on the Right, no associated Adamkiewicz.
CTA and MRA could be helpful in pre-DSA work up.

Treatment
L2-3 hemilaminectomy, open dura
Fig. 6.10 – p. 54: Localize arterialized vein leading to root sleeve → temporary clip (note vein caliber decrease) → coagulate and divide fistulous connection → remove clip → completion DSA.
Watertight dural closure ± drain → bedrest.

Complication

A) Postop, after resuming ambulation, develops weakness and numbness → MRI (epidural hematoma fig. 6.11 → evacuation); if MRI negative → DSA.
B) 12 months later, develops weakness and numbness → MRI (myelomalacia?); if MRI negative → MRA, CTA, DSA for recurrence

CASE V5 – carotid stenosis, TIA

70 yo M with HTN, smoker. 2 hour episode of R arm weakness, mild aphasia, visual disturbance, dizziness, nausea = TIA (risk of stroke: 5% in first month, 12% in first year)
N.B. hemodynamic TIAs resolve within minutes, embolic TIAs – within hours.
On exam – only L carotid bruit.

Management
Head MRI – normal
Head + neck CTA (fig. 6.12 – p. 55): patent circle of Willis, L ICA stenosis with smooth calcified plaque, no tandem lesions!
MRA overestimates, Duplex underestimates degree of stenosis
Cardiac ECHO + **ECG** also needed!!!

Treatment
ASA 325 + statin + BP control
CEA is better (male with 50-70% stenosis) – within 2 weeks after TIA / nondisabling stroke:

- general (EEG) or local anesthesia (neuro exam).
- expose CCA and ICA beyond plaque.
- divide facial vein.
- keep ansa cervicalis medial.
- HEPARIN 5000 units IV
- cross-clamp ICE + superior thyroid: if EEG↓ → increase BP → shunt (first into ICA, then into CCA)
- remove plaque → inspect both stumps for residual, intimal flaps (tack with 7-0 monofilament double-ended suture placed from intimal side)
- close
- remove clamps:
  1) superior thyroid
  2) ECA
  3) CCA (flushes debris into ECA) → clamp again
  4) ICA (flushes debris into ECA) → clamp again
  5) CCA
  6) ICA
- do not reverse heparin
- continue ASA at least 3 months postop
- tight BP control – to prevent ICH

Complication
Wound hematoma; if airway obstruction → awake fiberoptic intubation; if fails → direct laryngoscopy (re-opening incision may help); at worst – emergency tracheostomy; hematoma evacuation.
Cerebral hyper-perfusion – brain edema (unilateral HA / face / eye pain, seizure, focal deficits), ICH is rare. H: tight BP control
CN injury (most are stretch injuries – resolve within months): mandibular branch of CN7, recurrent laryngeal (due to medial retractor blade) / superior laryngeal of CN10, CN11, CN12

CASE V6 – ICA dissection, MCA stroke

45 yo F found down at home after 2 days. Admitted to ICU for rehydration.
On exam, Left Horner (without anhydrosis), Right hemiplegia, dysphasic
CT – > 50% Left MCA territory hypodensity = "malignant MCA stroke"
CTA – L ICA occlusion from dissection

Treatment
Patient is < 60 yrs → discuss with family early (< 48 hrs) **DHC with duraplasty**
Dr. Thomas Leipzig – side of stroke should not matter: aphasia improves, hemineglect as detrimental as aphasia

ENDOVASCULAR

BA stroke – see N1 >>

CASE E1 – ruptured AComA aneurysm

58 yo F with worst-headache-of-her-life, N/V in ED. Lethargic, but oriented x3 and intact.
Noncontrast **CT** (fig. 7.1 – p. 64) – diffuse SAH, mainly in anterior aspect of corpus callosum, no IVH, no HCP, no hypodensities.
if CT was negative → LP
DSA (fig. 7.2 – p. 64) – AcomA aneurysm 2x1.5 mm

Treatment – multidisciplinary team approach – decided on coiling
ICU
Nimodipine
A-line + Swan-Ganz for hemodynamic monitoring (goal SBP < 140-160)
EVD
Monitoring: MEP, SSEP, EEG, BAER
General anesthesia
Insert (Seldinger technique) 7F sheath through R common femoral artery (alt: radial artery) connected to heparinized flush
Advance guiding catheter over guidewire to aortic arch
Selective catheterization of L ICA → multiple contrast runs in different views → advance microcatheter over micro-guidewire into aneurysm → deploy platinum coils.
Completion DSA
Remove sheath, hold pressure for 20 mins → immobilize leg for 2 hrs.

Postop: CTA / MRA at 6 mos, 1 year, then depending on occlusion status – if recurrence → DSA.
DSA at 16 mos (Fig. 7.3 – p. 65) – complete occlusion of aneurysm

Complications
1. Access-related: hematoma (groin, retroperitoneum), pseudoaneurysm
2. Thromboembolic / vessel dissection
3. Aneurysm / vessel rupture

CASE E2 – unruptured cavernous ICA aneurysm

68 with persistent headaches and 2 episodes of diplopia (family hx of SAH).
CT – negative
CTA (fig. 7.5 – p. 67) and **DSA** (fig. 7.6 – p. 67) show R cavernous ICA 10 mm wide-neck lobulated aneurysm

Management – options:
1. **Observation** with periodic F/U (treat if aneurysm [size, morphology] changes)
2. **Endovascular** – best choice (older female with symptomatic > 10 mm aneurysm and positive family history of SAH)
3. **Clipping**

PIPELINE flow diverter was chosen (due to wide-neck, dome large);
10 days preop start ASA81 and PLAVIX (check P2Y12 on day of surgery*) – make sure patient agrees with compliance! (else – abort procedure or use WEB – does not need DAP)
if < 60-90 – do not proceed (if bleeding happens it will be catastrophic);
if nontherapeutic (> 194), proceed with ReoPro intraop, then prasugrel (Effient) postop
Monitoring: MEP, SSEP, EEG, BAER
General anesthesia
HEPARIN bolus (ACT goal 2-3 times baseline) – difference from simple coiling!
Stop heparin at end (no reversal)

CASE E3 – unruptured AComA aneurysm

61 yo with stroke; nonsmoker;
MRA (fig. 7.8 – p. 69) found incidental 6 mm AComA aneurysm
DSA (fig. 7.9 – p. 70) – wide-necked 6.8x5.7 mm aneurysm

Management – ***stent-assisted coiling*** (due to wide neck) with bifurcation stent PULSERIDER
10 days preop start ASA81 and PLAVIX (check P2Y12 on day of surgery)

CASE E4 – unruptured ICA and MCA bifurcation aneurysms

66 yo with incidental L ICA bifurcation 6.5x4.4 mm aneurysm (wide neck) + 1x1.6 mm MCA bifurcation aneurysm – **DSA** (fig. 7.12 – p. 73)

ICA aneurysm is large and needs treatment – it is at bifurcation – options:
a) stent-assisted in Y configuration
b) PulseRider, pCONus
c) WEB – does not need antiplatelets!
N.B. flow diverters (Pipeline) are not an option at bifurcations!

CASE E5 – AVM

21 yo with de novo grand mal; neuro intact.
CT (fig. 7.14 – p. 75) – L temporal tubular hyperdensity

Management
DSA (fig. 7.15 – p. 75): Left temporal 2.4 cm AVM with M3-4 feeders and superficial drainage.
ARUBA says that medical management is superior for up to 33 months.
Because of seizures, decision was made to **embolize** – accomplished complete obliteration with ONYX in 2 sessions.
Postop - ICU – to maintain mild hypotension for 24 hrs

CASE E6 – MCA stroke

77 yo in ED with aphasia, R hemiplegia. LKWT – 5 hrs. NIHSS – 22.
CT (fig. 7.17 – p. 78) – subtle loss of gray-white differentiation.

Management
ABC, labs (CBC, BMP, coags), ECG
TPA IF ≤ 4.5 HRS
N.B. stroke imaging should not delay tPA
CTA (fig. 7.18 – p. 79): cut off of M1
pCT: increased transit time (fig 7.19), decreased flow (fig. 7.20), but normal blood volume (fig. 7.21) in L MCA territory = mismatch

Thrombectomy if ≤ 8 hrs – with stent-retriever under general anesthesia.
- femoral access in paralyzed leg
- if proximal disease – angioplasty ± stenting to allow access to thrombus
- postop to ICU

Complication
ICH – reverse heparin, give platelets and FFP, BP↓; if large ICH – mannitol, intubation, consider clot evacuation

BRAIN ONCOLOGY

Tumor Near Language Area – see F1 >>
Tectal Glioma – see P3 >>
Posterior Fossa Tumor – see P4 >>

CASE O1 – melanoma mts

72 yo with acute n/v, ataxia, confusion, HA. On exam – R dysmetria, gait ataxia, motor 5/5.
Smoker, insulin pump, multiple cardiac stents.
Systemic melanoma – controlled with Nivolumab

CT, MRI (fig. 5.1 – p. 24) – multiple enhancing lesions with surrounding edema: three in cerebellum (largest 2.3 cm), one in R frontal (2.5 cm)
Do not jump on surgical plan!!!
Start with:
1. Performance status (operate if KPS > 70 – functions independently, spends < 50% time in bed)
2. Metastatic burden (ask for recent CT CAP, PET scan) – discuss at Tumor Board, ask for life expectancy (aim > 6 mos)
3. Differential – multiple hemorrhages (embolic infarcts, amyloid angiopathy), abscesses, demyelinations, immune-related lesions (2/2 systemic therapy) only then multifocal glioma vs mts vs lymphoma

Single metastasis – no brainer (class 1 evidence): surgery → XRT
Oligometastases – bit controversial but be aggressive surgically* (even if it involves multiple craniotomies during the same setting – remove all possible lesions [even small ones – use intraop US to localize] through each craniotomy). *historical hesitance was due to poor prognosis in brain mts (now it is different – modern systemic therapy!)

MANAGEMENT

Cerebellar lesions are symptomatic - **resection** of all 3 through same craniotomy
Frontal lesion – edema probably contributing to HA, edema may worsen with XRT – reasonable to **resect** now (reasonable to also discuss with the patient and **observe** – if worsens after XRT, may resect then)

Position – prone (will need to reposition for frontal crani after suboccipital crani) or lateral (may do both craniotomies).
Approach for frontal:
a) frontal crani – too big
b) eyebrow crani – frontal sinus is too big
c) keyhole frontal crani through forehead wrinkle → tubular brain retractor
Use microscope, navigation and US (esp. to localize deeper cerebellar lesions).

Resection for metastases – en bloc* (to minimize leptomeningeal spread), with 5 mm brain margin (to reduce recurrence) *may shrink lesion capsule to ease dissection

Postop – SRS at 2-3 weeks (incision healed, resection cavity is smallest)

MRI every 2 months (along with systemic staging)

CASE O2 – pituitary adenoma

35 yo F is seeing gynecologist for amenorrhea. [prolactin] 86 (normal 2-29). Patient also admits "running into objects"

Management
Humphrey visual field testing (fig. 5.3 – p. 26) – significant vision loss in L eye
MRI (fig. 5.3 – p. 26) – 2 cm pituitary mass with suprasellar extension displacing optic chiasm, no cavernous sinus extension.
N.B. check MRI for kissing carotids (intercavernous distance)
N.B. check CTA for bony floor dehiscence
Endocrine battery: [prolactin] 86 remains after dilution – not prolactinoma!
Ask **ENT** to evaluate for access and nasoseptal flap.

Top differential – pit adenoma (but know the whole list)

Treatment – TSR with harvesting nasoseptal flap
± LD (may defer to see if CSF leak happens)
if tumor had significant suprasellar extension, would add subfrontal
reconstruct sella floor: bolster arachnoid web with Gelfoam → DuraMatrix → piece of vomer → fibrin glue → nasoseptal flap → nasal splints

Complications
1. **CSF Leak** (with large tumors, esp. extending into floor of 3rd) H: LD, nasoseptal flap, HOB up, Diamox, surgical repair, shunting.
2. **Optic Nerve Injury** (avoid excessive packing of sella vs. optic chiasm herniation into empty sella – need pack sella)
3. **Carotid Injury** (prophylaxis – avoid cutting burs and carefully remove intra-sphenoid septations, avoid traction on tumor):
   - alert anesthesia and start resuscitation (maintain slight HTN – to promote perfusion) + carotid compression in the neck
   - large bore suction
   - place endoscope in opposite nare and apply pressure with cottonoid (ideally place crushed muscle or fat to promote hemostasis), pack nasal cavity to stop bleeding (do not occlude carotid!)
   - transport to DSA: stenting, sacrifice; vs need surgical bypass
4. **DI intraop** H: DDAVP

Postop
CSF leak prevention
Monitor for **DI**: strict Is and Os, BMP and urine spec gravity QID
Ancef with nasal packs for 3 days
Hydrocortisone PRN with taper
MRI – residual lesions should be monitored

- cavernous sinus inflammation (from tumor resection, sella packing, fracture, hematoma, residual tumor, infection) – delayed oculomotor palsy; LP to rule out infection → short course of steroids.

CASE O3 – GBM

74 yo with few weeks of L hemineglect, L hand weakness, confusion
MRI (fig. 5.4 – p. 29) – large R occipito-temporo-parietal lesion, heterogeneously enhancing, significant edema

Differential: mts, high-grade glioma (most likely given age and rapid progression), lymphoma, tumefactive MS, subacute stroke, abscess

Treatment – maximum safe **resection** (aim for **GTR** – location is permissive)
Discuss other options: observation, biopsy, chemoradiation

Postop – MRI, **Stupp protocol** (watch for hematotoxicity)

At 9 mos, MRI (fig. 5.6 – p. 31) shows area of enhancement anterior to resection cavity;
pMRI – increased rCBV = recurrence → **redo resection** (as KPS still OK, no eloquent involvement)
Restart TEMODAR; first MRI showed progression (incl. FLAIR↑ with mass effect↑) → AVASTIN (risk of bleeding & wound dehiscence) + STEROIDS
If keeps progressing – consider CARMUSTINE wafers, **SRS**, **LITT**, **GammaTile**, **Optune**

CASE O4 – LGG

32 yo with R-sided HA
MRI (fig 5.7 – p. 33): nonenhancing FLAIR-homogenous R insular mass = likely low-grade glioma.

Management
a) observation – historical option
b) XRT
c) surgery – first choice (gives prolonged overall survival)

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

Insula function – multimodal integration and association of sensory and limbic functions!
Important subcortical tracts – internal capsule, uncinate fascicle, IFOF

Preop fMRI and DTI

Awake craniotomy + multidisciplinary team
Keep mild sedation but avoid needing intubation (esp. obese, sleep apnea)
KEPPRA ± SECOND AED – to prevent seizures during stimulation!!!
Navigation
Electrical cortical and subcortical mapping (sensory, motor; if tumor was on dominant side – add language mapping) – bipolar Ojemann stimulator at 60 Hz, increasing current from 1-2 mA to max. 6-10 mA while watching for afterdischarges.

Dr. Komotar uses 5 mA bipolar for **cortical**, 5 mA monopolar for **subcortical** mapping

- if *seizure* – stop mapping, ice cold irrigation, ↑oxygen, small doses of PROPOFOL, load with PHENYTOIN
- motor mapping can also be done asleep (but not sensory or language mapping – not acceptable for insular resections) – needs up to 13 mA

A) **Trans-Sylvian approach (Yasargil)** – split fissure widely, mapping, avoid coagulating M2 perforators and lenticulostriate vessels.
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)

Postop MRI (fig. 5.8 – p. 34) – *subtotal resection** – needs immediate** adjuvant therapy:

N.B. discuss at Tumor Board (for best strategy + available clinical trials)

1. **XRT** - low dose (equivalent to high dose)
2. **Chemo** – Temodar or PCV

*if it was GTR, oligo, IDH-mutant, < 40 yo – regular MRI surveillance was an option (progression – start adjuvant)
** increases PFS but not overall survival – as compared to delayed XRT

Regardless of adjuvant therapy timing, need **surveillance MRI** q3-6 mos for 5 yrs (then q6-12mos)

CASE O5 – olfactory groove meningioma

59 yo in ED after grand mal. Neuro intact. Family mentions progressive personality change.
Check for Foster-Kennedy syndrome (anosmia, papilledema – optic atrophy).
MRI (fig. 5.9 – p. 36): large enhancing mass arising from planum sphenoidale, bifrontal edema.
Dif: meningioma, hemangiopericytoma, mts, pituitary adenoma, craniopharyngioma.

Management
KEPPRA
DEX 10 mg → 4q6
MRA or DSA to assess feeders + ACA location

Surgery – options:

A. **Endonasal** – allows early access to feeders, avoid brain retraction; make sure tumor does not extend lateral to lamina papyracea; need through multilayer dural closure (CSF leak is common).
B. **Pterional** – allows early exposure of optic apparatus and ICA; long reach to contralateral side of tumor; difficult to reach superior tumor; difficult skull base repair.
C. **Interhemispheric**
D. **Subfrontal** (best choice!) – allows early access to ethmoidal feeders (tumor disconnection minimizes blood loss)
    - check CT for size of frontal sinus – develop ***pericranial flap*** during bicoronal incision (protect CN7 in temporal fat pad), remove posterior wall of frontal sinus and strip sinus mucosa down to nasofrontal duct (***exenteration***), remove mucosa islands with diamond burr and plug with fat / muscle / Gelfoam and cover with pericranial flap – else, risk of mucocele.
    - orbital osteotomies minimize frontal lobe retraction.
    - scalp reflected over orbits (may develop oculocardiac reflex bradycardia if too much pressure).
    - need to sacrifice anterior part of SSS (study MRV to prevent venous stroke).
    - debulk tumor with CUSA
    - carefully separate posterior tumor from ACA, optic nerves and chiasm (→ postop vision loss H: steroid boost).
    - remove tumor-invaded dura, drill off hyperostotic bone.

Postop:

- continue dex
- recurrent or malignant tumors need XRT (SRS).

Complication
POD2 – severe HA, grand mal; MRI shows extensive frontal edema H: dex booster, dual AED.

NEUROLOGY

Acute focal presentation with negative head CT:

1. Stroke
2. Seizures
3. Complicated migraine
4. Hypoglycemia

CASE N1 – BA stroke

88 yo (takes dual antiplatelets, XOL, HTN) presents with AFib → admitted → AMS, weak cough / gag, extends arms → intubated
Head CT – negative (old cerebellar stroke)
Determine candidacy for thrombolysis: LKWT 30 minutes, no anticoagulants, no recent trauma / ICH / major bleeding
Thrombolysis 0.9 mg/kg (max 90 mg)
Only then do **CTA** – M1 / ICA / VA / BA occlusion within 6 hrs? (now also M2-3 within 24 hrs)
CTA and then DSA - distal BA occlusion (fig. 13.2, p. 188)
Thrombectomy fails
Repeat hCT – SAH, midbrain bleed
Reverse tPA: cryoprecipitate (10 U), TXA (1 gm over 10 minutes), platelets (6-8 units) → send aPTT, INR, fibrinogen (repeat reversal if needed)
Goals of care discussion

CASE N2 – ALS

68 yo with 6 months of worsening R foot dorsiflexion weakness (with tibialis anterior atrophy), leg spasticity with bilateral Babinski, bilateral deltoids 4/5, no other symptoms, normal sensory
N.B. UMN and LMN signs
CPK elevation - persisted after stopping statins.
C, L-spine MRI – mild-moderate central canal stenosis, cord normal.
→ **EDX**: thoracic paraspinal muscle denervation bilateral, normal H and F, normal sensory nerves.
N.B. that means selective involvement of motor roots.
Rx: supportive, RILUZOLE (slows down progression but does not change outcome).

CASE N3 – baclofen withdrawal

28 yo with old TBI and baclofen IT pump.
Presents with AMS, confused, agitated, spasticity↑ with bilateral Babinski, sinus tachycardia, 39º, diaphoresis, BP 95/50
Head CT – encephalomalacia (old TBI)

Differential:

1) sepsis (cannot explain spasticity↑) – send blood Cx, UA, CXR → broad spectrum abx
2) baclofen withdrawal - check **KUB XR** – baclofen pump and catheter integrity, normal bowel gas pattern → interrogate pump, aspirate catheter for dye study

N.B. may progress to rhabdomyolysis, coma, BP↓ (cardiac depression, vasodilation)

Treatment
Oral baclofen – 20 mg q6 via NG tube
Diazepam
Cyproheptadine
Cooling
Pump exploration in OR (or at least IT delivery via LP or LD)

CASE N4 – Guillain-Barre

58 yo M with 2 days of walking difficulty progressing to arm weakness, back pain, mild dysarthria, flattened nasolabial folds bilaterally, all reflexes↓; he had URVI 2 weeks ago (/ vaccination / diarrhea)
Brain + C-spine MRI normal
Rapidly progressing weakness + areflexia = Guillain-Barre (dif: botulism, myasthenia gravis)
LP: albuminocytologic dissociation
Treatment
Consider ICU
Measure q4hrs – vital capacity, negative inspiratory pressure
IVIG or plasma exchange
N.B. **no to steroids**!

CASE N5 – Status Epilepticus

64 yo F with HTN, presented with ICH and herniation (pupillary dilation, posturing) – underwent decompressive hemicraniectomy (but ICH was left untouched – see fig. 13.8 p. 193) – postop pupils normal, hemiplegia, follows commands
On POD2 – eyes closed, localizes, **gaze deviation***:

- repeat head CT – stable (no worsening) edema and ICH, basal cisterns open.

*suspect status → STAT LORAZEPAM 0.1 mg/kg in 4 mg doses, **prepare to intubate** (i.e. OK to give benzos even if not intubated), increase (double) KEPPRA dose 750 → 1500 BID, **vEEG** (if still seizing → load second ASM → if still seizing, start IVI MIDAZOLAM / PROPOFOL / PENTOBARBITAL – all may cause hypotension, so have pressors ready!).

N.B. avoid **valproic acid** postop (antiplatelet effect)!
N.B. treat SE first before transporting to CT

CASE N6 – MS

42 yo F with 1 month gait unsteadiness, now LLE weakness. 6 mos ago had ↓vision in left eye that improved spontaneously.
On exam, afferent L pupillary defect, LLE 4/5, bilateral Babinski and DTRs↑
MRI – several periventricular FLAIR↑ but non-enhancing (fig. 13.9, p. 194)
Relapsing course in young patient without vascular risk factors (else – suspect microvascular disease) = MS
CSF: oligoclonal bands + myelin basic protein + Ig index

- also check PCR for viruses (HSV, VZV, EBV, CMV)

Serum – check for neuromyelitis optica and MOG (myelin oligodendrocyte glycoprotein) antibodies.

Treatment: 1000 mg METHYLPREDNISOLONE → disease-modifying therapy.

CASE N7 – untreated TGN

52 yo F with x 1 year of Left cheek and temple "electric shock" when chewing / talking / washing face.
MRI normal (no CN5 root compression).
Treatment – carbamazepine; may add baclofen, lamotrigine, gabapentin.

TBI

CASE T1 – DAI

18 yo F after high-speed MVC. Intubated, CXR – PTX (ask for chest tube!)
Significant facial trauma, R pupil is blown, motor – M3.
Ask about **hemodynamics** (always ABC, esp. in trauma): BP 80/40, HR 120 – ask for resuscitation (2 liters LR – rapid improvement – major injury is less likely)
Ask for **labs**, incl. tox screen, pregnancy test, coags
Ask for **trauma CT: head, spine**!!! (do not miss terrible Chance fracture!): punctate IPHs*, R orbital fractures, no mass lesions, cisterns "tight"
*DAI – due to angular acceleration-deceleration when head rapidly rotates on its axis

Treatment No steroids per CRASH study!
ICU
Goals - normotension, no hypoxia
KEPPRA? *Insufficient evidence* but safe to give 1000 mg BID.
R frontal EVD (indication – GCS < 8, abnormal CT; EVD allows CSF drainage and easy recalibration and MRI-compatible) – antibiotic-impregnated catheter, Level 3 evidence favors continuous drainage over PRN, ICP goal < 20, CPP goal 60-70.
Dr. Gary Simmonds – PtiO2 monitor is not better than EVD
EVD shows 44 mmHg – HOB up, neutral neck, sedation, hydration with NS + 24.3% NaCl or mannitol, CSF drainage.
Hyperventilate? – no (or at best for short duration) as within first 24 hrs brain is especially sensitive to vasoconstriction-induced hypoxia.
ICP was well controlled, but suddenly increased – make sure EVD is leveled, no mechanical causes, seizures, hyponatremia, not sedated adequately, hypercarbia – if none → STAT CT; check for exam asymmetry (→ STAT CT)
STAT CT shows that **1 cm of EVD is in thalamus** – if good wave form and draining CSF – do nothing!
STAT CT shows **2 cm hematoma around EVD** – if ICP controlled, do nothing; if needs decompressive hemicrani (for ICP), consider evacuating it

CASE T2 – DAI, refractory ICP

Same as in Case 2, just ICP gets refractory (EEG – slowing but no seizures) although CPP 60

A) pentobarbital coma (risk of systemic complications, prolonged lack of neuro exam)
B) **decompressive craniectomy** (better choice for young patient without anoxic injury):
   a) one side is worse → hemicrani
   b) CT symmetric → bifrontal

Postop – normal ICP but next morning ICP 50 – unwrap head, check flap, STAT CT.

5 days later: fever, neuro↓ - send CSF and start vanc (Staph) + cefepime / meropenem / cipro (Gr-rods)

CASE T3 – GSW

21 yo with GSW to the Right head
Intubated. R pupil blown. M5 with R hand, L hemiplegia
Head CT – thick acute R SDH with 3 cm MLS.

Treatment
Post for level 1 crani
Resuscitate (ABC!), hyperventilate, mannitol
Keppra, Ancef for 7 days, tetanus toxoid
Shave entry and exit wounds
Large trauma flap
Evacuate hematoma (leave small amount along SSS and place Gelfoam along it)
Bullet track: gently debride, remove large readily-accessible fragments (do not go deep to chase every bit – does not help with infection risk, may cause deep bleeding)
Bleeding superficial brain vessel – tamponade with cottonoid patty → peel it back slowly → bipolar → leave Gelfoam over it
Do not replace bone – GSW tend to swell
Place **EVD**
CTA at day 5 – look for pseudoaneurysms

CASE T4 – EDH

17 yo football trauma – knocked unconscious → lucid → collapses: hemiplegic, pupil blown
Do not rush to CT and surgery – ABC first (intubate, resuscitate) → STAT CT head & panspine
Head CT shows 2.5 cm convexity EDH → STAT craniotomy (to encompass entire width of EDH – so can place 4-0 silk dural outer layer tack-ups along perimeter + centrally; place drain; replace bone* [unless obvious brain edema = something else is going on]!!!)
*vs. in SDH – more often bone is not replaced (unless brain is relaxed and not contused)

Postop extubated, intact. Next morning – 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
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 KEPPRA 60 mg/kg
4) send STAT labs
5) if unknown patient – give thiamine and D50
6) if still seizing – intubate, start IV drip (PROPOFOL or MIDAZOLAM), vEEG (ask for neurology)

"*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

If CT is available (side of EDH is known): at root of zygoma → over max thickness of hematoma

CASE T5 – AVM bleed

25 yo car vs pole: awake, talking, amnestic (does not remember circumstances or HA), facial abrasions, seatbelt sign on chest, no major injuries, hemiparetic, cranial nerves intact

Head CT (fig. 8.5, p. 96): 5x4x3 cm ICH in deep frontal lobe with small IVH
N.B. it is likely not trauma case! → ask for hx of syncope, epilepsy, HTN, HA, tox screen, CTA

Awake patient, rather deep location – OK to watch

Differential (young pt with spontaneous ICH): AVM, aneurysm, illicit drug, tumor, venous sinus thrombosis (judicious anticoagulation + hydration + observation)

CASE T6 – open depressed skull fracture

30 yo fell from horse without helmet – dirty scalp laceration.
Ortho injury needing repair.

Head CT (fig. 8.6 p. 98) – comminuted depressed (2 cm) skull fracture, small pneumocephalus and subjacent contusion.

Treatment – **surgery** ASAP (within 24 hrs) Keppra + tetanus + broad-spectrum abx for 7-10 days!

Indications: > 1 cm depression, dural laceration, gross contamination.
Other indications: cosmesis (low importance for children* – fracture smoothens as skull grows), frontal sinus, significant hematoma / contusion, related neuro deficits

N.B. be less aggressive with:

1) **closed** depressed fractures!
2) depressed fractures **over major venous sinus** (risk of bleeding / sinus occlusion)

N.B. elevating fracture does not change seizure risk (seizures are not an indication)

*ping-pong (greenstick) fractures do not lacerate dura! (i.e. elevate only if neurological deficit or still CSF leak) – small bur hole adjacent to fracture and pop it back with Penfield elevator (may place temporary cranial screw through the middle of fracture to assist with grasp for elevation)

Details

- incorporate laceration into incision
- expose normal skull around fracture
- check for fragment mobility; drill bur hole next to fracture → slide Penfield dissector and elevate fragments (may need to drill around more) → soak fragments in Betadine → inspect dura: open laceration wider to inspect and debride clearly contused brain → irrigate profusely (Dr. Simmonds says "with bacitracin") → Surgicel on brain (hemostatic and bactericidal) → close dura water-tight → dural tack-ups → bone fate:
  a) try to reconstruct with microplates and replace (infection rate the same) – preferable!
  b) *hopelessly comminuted, terribly dirty* – discard

Doing well postop (lucid) but next day – difficulty to arouse, nonfocal, tachypneic, hypoxic, petechial rash – fat embolism! (H: steroids, hyperbaric oxygen with PEEP)

CSF leak / neuro deficit and fracture over SSS
Try to isolate other fracture fragments and leave bone over SSS untouched.
If need to elevate – be prepared to repair sinus – wide exposure, have Fogarty catheter (for temporary occlusion), large-bore suction, central line, blood ready. Also think air embolism!

PNS

CASE PN1 – benign nerve tumor

45 yo with 6 months of calf pain and dysesthesias radiating to plantar foot. No other symptoms (incl. no back pain, negative Lasegue)
Tinel at proximal posterior calf – suspect tibial neuropathy
OSH L-spine MRI – normal
EDX – normal

It is unusual site for compression – order **MRI of proximal legs**: T2 hyperintense, well-circumscribed 2 cm lesion on tibial nerve (fig. 10.1, p. 122) – suspect benign tumor

Check family history + skin for NF stigmata

Main concern for Boards – identify malignant tumor preop:

Hx of NF, rapid growth, refractory pain, motor deficits! → MRI (irregular borders, irregular enhancement, necrosis, invasion) → PET CT (↑ avidity with standardized uptake value [SUV] > 5.2)

Treatment – discuss:
A. **Observation** (for small asymptomatic tumors)
B. **Resection** (better choice as tumor is symptomatic):
- prone
- use US to localize incision
- open interval between gastroc heads and identify tumor, proximal and distal nerve
- use stimulator (1-2 mA, watch for EMG and/or nerve action potentials) to find where it is safe to open capsule, then identify and stimulate entering and exiting fascicles
- sweep unrelated fascicles away and resect tumor (i.e. tumor resection is at fascicular level).

In PACU: severe refractory calf pain, weak plantarflexion, numb plantar foot – suspect hematoma: inspect wound → evacuate emergently.

CASE PN2 – sharp nerve transection

40 yo with sharp machete injury into popliteal fossa with immediate foot drop; wound was closed in ED; you see patient 4 days later – suspect sharp nerve transection → immediately prepare for OR

Rule out: tibialis injury (normal plantar flexion; tibial nerve is deeper), popliteal artery injury (normal pedal pulses)

No other test (imaging, EDX*) is needed

*it takes 3 weeks to show denervation

Treatment
Consent for possible nerve (sural) grafting
Open wound, may need to extend incision to see both nerve ends clearly (do not get fooled – if stimulating distal end, will still get muscle contraction as wallerian degeneration did not happen yet);
- may also find transected lateral sural nerve that branches off common peroneal nerve (fig. 10.7) – this does not preclude sural grafting (wallerian degeneration did not happen yet)

Dissect stumps circumferentially and freshen ends.
Always aim for **direct end-to-end repair without tension*** (release fibular tunnel, flex knee): Prolene 8-0 to 10-0 microsurgically into epineurium (align fascicles as best as possible); may reinforce with fibrin glue.
- if too much tension – use sural nerve (may yield several grafts) **interposition grafts**.

Postop – **immobilize knee** in 30-45 degree flexion for 3 weeks (patient has to use **crutches**) → ambulate as tolerated with **AFO** while keeping heel cord supple;
- once strength returns in several months, wean AFO.
- if strength does not return → referral to ortho for tibialis posterior tendon transfer.

*techniques to decrease tension:
1. **Dissect** stumps circumferentially for mobilization
2. **Transpose** nerves, if feasible, to make a straighter line (e.g. ulnar or radial nerves)
3. **Flex** and immobilize joint for 3 weeks

N.B. immobilize limb for 3 weeks after any nerve repair!

CASE PN3 – brachial plexus stretch

18 yo was in MVC 6 months ago – not improving paralysis of dominant arm (shoulder motion, elbow flexion); Tinel in supraclavicular fossa.
EDX: EMG shows no activation and 3+ fibrillations in deltoid, biceps, infraspinatus (but rhomboids and cervical paraspinal muscles normal); NCS in lateral antebrachial nerve is absent.
CXR – normal
CT myelogram – no pseudomeningoceles.

Diagnosis: post-ganglionic upper trunk plexopathy

Treatment - **supraclavicular approach**: zigzag incision (posterior to SCM, then parallel to clavicle), mobilize EJ vein, divide omohyoid, reflect fat pad laterally, see phrenic nerve on anterior scalene and trace to C5 nerve. Divide anterior scalene to uncover brachial plexus in interscalene space (trunks are lateral to anterior scalene, subclavian artery is caudad to lower trunk).
- 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**** or **nerve transfer**

*to good fascicular structure visually (may even use microscope and frozen section to confirm)
**may attempt end-to-end repair if possible without tension; else, harvest longer donor nerve segment than the gap (preferably, sural – incision from ankle extending up to popliteal fossa – may give up to 40 cm of nerve)

What if it was preganglionic injury (rhomboids and cervical paraspinal muscles affected as well, abnormal myelogram – asymmetry or frank pseudomeningoceles) – intraop recorded NAPs but absent evoked potentials – only option is **nerve transfer**
1) distal spinal accessory nerve to suprascapular nerve
2) branch of triceps to axillary nerve
3) T3-5 intercostal nerves to musculocutaneous nerve (in axilla) or Oberlin transfer (expendable fascicle of ulnar nerve to biceps branch of musculocutaneous nerve

N.B. closer donor nerve is to end-organ, faster and better recovery of function.

CASE PN4 – brachial plexitis (Parsonage-Turner)

35 yo got tetanus shot* → severe periscapular pain for 10 days → weakness of raising arm above head for 6 months. *ask about any infections, vaccinations, surgeries, trauma
Sensory normal.
Able to abduct and flex forward shoulder 90º (strong deltoid and supraspinatus)
Prominent scapula winging (serratus anterior)

> Parsonage-Turner classically affects long thoracic nerve ± suprascapular, axillary, AIN, PIN; vs. **spinal accessory to trapezius** (but not SCM) with posterior cervical triangle surgeries; vs. **dorsal scapular nerve to rhomboids**

C-spine MRI – mild multilevel NFN
Brachial plexus MRI – subtle T2 hyperintensities (nonspecific inflammation)
EDX (N.B. routinely does not include serratus anterior – ask for it!) - serratus anterior fibrillations but also nascent units (sign of reinnervation!)

Treatment
1. **PT**
2. **Pain management** PRN
3. Short course of steroids empirically (no proven benefit)

4. Surgical decompression (at middle scalene level) is controversial – given reinnervation signs it is not indicated
5. **Counsel** about:
   1) risk of second attack or family members
   2) recovery may take up to 2.5 years (long nerve!) – 80% reach good (but incomplete) recovery; tendon transfer to stabilize scapula / address pain may be considered at 2 yrs.

CASE PN5 – meralgia paresthetica

38 yo obese man with 3 yrs of burning lateral thigh pain (unable to wear long pants) with allodynia and numbness. No back pain, no weakness (incl. quad), normal DTRs. Tried many pain meds.

Tinel (+) just medial to ASIS
L-spine MRI – normal (main dif. L3 radiculopathy)
EDX (limited in obese, LFCN not routinely tested) – asymmetry in LFCN
MRI/US of LFCN – subtle abnormality

Treatment
Weight loss, avoiding tight belts.
US-guided LFCN block – diagnosis, first-hand experience of numbness.
Surgical exploration: transverse incision along Langer lines just medial to ASIS (longitudinal incisions – more problems); LCFN is large nerve just distal to inguinal ligament beneath fascia that overlies sartorius (may use US to find nerve); compression against inguinal ligament was found:
   a) release inguinal ligament laterally (to avoid hernia)
   b) neurectomy (allow proximal stump to retract into pelvis)

CASE PN6 – failed CTR

(open and endoscopic CTRs have similar outcomes long term; endoscopic – better within first 3 months but also higher risk of neurological complications)

57 yo had CTR 2 months ago (scar does not extend distally enough – fig. 10.13, p. 132). Immediately postop he noticed dense numbness in radial 3.5 fingers and new thumb weakness (on exam – it is APB).

EDX – severe complete median neuropathy across wrist with fibrillations (and no motor units) in APB.
MRI of wrist (fig. 10.14) – flattened T2↑ nerve at distal carpal tunnel (incompletely divided transverse carpal ligament) but nerve is in continuity (main goal of imaging was to rule out transection!)

Treatment – **revision surgery**:
- lengthen incision distally and proximally (to identify normal median nerve).
- dissect nerve circumferentially (complete decompression).
- distal ***transverse carpal ligament was divided**** – indentation and hyperemia is seen (fig. 10.15) N.B. if did not have MRI preop, needed to consent for nerve grafting.

*make sure see palmar fat – indicator of distal release!

SPINE

CASE S1 – bilateral locked facets C6-7

18 yo after fall – in ED (9 hrs later) with C6 ASIA A (wrist extension 4/5), neurogenic shock* (BP 90/60, HR 45), respiratory stable. *common with SCI above T6 (enough sympathetic output disrupted)
CT – bilateral locked facets C6-7 with 50% listhesis and significant canal narrowing
STAT MRI if hemodynamically stable (fig. 9.2, p. 104) – C6-7 disc extrusion and/or hematoma behind C6, significant disruption of posterior elements, cord edema
CTA – if VA injury, state right away "Aspirin will be needed at 3 days postop"

Management
Stabilize first!
1) C-collar
2) ICU
3) A-line (MAP goal > 85), IV fluids, pressors (norepinephrine, dopamine)
4) Get ready to intubate (esp. if SCI ≥ C4) – inline traction or awake fiberoptic
5) Steroids "not recommended" (by current CNS/AANS guidelines) but may discuss in *young patient within 8 hrs of trauma* (know Bracken protocol dosage!)

30 mg/kg IV bolus (over 15 min) → after 45 min, IVI 5.4 mg/kg/h over 23 h.

Reduction preop
Dr. Levi states ***manual reduction*** under fluoroscopy in OR is safe (in awake patient, although needs sedation) and faster (vs. ***graded weights***)
"Safe" MRI or unknown MRI but cooperative intact patient → closed reduction
All other cases → open reduction

Surgery as soon as stable (even in complete SCI, esp. cervical [vs thoracic – prognosis much worse])
In this case (herniated disc) – safe to do anterior discectomy first → reduction*
*if anterior reduction (after discectomy) fails, drill off superior C7 facets and reduce → PCF (1 or 2 levels above and below injury) with lateral mass screws and bone graft + bone extender (DBM)
C-collar for 6-12 weeks.
Aggressive chest PT (high cervical SCI likely will need intubation → tracheostomy).

CASE S2 – calcified thoracic disc

72 yo with generalized leg numbness (sensory level T10), weakness and hyperreflexia
CT, MRI (fig. 9.7, p. 107) – T10-11 calcified disc central herniation (dif. calcified meningioma – but no dural tail, lesion at disc level) with cord compression.

Treatment Absolute failure – midline laminectomy
Use IONM!!!!

A. **Lateral approach** (via thoracotomy with 9th rib resection – side depends on disc eccentricity – if all equal, use left side – easier to mobilize aorta than vena cava): deflate lung, identify 11th rib head – it leads to T11 pedicle → drill that pedicle off (access to lateral canal) → lateral discectomy and partial corpectomies of T10 and T11 → push disc material into corpectomy defect (risk of CSF leak! - extremely difficult to repair directly*) → Number 28 or 32 chest tube on water seal for 24 hours (to prevent CSF fistula)
B. **Costotransversectomy** (T10-11 facetectomy, T11 pedicle removal, 11th rib resection, partial corpectomy – may need pedicle screws and rod): reach semi-blindly with reverse-angle curette in front of thecal sac → push disc material into corpectomy defect (risk of CSF leak!*)

*needs indirect patch with collagen matrix dural substitute + glue + lumbar drain.

Decline of MEP on contralateral side (due to disc fragment rotation) fig. 9.8
Rule out hypothermia (it affects SSEP but not MEP), hypotension, anesthetic gases
Remove more bone to get better access to disc, steroids, BP↑

Patient returned with SOB and orthostatic HA:
CXR – L pleural effusion; H: repeat thoracotomy for CSF leak repair and cervical CSF drain for 5 days.
Head CT (fig. 9.10, p. 109) – chronic SDH (with midline shift and small amount of acute blood); H: just observe as neuro intact + CSF leak repaired

CASE S3 – isthmic spondylolysis

56 yo with LBP since adolescence. Now radiates to lateral legs (L5), neuro intact.
XR (fig. 9.11 p. 109) – grade 1 spondy L5-S1
Oblique XR (fig. 9.12-13, p. 110) – Scotty dog
CT (best sagittal but here axial fig. 9-14, p. 110 shows pars fracture)

Treatment
Always start with NSAIDs + PT + ESI
Eventually surgery is needed:

a) historical – L5 laminectomy + Gill procedure.
b) modern – add fusion L5-S1 ± interbody graft such as PLIF (highly desirable – adds indirect decompression, improves fusion rate); use either **navigation** or **fluoroscopy** with screw stimulation and EMG in EHL and gastroc
   stimulate 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).

Patient wakes up with burning pain along L5, dorsiflexion weakness
CT, MRI – hematoma?, malpositioned screw?, disc fragment? – if none, likely L5 root retraction injury H: GABAPENTIN

CASE S4 – cervical mts

56 yo with 4 weeks of neck pain (incl. at night), gait instability, hyper-reflexia, intrinsic weakness
XR – C6 VB destruction
CT - C6 VB destruction with preserved C5 and C7 endplates (mts or tuberculoma; vs. routine infection), facets and posterior elements intact
MRI w (fig. 9.21, p. 113) – cord compression

ASAP – C-collar, DEX 100 mg bolus → 10q6

Order metastatic survey:

1) bone scan
2) CT chest-abdomen-pelvis
3) PSA
4) multiple myeloma markers (incl. skeletal survey)

Here metastatic work up was negative (= solitary lesion)
Needs surgery (tissue diagnosis, cord decompression, spine stabilization): **C6 corpectomy**

- cage options variable – expandable cage, iliac crest, methylmethacrylate with Steinman pins (fig. 9.23, p. 114) → anterior plate → after incision healed: adjuvant therapy

CASE S5 – lumbar sagittal deformity

81 yo with chronic LBP, leg pain and paresthesias (worsen with walking 1 block = *neurogenic claudication*), inability to stand straight (*sagittal imbalance*).
Spine survey (fig. 9.26, p. 116) - SVA 19 cm, PI-LL mismatch 77 degrees
CT, MRI (fig. 9.29, p. 117) – no fusion at disc levels, stenosis at L1-2

Treatment IONM + TXA + CellSaver
Balance correction (need 67 degrees to achieve PI-LL mismatch 10 degrees): ALIF at L4-S1 → lateral approach with ALL release and hyperlordotic graft at L3-4 → decompression at L1-2 → Ponte osteotomies (each level gives 5 degrees) → T10-pelvis fusion

PEDIATRICS

CASE P1 – MMC, HCP

1-hr old neonate with MMC, macrocephaly, convex anterior fontanelle, no plantar flexion.
Head **CT** / **US** shows severe HCP with thin cortical mantle (fig. 12.3 p. 163)

- describe MMC size and level.
- measure OFC, evaluate for ortho (scoliosis/kyphosis, club feet), neuro (cry, suck, motor & sensory in extremities, anal sphincter).
- **check for Chiari II** – may cause respiration↓ (up to stridor, apnea), dysphagia (aspiration), spastic weakness; for older kids – syncope, oscillopsia / nystagmus, lower CN palsies, spastic quadriparesis.
  N.B. *symptomatic Chiari II needs prompt surgery* – bony posterior fossa and upper cervical canal decompression (no duraplasty due to low lying transverse sinuses!)

MOMS trial – intrauterine fetal MMC repair: ↓need for shunting, ↑motor outcomes but ↑preterm labor and uterine dehiscence.

MANAGEMENT

MMC closure within 72 hours;

- preop keep prone, MMC covered with sterile saline soaked gauze → cover with plastic wrap → trickle saline at 3 mL/hr.
- start IV fluids + abx (ampicillin and gentamicin).
- intraop (placode is functional tissue, blood supply passes through laterally reflected dura): separate placode by circumferential incision between normal and thinned skins → trim placode sides from any dermal / epidermal remnants (will form **inclusion dermoid** if left in place) → pial-to-pial closure with 7-0 nylon to recreate tube → disconnect dura at its most lateral extent where it is attached to underside of skin leaving small rim of dura attached to skin (this reinforces skin to aid closure) → close dura watertight with 6-0 silk without constricting tube → mobilize paraspinal muscles and fascia → correct severe kyphosis (if present) → mobilize skin → close skin tension-free with 5-0 nylon.

Complications: CSF leak (H: shunting), wound breakdown (H: wet-to-dry to let granulate).

Shunting – HCP is severe (compromises neurological function, may cause MMC wound breakdown) – at the time of MMC repair:

- either frontal or occipital.

- either fixed medium pressure or programmable valve.
- for occipital:
  - supine, gel roll under shoulders, head rotated to the left (on gel donut)
  - occipital incision 3 cm off midline, 1 cm superior to lambdoid suture → strip pericranium
  - abdominal incision in midline, 2 fingerbreadths below xiphoid → open linea alba to preperitoneal fat → open peritoneum (protect bowel, check entry with Penfield 4) → small burr hole by hand (enlarge with Kerrison).
  - tunnel, pass shunt (cover both ends with bacitracin-soaked sponges).
  - cauterize dura and open
  - abx-impregnated catheter is passed to occipital → frontal horn (depth – just past coronal suture)
  - send CSF
  - secure with 3-0 silk
  - check distal CSF flow → place into abdomen
  - inject 10 mg vancomycin + 4 mg gentamicin into valve reservoir
  - close peritoneum, fascia, galea, subQ (all with Vicryl), skin with Monocryl 5-0 and/or skin glue.

CASE P2 – METOPIC SYNOSTOSIS (TRIGONOCEPHALY)

4 mos old, developmentally normal.
Metopic ridging (frontal keel), posterior retrusion of lateral supraorbital ridges, widened biparietal.

- diagnosis is clinical (CT or XR is unnecessary – radiation exposure)

TREATMENT

Goals:
1) cosmesis – psychosocial: untreated metopic synostosis will lead to severe deformity
2) ICP

Endoscopic or **open** (better for Boards)
Best <u>timing</u> 4-8 months (calvarial bone is thick enough but still moldable, heals fast).
Just resection of suture will not correct skull shape.
<u>Pediatric neurosurgeon + craniofacial surgeon + pediatric anesthesiologist</u>
Type and cross 1 unit
2 large bore IVs, A-line, Foley, precordial Doppler + end-tidal CO2 monitor, corneal protectors.
Have resorbable plates, bone benders, drill, saw
Supine, head on well-padded (!) horseshoe, gel roll under shoulders.
Place corneal protectors.
Bicoronal incision (behind coronal suture and behind hairline, with widow's peak; 2-0 silk suture is pressed against scalp from ear-to-ear) → dissect in supraperiosteal plane (to minimize blood loss) → reflect posterior flap to mid-parietal region, anterior flap (together with elevated temporalis muscle) to 1 cm above orbital rim.
Incise pericranium parallel to rim → dissect subperiosteal to preserve periorbital fascia → free supraorbital nerve with osteotome → periorbital dissection to mobilize globes and expose entire rim + nasofrontal and frontozygomatic sutures.
Bifrontal craniotomy: 2 cm behind coronal suture, extension behind sphenoid wings, 1 cm above orbital rim → strip dura off anterior and temporal fossae, sphenoid wings → **remove supraorbital bar** (it is the foundation of reconstruction) with osteotomies (protect brain and orbital contents with malleable brain retractors), split it, reshape, and interpose parietal bone autograft (to widen bar) → wax bone edges, repair dural rents → extensive reconstruction with frontal reshaping (bone benders, cortex burring, barrel-stave osteotomies) and orbital bar advancement → all rigidly fixed back with resorbable plates* and screws (aim for overcorrection!).
*molded in heated water

CASE P3 – TECTAL GLIOMA & SHUNT

7 yo presents to ED 5 days after sports TBI: peristent HA, nausea, light / noise hypersensitivity, bilateral papilledema (unlikely from TBI as it takes time to develop – think about tumor or infection), dysmetria.
Head CT (then MRI) – multiple craniolacunae, splaying of coronal suture (fig. 12-17, p. 170), massive lateral and 3rd ventricles, transependymal flow, small aqueduct, tectal calcification (tectal plate glioma). fig. 12-19, p. 171

N.B. **70% chronic HCP cases** present with lethargy, HA, vomiting → coma, death;
30% chronic HCP cases present subtly – daily HA, decline is school performance, changes in behavior

TREATMENT

Tectal glioma – **conservative**
HCP:
A) ETV
B) **VPS** – programmable with SiphonGuard (set valve depending on opening pressure in OR!); never place connector at abdominal incision (will prevent shunt lengthening and will break)

Children with shunt-dependent HCP – need life-long follow up
1) it is always the shunt
2) the parents are always right

Electively lengthen shunt if ***known shunt-dependent*** (= slit ventricles / thick calvarium, symptomatic prior shunt failures)

Short shunt tubing, never had failures, completely asymptomatic → **close observation**

Overdrainage → craniosynostosis (with craniocerebral disproportion), SDH, slit ventricles

SHUNT FAILURES

<u>6 mos later, recurrence of symptoms and HCP</u> (compare to postop CT) → **shunt series XR**
Proximal failure (ICP raises quickly) → book emergent OR
- pulling proximal catheter my tear choroid plexus → bloody CSF (fig. 12-25) → place temporary EVD until CSF clears

Distal failure – two major causes:
1) tubing disconnection – shunt series
2) infection – **tap shunt**, **abdominal CT** (pseudocyst [fig. 12-23, p. 174] – maybe also seen on XR)

N.B. in distal malfunction, if catheter is not disconnected, suspect infection – examine CSF prior to revision!
N.B. pseudocyst (abdominal distention) = infection until proven otherwise!

<u>Shunt infection</u> (5-15% lifetime risk): 90% within first 6 months
- risk factors: CSF leak, poor skin condition, long surgery, multiple revisions
- abdominal pain, irritability, low grade fever!!!!
- head CT may be normal; abdominal CT – pseudocyst
- most commonly – Staph
- tap valve with 25G needle → CSF full study; ESR, CRP, WBC → start abx (vanc + cefotaxime)

- if CSF positive (WBC↑ or stain/cx) → OR: shunt removal, EVD + central venous line → CSF q2days; continue abx (adjust based on sensitivities) until 14 days after first negative CSF cx → new shunt in OR

CASE P4 – POSTERIOR FOSSA TUMOR

16 yo in ED with days of HA, vomiting. On exam – arm dysmetria.
MRI – 4x4 cm enhancing mass from cerebellar tonsils, HCP – ependymoma, medullo, juvenile pilocytic astrocytoma, hemangioblastoma? – analyze for *brainstem involvement* (resectability)

1. EVD (avoid shunting upfront!) vs if minimally symptomatic + surgery is imminent, may just do Diamox and prep for Frazer burhole (6-7 cm above inion, 3 cm off midline + make sure have EVD catheter on the field)
2. Decadron 4q6 + PPI
3. Plan surgery next morning
4. Meanwhile, **MRI w/wo of neuraxis** (may need general anesthesia) – drop mts? von Hippel-Lindau?

During consent, tell parents about prognosis:

a) **medullo** – extent of resection (OK to leave 1.5 mL), age (worse if < 2 yo), drop mts, molecular group; will need postop chemo (and radio if > 3 yo).
b) **ependymoma** – extent of resection; if incomplete resection → XRT (if > 3 yo)
c) **astrocytoma** – GTR is curative, no adjuvant therapy.

Cross-match 1-2 units of pRBC.
Prone (better) or sitting (have central line, precordial Doppler, end-tidal CO2 monitor).
Head fixation:
> 7 yo – adult pins
3-7 yo – pediatric pins
< 3 yo – well-padded horseshoe head-holder (check eyes!)
Gently flex head (but leave 2-3 fingerbreadths between chin and sternal notch – venous compromise)
If tumor extends to CP angle – cranial nerve 7-12 monitoring!
Midline incision from inion to C2 → burr holes at superior corners → bone flap from transverse sinus to foramen magnum +/- CLAM
Open dura in Y shape and tack edges to fascia → drain CSF from cisterna magna!
Bleeding from dural venous lakes / circular sinus → hemostatic clips / over sewing dural edges
N.B. keep track of blood loss and transfuse PRN!

a) Telovelar approach
b) Split vermis in midline

Resect tumor – goal GTR (including enhancing cystic wall) while avoiding damage to brainstem, deep cerebellar nuclei*, middle cerebellar peduncles, cranial nerves! Start with debulking with brainstem decompression → take down attachments to those critical structures using microscope
Close dura watertight with patch → replace bone

*cerebellar mutism (says few words postop → absent speech, CN palsies, irritability, ataxia) – invariably recovers (may take up to 6 months)

CASE P5 - MOYAMOYA

Child with ischemia – think moyamoya

10 yo in ED with sudden Left hemiparesis (incl. lower face); hx of headaches, seizures, TIAs with hyperventilation (crying, physical exertion).
MRI – Right frontoparietal stroke in watershed area (fig. 12.34-35) with *flow voids* in basal ganglia and thalamus (fig. 12.38) → **MRA** – bilateral MCA narrowing (fig. 12.36) → **DSA** – ICA narrowing, prominent lenticulostriate vessels (fig. 12.37) with no pathology in VA-BA and ECA.
Patient has Grave's disease - so it is moyamoya SYNDROME.
SPECT with Diamox is not needed for treatment but may predict progression (detects regional perfusion instability).

TREATMENT

No medical therapy that works but order ASA81 (increase to ASA325 in adolescents)
Treat even asymptomatic cases *as soon as diagnosis is made*! (do not wait for symptoms! may check SPECT with Diamox if completely asymptomatic) – excellent outcomes with revascularization (if before stroke).
Any surgical procedure works!
Pial synangiosis: dissect parietal branch of STA with galeal cuff → split temporalis → bone flap subjacent STA → stellate opening of dura (do not disturb meningeal collateral vessels!) → open arachnoid widely → suture STA cuff to pia using 10-0 nylons → replace bone → close temporalis except where STA travels.
MRI/MRA at 1 year postop.

N.B. complications are related not to surgery but to anesthesia - extreme sensitivity to BP and CO2 changes - general anesthesia may cause stroke!
H: admit day prior OR and start IV fluids at 1.5x maintenance rate; **periop avoid hypotension, hypovolemia, hypocarbia, and hyperthermia**; intraop EEG

FUNCTIONAL

Baclofen Withdrawal – see N3 >>
Status Epilepticus – see N5 >>

CASE F1 – TUMOR NEAR LANGUAGE AREA

Multilingual (polyglot) R-handed patient with de novo seizure (dysphasia episode), now intact →
MRI: **left middle temporal gyrus** superficial nonenhancing **tumor**.

- likely two distinct but adjacent language areas: map language (at least two most important languages) – noninvasively (fMRI or MEG): language areas seen on the left but NOT adjacent to the tumor.
- fMRI sensitivity is only 80-85% (i.e. only good for lateralization) → **awake crani with language mapping** (make sure patient is cooperative, no claustrophobic, no anxiety, and language functions* nearly intact [else even mild sedative effects will make mapping futile)
  *the ones you wish to map (e.g. naming, repetition).
- anesthesia only **TIVA** (REMIFENTANIL or SUFENTANIL for pain; PROPOFOL or PRECEDEX for sedation), **LMA**, **neuroanesthesiologist**.
- load AED one day preop (so not sedated from loading dose during surgery) – stimulation may cause seizures (will limit mapping): Keppra 20 mg/kg (or lacosamide 3 mg/kg or fosphenytoin 20 mg/kg)
- dex, ± mannitol
- lateral position secured with tapes: 1) patient comfortable 2) access to airway
- pins (after bupivacaine field block)
- crani → infiltrate dura with anesthetic
- remove LMA and awaken.
- **neuropsychologist** presents tasks* while surgeon stimulates

*object naming, repetition, spontaneous speech (e.g. counting), auditory naming (answering questions)

- Ojemann or Grass stimulator + ECoG
- 1-10 mA (1 mA below after-discharge threshold or where phenomenology occurs), 50 Hz, stimulate for 3-5 seconds – mark cortical areas that produce deficits (speech errors, delay, arrest)
- if seizure – irrigate with ice-cold saline.
- postop continue AED for 2-4 weeks
- delayed postop language deficit → MRI (stroke?), EEG.

CASE F2 – R MTS

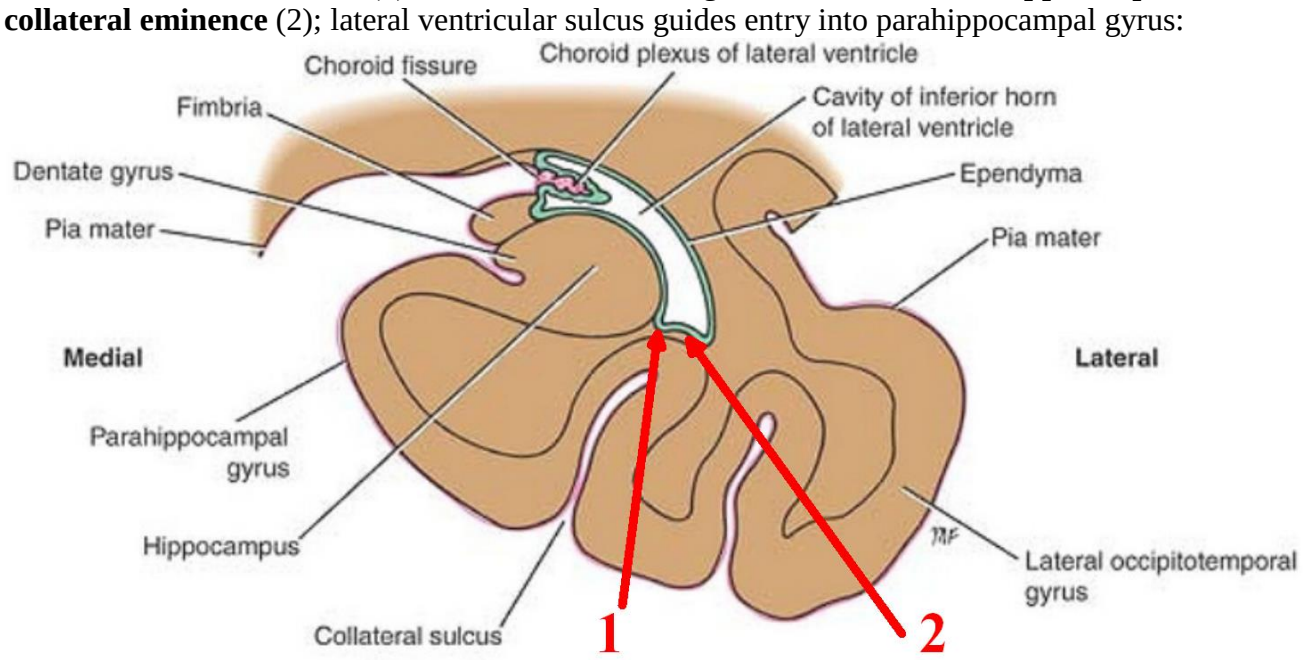
Young pt with refractory epilepsy (hx of febrile seizures in childhood) – rising abdominal sensation, loss of awareness, R hand automatisms + tonic posturing of L arm; sometimes GCTs. Failed 3 AEDs.

- vEEG – spikes at F8-T4, seizure onsets in R hemisphere; speech recovers immediately after electrographic seizure stop.
- MRI – R MTS. PET – hypometabolism in R hippo.
- neuropsych – IQ 110 (verbal IQ 114, performance IQ 104), deficits in visuospatial memory.
- confirm dominance with fMRI (WADA is not needed).
- proceed with surgery: either ATL or SAH or LITT.

ATL

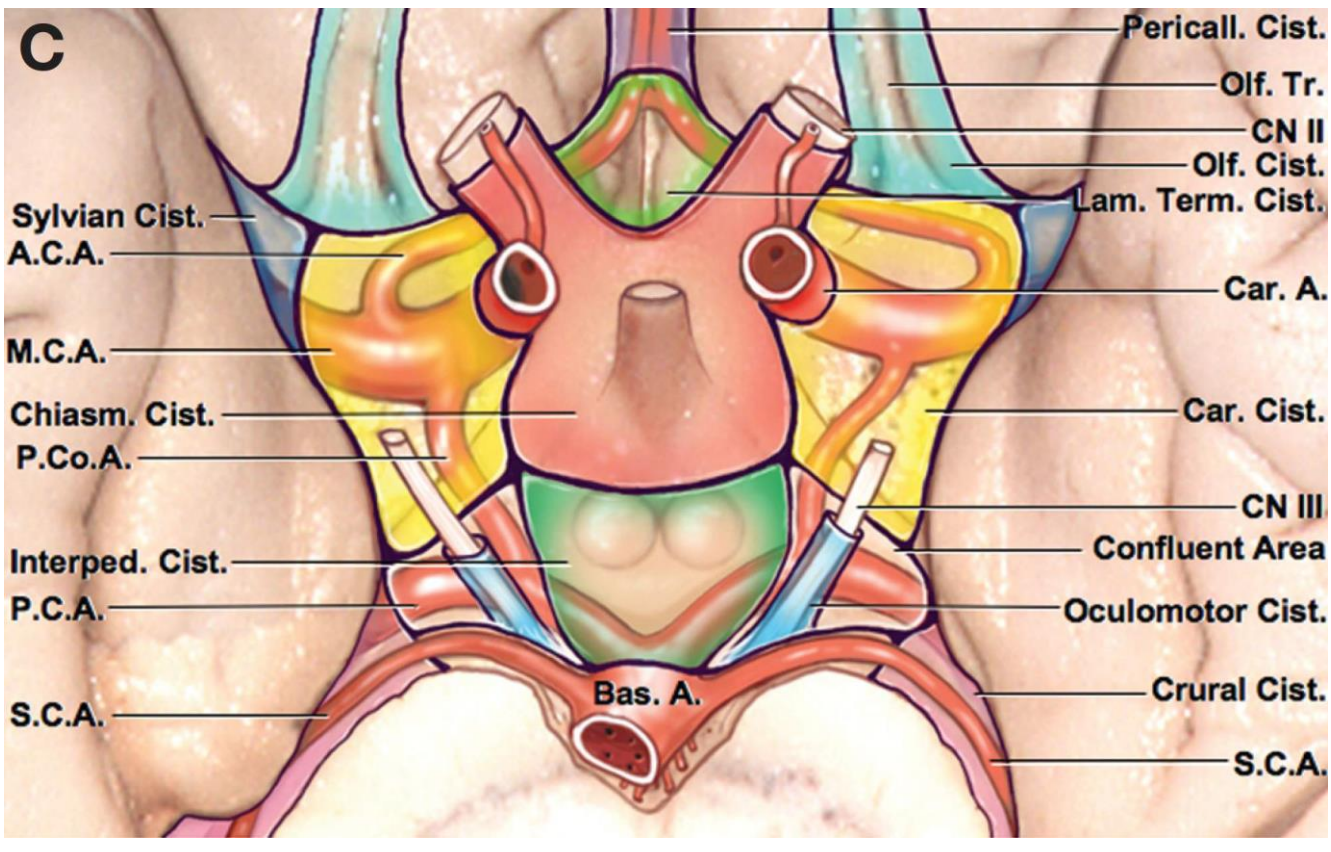
- lateral position, shoulder roll, head slightly extended and tilted towards the floor.
- incision - small inverse question mark → myocutaneous flap
- bone flap as low as possible on temporal floor (wax mastoid air cells – else CSF rhinorrhea)
- open dura in C-shape.
- Goodman says to perform ECoG to confirm diagnosis
- measure 5 cm from temporal tip along middle temporal gyrus – from this point:
  - **horizontal corticotomy** in MTG (or STG if on R side) and extend forward toward temporal pole → elevate subpially MTG (or STG away from Sylvian fissure) towards inferior limb of circular sulcus of insula (fig. 11-7 p. 145)
  - **vertical corticotomy** extending inferiorly and then medially to encounter collateral sulcus → trace superiorly until white matter → continue superiorly until lateral ventricle (temporal horn) is entered → deepen vertical cut in STG, through temporal stem, floor of temporal horn, lateral ventricular sulcus*, until both cuts are joined
  - temporal lobe is removed en bloc

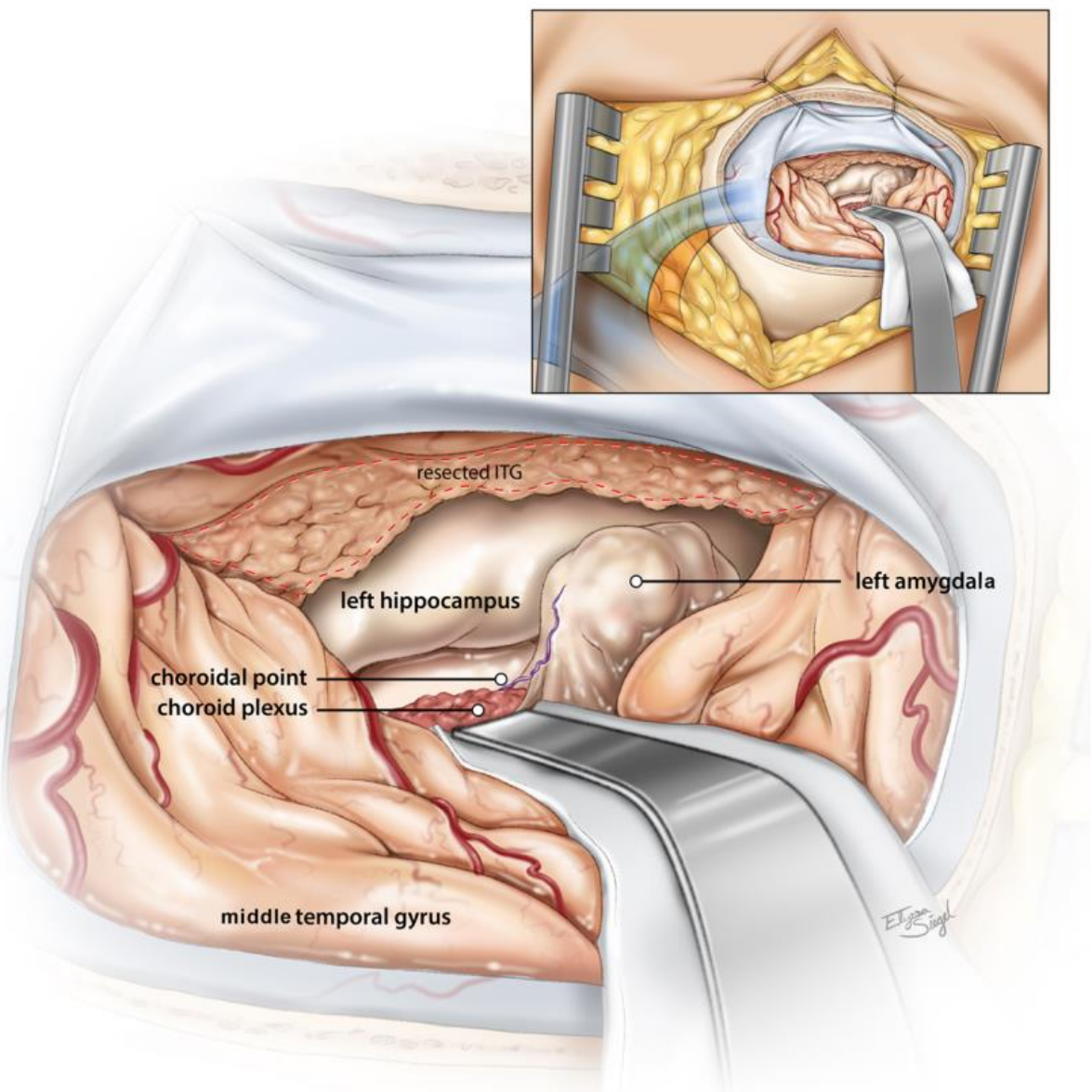
***lateral ventricular sulcus** (1) is between the two bulges into the ventricle - **hippocampus** and **collateral eminence** (2); lateral ventricular sulcus guides entry into parahippocampal gyrus:



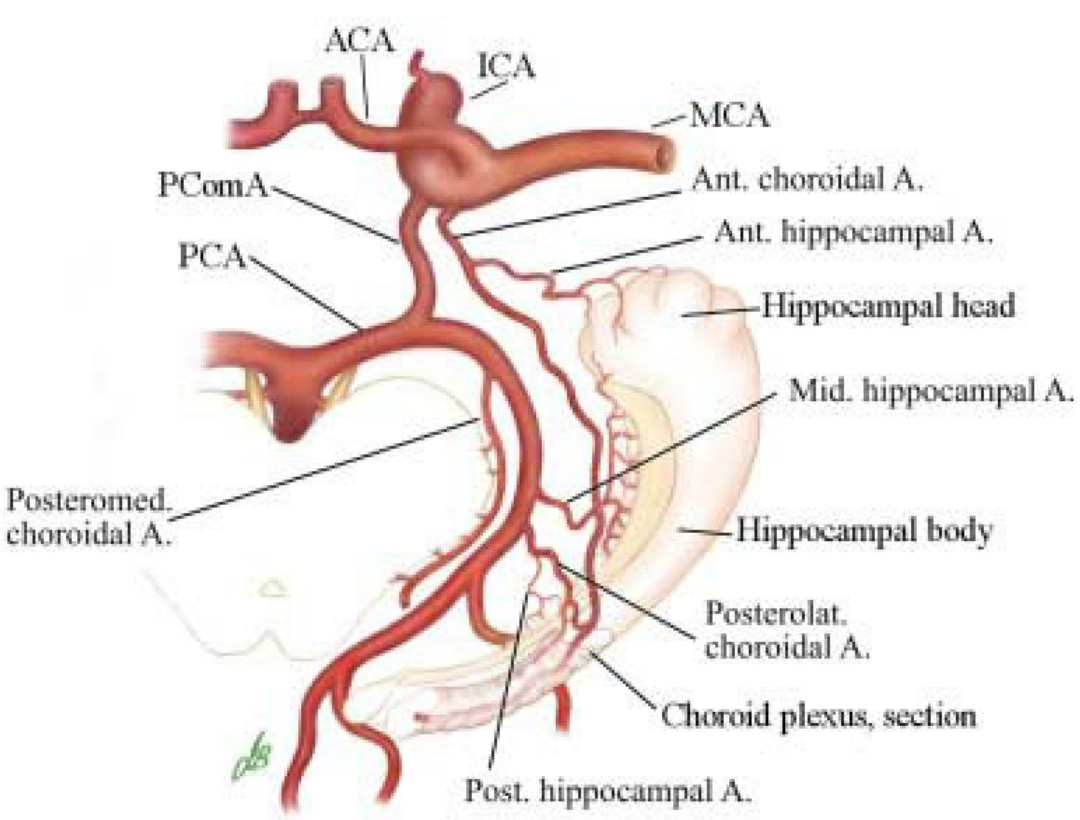
- second part (use microscope) – AH: identify choroid plexus → choroidal point is anterior to it → disconnect amygdala from head of hippocampus by cutting below the imaginary ***line connecting choroidal point to MCA genu***
- subpially resect amygdala (preserving contents of ambient cistern – PCA, CN3)
- retract hippocampus laterally away from choroidal point → aspirate fimbria along its length to expose vessels in hippocampal hilus → coagulate and cut feeding vessels as distally as possible (to avoid "en passage" feeders to brainstem)
- rotate hippocampus more laterally and cut its tail → permanent histology.
- uncus and remnants of tail are aspirated subpially.

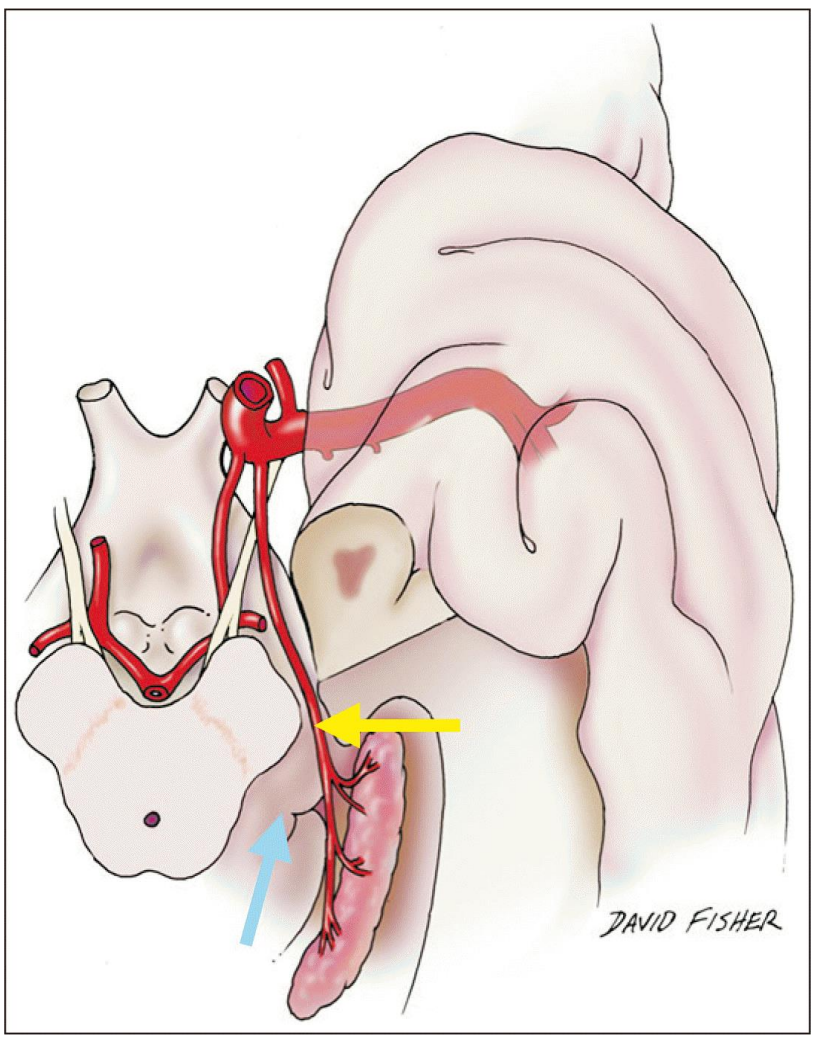
Inferior View of Basal Cisterns





Hippocampus blood supply:





SAH (transcortical) – seizure control slightly worse but neuropsych outcomes almost the same (due to collateral white matter damage).

Complications:
AChA stroke (fig. 11-9, p. 147) – from too much manipulation at choroidal fissure: hemiplegia, hemianopsia, aphasia (on L side).
Hemianopsia – from laser, retraction on temporal horn roof.
Diplopia (CN3) – from laser too close to cavernous sinus, excessive bipolar use, not using subpial technique

LITT

– general anesthesia, bone fiducials, O-arm, occipital entry point, ROSA (not stereotactic arm!), bolt, guiding rod to create trajectory and verify with O-arm, to MRI, insert 3 mm laser, T1 MRI, place **temp +50C safety points** (ventral thalamus) **and +90C along laser fiber** (to prevent evaporation) → **low power test laser pulses** (to verify heat spread) → ablate (MR thermography overlaid on structural MRI) with 15W laser at 80% power → move laser fiber → postablation T1w.

N.B. it is OK to offer LITT on Boards!

Regardless of surgery, neuropsych eval at 12 months.

CASE F3 – TRIGEMINAL NEURALGIA

Untreated TGN case – see N7 >>

49 yo F with progressive series of shooting pain in L face (CN2) with trigger points. Tegretol was effective but caused Na↓. Now on gabapentin – only partially effective = medically refractory.

High resolution MRI w/wo:

1) to rule out secondary TGN - MS, tumor, vascular lesion
2) to identify vascular loop conflict: 67.5% - SCA, 20% - AICA, 25% - vein (e.g. aberrant trigeminal vein) – visible on T1w but may not be visible on MRA.

Treatment

Healthy patient → MVD (N.B. age is not a contraindication for MVD!!!)

Not medically fit → percutaneous retrogasserian destructive* procedure – know at least one procedure in great detail

*expected partial sensory loss (i.e. it is not complication!; but rarely it may cause hard to treat painful extreme numbness [anesthesia dolorosa])

Patient prefers no invasion → SRS – least effective and results are delayed.

Tumor → resection / SRS (tumor protocol, not TGN protocol)

MS → percutaneous / SRS (TGN protocol)

MVD

- retromastoid craniotomy:
  a) supine with shoulder roll
  b) "park bench" lateral position with head turned (sagittal plane parallel to the floor)
- bilateral BAER
- ipsilateral EMG: CN5 (masseter), CN7 (frontalis, periorbital, perioral)
- craniectomy to open transverse-sigmoid junction
  - wax mastoid air cells twice – during opening, during closure!
- **microscope**: retract cerebellar hemisphere inferomedially → follow superolateral corner of posterior fossa to arachnoid membrane of cerebellopontine angle cistern (open it, drain CSF)
- ***coagulate and cut greater petrosal vein of Dandy*** (else guaranteed will get vein avulsion and hard-to-control venous bleeding)
- ***gentle dynamic retraction***
  - *avoid (if possible) rigid retraction* by using mannitol + draining CSF.
  - endoscopic-assistance is not standard of care yet.
- orient yourself: identify CN7-8 complex (lies inferior, posterior to CN5)
- identify vascular loop conflict (1 or 2 vessels) on trigeminal root few millimeters from brainstem.
- dissect vessel away from nerve (not the other way around!) → place **nonabsorbable felt-like material** (e.g. shredded Teflon pledgets inserted one after another) between vessel and CN5.
  N.B. if conflict is vein – coagulate and cut it!
- inspect the whole cisternal portion of CN5 – between brainstem and porus trigeminus (else will miss additional vessels).
- if no vascular conflict → **internal neurolysis** (comb nerve fascicles with nerve hook) or gently **compress nerve** – rather than rushing to transect nerve (trigeminal rhizotomy).
- close dura watertight primarily or with patch
- close bone with flap or cement (+/- plate).

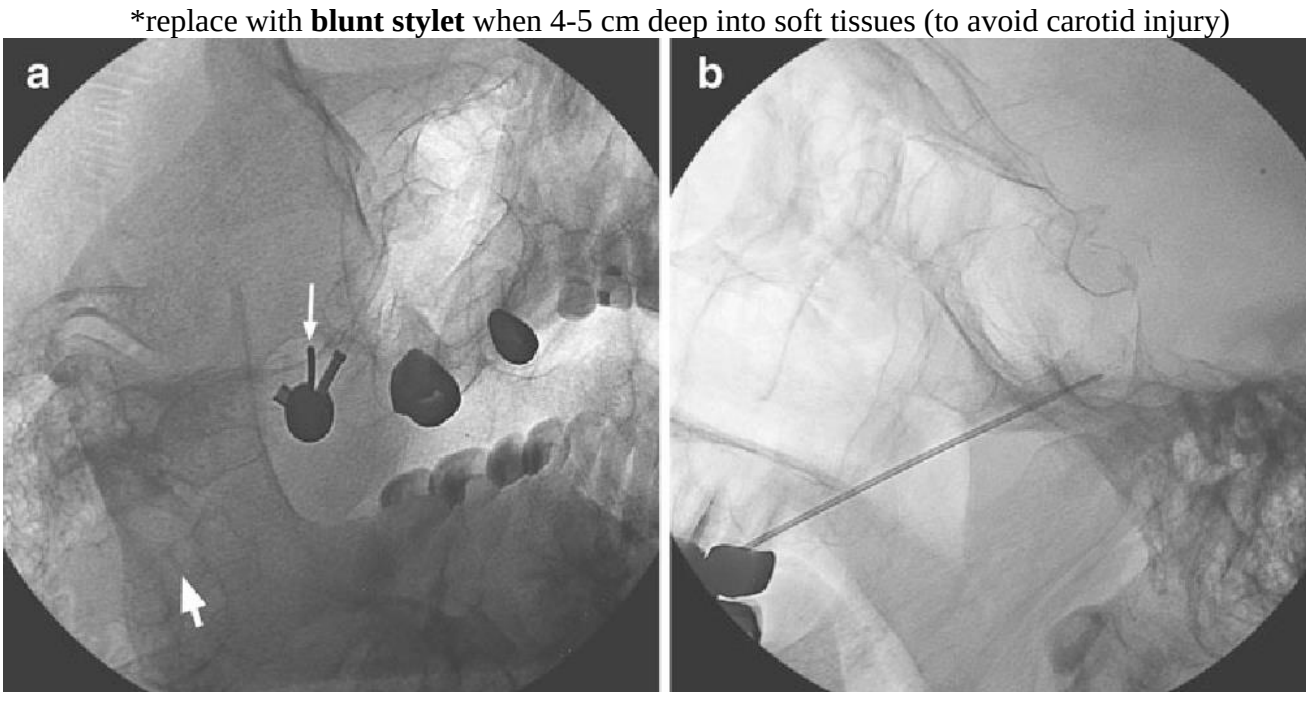
Complications

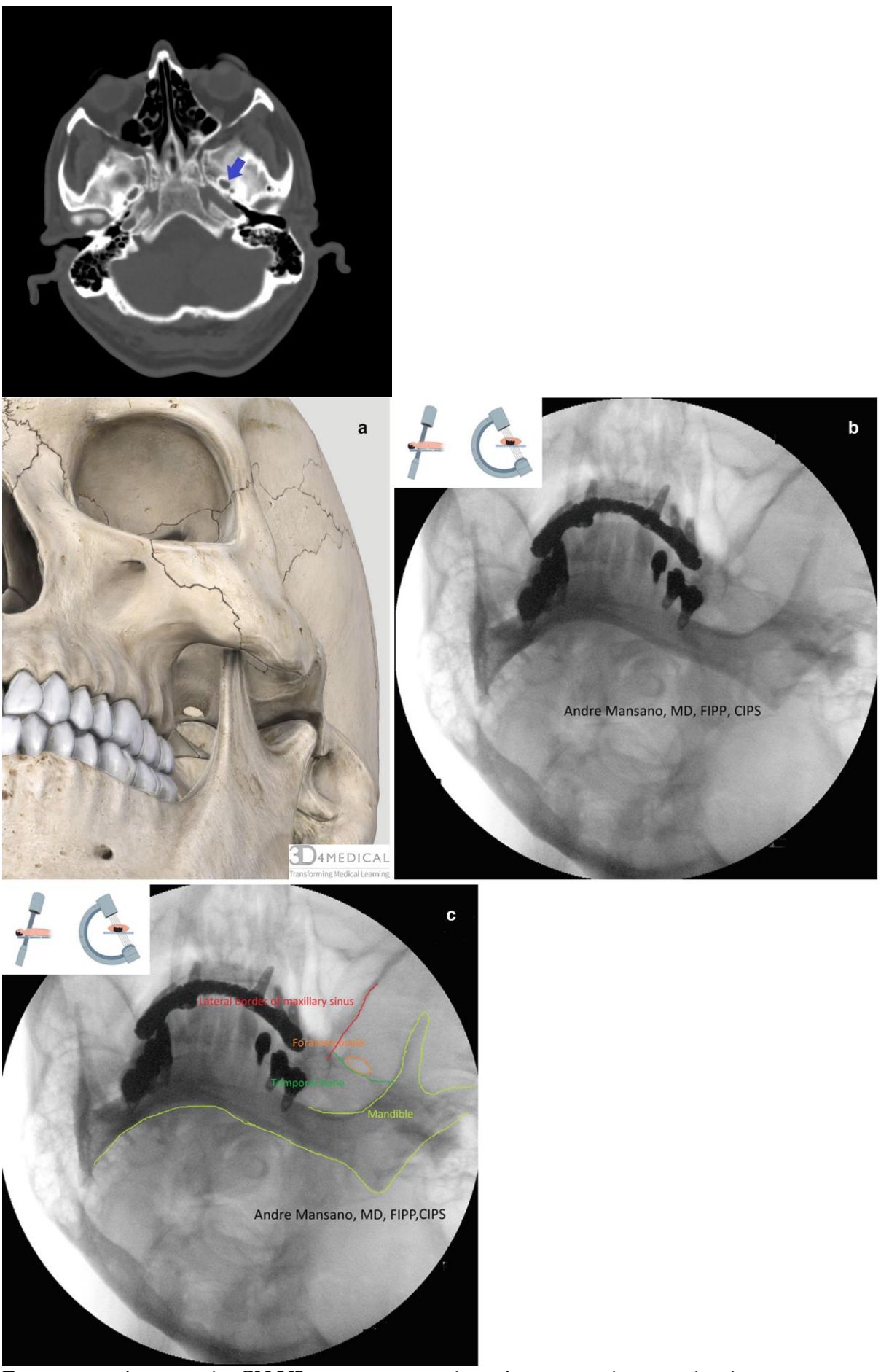
1) **CSF leak** → explore and patch dura
2) **Hearing loss**: a) partial (CSF leak into middle ear from poor waxing) b) complete (if BAER is not used and CN8 too stretched with retraction) → consult ENT, expectant management
3) **Facial numbness** (too much CN5 manipulation)
4) **No pain relief** (missed vessel / migrated pledget) → explore (redo MVD)
5) **Pain recurrence > 6 mos postop** – risk of facial numbness too high with exploration; H: other methods.

PERCUTANEOUS

Foramen ovale cannulation – Härtel's technique: cannula with **sharp stylet*** inserted 2-3 cm lateral to mouth corner (and 1 cm below it for RF vs same level for balloon to allow more flat path) → holding finger inside mouth, using fluoroscopy (submental-vertex view – to clearly see foramen ovale) aim to ipsilateral medial epicanthus + 1-3 cm in front of tragus → once lodged inside foramen ovale, remove stylet, use lateral fluoroscopy → insert device into Meckel cave.

*replace with **blunt stylet** when 4-5 cm deep into soft tissues (to avoid carotid injury)





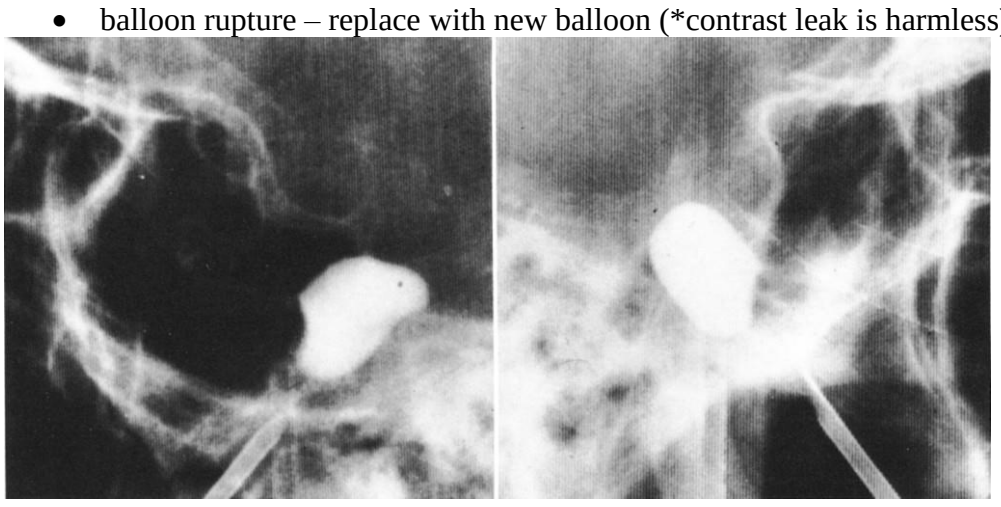
Foramen ovale transmits CN V3, accessory meningeal artery, emissary veins (cavernous sinuses → pterygoid plexus), otic ganglion, and occasionally the nervus spinosus and lesser petrosal nerve.

RF thermocoagulation – procedure of choice as most selective procedure, good for V2 and/or V3 – requires awake patient participation to guide electrode position.

- insert probe under sedation → awaken → curved Tew electrode: low-voltage stimulation (test paresthesias and sensory threshold) → RF lesion 65-70ºC for 60-90 seconds (if hotter / longer – risk of anesthesia dolorosa) → test for expected loss of sharp-dull discrimination and loss of trigger zones (may need several lesions to cover all areas; retract-rotate-reinsert curved electrode vs straight electrode may be advanced deeper).

V1 disease, uncooperative patient → balloon or glycerol - done under brief general anesthesia.
Balloon compression – insert balloon with stylet until it is on Meckel cave: inject 1 mL of contrast (safe for intrathecal use*) – watch for pear-shape (dural fold of porus trigeminus) – that is where compression must take place → inflate balloon for 90 seconds – up to 3 minutes (bradycardia may occur from trigemino-vagal reflex); if longer / higher volume - risk of anesthesia dolorosa!

- balloon rupture – replace with new balloon (*contrast leak is harmless)



Complications:

1) anesthesia dolorosa – H: tricyclic antidepressants → destructive surgery (open or CT-guided trigeminal tractotomy and nucleotomy – patient prone, myelogram, needle goes into posterolateral cord quadrant fig. 11.11) or motor cortex stimulation (epidural electrode over face motor area selected with fMRI ± intraop mapping).
2) carotid puncture – it is extracranial so risk is low: withdraw cannula and abort procedure (wait 1-2 weeks before repeat attempts)

SRS

(avoid brand names, such as Gamma Knife of CyberKnife)
FIESTA / CISS MRI (or CT cisternography)
80 Gy to cisternal segment

Not uncommon for TGN patients to have repeat surgeries (no data that SRS or perc makes MVD less effective and vice versa)
N.B. recurrent TGN – surgery again (neurodeficits are not contraindication)

vs

trigeminal neuropathic pain (**sensory deficit + constant pain** as in type 2 TGN but **no trigger-able shooting pains**) – does not respond to MVD/perc/SRS (H: peripheral nerve stimulation)

CASE F4 – UNRESECTABLE LUMBAR PLEXUS METASTASIS

Patient had XRT, chemotherapy – still unilateral pain, opioid-resistant
What is life expectancy? No spine / brain mts. Liver and lung mts.

Choice between **neuromodulation** (best for neuropathic pains*) and **destruction** (immediate very effective but pain recurs after 6-12 months).

*cancer often nociceptive pain

This patient (stage 4, unilateral pain):

life expectancy ≤ 3-6 mos → contralateral cordotomy
life expectancy ≥ 6 mos → IT pump

IT PUMP

– allows boluses (such as PCA) in addition to constant infusion (use programmable pump!)
First line choices for **neuropathic** pain:

a) morphine* (equianalgesic dose 100:1 to IV morphine)
b) ziconotide* (Ca channel blocker, start low dose to avoid psychosis)
c) morphine + bupivacaine

First line choices for **nociceptive** pain:

a) morphine
b) hydromorphone
c) fentanyl
d) bupivacaine

Other choices - clonidine

*FDA approved

Trial (e.g. single dose or multiple doses through lumbar drain); simplest – 1 mg of preservative-free morphine IT → monitor for 6-8 hours:

> 50% pain relief → implant pump
> 50% pain relief + side effects → re-trial with lower dose
< 50% pain relief → re-trial with higher dose

Implantation: lateral position (choice of side – check for colostomies, scars, etc)
Oblique paramedian approach
Tuohy needle, below L2
Fluoroscopy – catheter tip to midthoracic level
Check for CSF drip after stylet removal
Shunt passer to abdomen
Pump pocket of right size (too big – pump migrates; too small – too much tension on tissues)
Fill pump
Anchor pump and catheter to fascia!!!
Prime bolus to fill catheter in vivo

Modern pumps are MRI-conditional; interrogate after MRI; some pumps need medication withdrawal and refill after MRI.

Complications
No pain relief → "catheter dye study s. pumpogram" – look for contrast going intrathecally vs. extravasation in soft tissues (fig. 11.14 p. 154)
Catheter tip granuloma – noninfectious, inflammatory intrathecal mass (fig. 11.15 p. 155), esp. with high-concentration drugs (esp. morphine)

- mostly asymptomatic but may cause gradual loss of pain relief (drug stays in granuloma and gets absorbed into blood stream), cord compression
- treatment:
  a) ***asymptomatic*** - change drug concentration to stop granuloma growth
  b) ***minimally symptomatic*** – stop pump and wait until granuloma regresses
  c) ***symptomatic cord compression*** – laminectomy and duraplasty (avoid aggressive resection – risk of cord injury).

Overdose – ABC in ICU, stop pump + empty reservoir, naloxone.
Withdrawal – supplement systemically

CORDOTOMY

- contralateral (to pain source) transection of anterolateral quadrant (lateral spinothalamic tract)
Open - mechanical transection with right-angled cordotome in upper thoracic level via hemilaminotomy
CT-guided – myelogram, supine, local anesthetic 1 cm below mastoid tip, insert needle* at lateral C1-2 level aiming parallel to floor and slightly caudal (repeat CT during advancement – minimizes risk of nerve and VA injuries); after IT entry, stylet is replaced with RF electrode → aim ventral to dentate ligament, cord entry is confirmed with impedance change + awake** patient feedback (paresthesias in pain areas) to electrical stimulation; curved RF probe allows redirect → 70ºC for 60 seconds (→ pain loss, tolerable numbness)

*standard cut-tip needle large enough to accommodate RF electrode (e.g. Kanpolat CT cordotomy kit)
**ask to move ipsilateral limbs during each step

N.B. bilateral cervical cordotomy may lead to Ondine's curse; thus, for bilateral pain → **midline myelotomy** (if patient already had previous cervical cordotomy, then use opposite thoracic cordotomy)

CASE F5 – CRPS TYPE 1

Trivial minor foot fracture → nondermatomal persistent pain, muscle atrophy, hair loss, skin discoloration, coldness (confirmed with thermography), hypersensitivity
CRPS type 1 (historic name - reflex sympathetic dystrophy).
[CRPS type 2, s. causalgia – if named nerve is involved]

Treatment – intense PT is a key to success to avoid disuse but pain precludes exercises.

- antidepressants, anticonvulsants → sympathetic blocks → SCS
- for CRPS, SCS may need only to be temporary (after pain subsides, and SCS was off for > 6 mos, may explant).

Indications for SCS: > 6 mos of disabling pain ≥ 6/10, established medical diagnosis, psych clearance, cognitive ability, preserved sensation, thoracic MRI showing > 3 mm CSF sleeve, successful trial (arms – cervical, LBP – T7-10, feet-perineum – below T10) with perc* or paddle**.

*awake with paresthesia testing in the clinic vs "tunneled / buried" trial with electrode anchoring and using extensions in OR
**e.g. T9-10 with 10 kHz

SCSs are MRI-conditional – check manufacturer recs.

Loss of response – lead migration, fracture, need to reprogram or change paradigm (10 kHz, burst), consider IT pump.
Superficial IPG site infection → abx
Other infection → full explantation → abx → reimplantation after several months.
Cord damage – hematoma (fig. 11.18 p. 160), excessive manipulation (H: use monitoring for asleep cases!)