Detailed prep imaging studies - large lesions may distort normal anatomy (esp. vessels – consider CTA!)

- angiography is important in evaluation of lesion's vascular supply and venous drainage (prior to interhemispheric dissection).
- preoperative tumor embolization can decrease intraoperative blood loss.
- surgery is scheduled on elective, but preferably urgent, basis.

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- 3 Mapping of eloquent cortex
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- 3 Operative corridor
- 3 Blood supply
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- 4 Intraoperative MRI (iMRI, isMRI)
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**PREP**

Detailed prep imaging studies - large lesions may distort normal anatomy (esp. vessels – consider CTA!)

- angiography is important in evaluation of lesion's vascular supply and venous drainage (prior to interhemispheric dissection).
- preoperative tumor embolization can decrease intraoperative blood loss.
- surgery is scheduled on elective, but preferably urgent, basis.

**DETERMINE RESECTABILITY**

In almost every instance in which brain tumor is diagnosed, first consideration is its surgical resectability! (exception - multiple brain metastases)

Surgery should be first therapeutic modality for tumor!

- even potentially curable tumors (such as MENINGEOMA OR ACOUTIC NEUROMA) may reside in positions that make complete resection technically impossible!
- only 46% of malignant gliomas in USA are gross totally resected (mostly for fear of functional deficits; other gliomas – only cytodestructive resection); how can it be improved?

1. **EMRI FOR CORITCAL MAPPING (BOLD - shows increased venous drainage [not electrical activity of neurons] from active cortex).**

2. **DTI (tractography) for subcortical structures - to see if tract is involved (usually that can tell clinically) but where eloquent tract is displaced by tumor (so we can see safely approach tumor).**
INTRAAXIAL TUMORS

- not always amenable to radical surgical resection;
- most gliomas lack microscopic boundaries; glioma cells may migrate several centimeters along white matter pathways, including corpus callosum, making complete resection impossible;
- nonglial tumors generally grow by expansion.

- debulking of even of major gliomas can be of some benefit (cytoreduction).
- N.B. brain stem tumors are not amenable to surgical therapy (even biopsy is hazardous);
- solitary brain metastasis is indication for surgical resection (depending on systemic medical status).

- use of radiosurgery

- avoid radical* operations on tumors involving: language areas, sensorimotor regions, basal ganglia, corpus callosum, brain stem.

- *partial removal may be surprisingly effective (if resection is confined to tumor itself, it rarely produces major new neurologic deficits)
- functional imaging (fMRI, DTI tractography) facilitates surgery by showing that tumor has pushed aside critical brain structures.

EXTRAAXIAL TUMORS

- potentially curable by surgery, but often located in regions that are difficult to reach surgically.

ANESTHESIA

- in era of modern neuroanesthesia, it is rare that craniotomy must not be done because of poor general medical status.
- anesthesia with lack of effect on ICV.
- increasing number of resections in dominant hemisphere are done under local anesthesia for purpose of speech mapping.

- Mannitol (1 g/kg) + hyperventilation (P aCO2 25-30 mmHg) for definitive ICV reduction in preparation for brain retraction; administration time varies – some experts give only at the beginning of “bone work”, others give at the time of prep start (Dr. Broaddus: “it takes 30 minutes for mannitol to start working and those 30 minutes are with increased rheological bleeding; mannitol peak effect lasts several hours”).

- Dexamethasone (usually 10 mg IV) should be administered before manipulating nervous tissue.
- AED if cortex will be violated or significant retraction of lobes is expected.
- some routinely administer bromocriptine/tuburine IV (during induction of anesthesia) - tumor labeling on fixed tissue postoperatively.

APPROACH SELECTION

For craniotomy details – see p. Op300 >>

Tumors that reach cortical surface are approached through craniotomy at that site.

Subcortical tumors are approached through:

- deep sulci (vs. gyral crown) avoiding eloquent areas (e.g. approaching lesion obliquely).
- cortical incision is ~ 3 cm in length.
- anterior corpus callosum (causes minimal, if any, deficit).
- dilated ventricles (intraventricular neoplasms).

- localization of subcortical tumors:
  - intraoperative ultrasonography
  - frameless MRI-guided navigation (markers on patient's scalp).

Skull base tumors:

- Anterior skull base:
  - tumor behind orbit (incl. tumors of gasserian ganglion and cavernous sinus) – orbitosphenoid approach (sphenoid approach through zygoma and orbital roof).
  - tumors in sella turcica – trans-sphenoid approach.
  - tumors of upper one third of clivus, lesions of odontoid process – transoral or transpalatal approach (may be extended by osteotomy of mandible).
  - tumors of parasellar sinuses and upper one third of clivus – transfacial approach (to expose mandible for osteotomy, midface can be deflected).

- Lateral approaches through temporal bone to middle skull base (e.g. petrosal or presigmoid approach in which petrosal bone is drilled away).

- Posterior approaches:
  - extreme lateral approach - exposes lower third of clivus, cerebellopontine angle, and petrous surface temporal bone.
  - lesions of cerebellopontine angle – retromastoid craniotomy.
  - lesions of petrous surface of temporal bone – suboccipital craniotomy.

SURGICAL PRINCIPLES

For craniotomy details – see p. Op300 >>

There is no surgical method that can eliminate all of obstacles.

POSITION

- prone position is comfortable for surgeon (registration for navigation might be challenging – solutions: a) skin fiducials, b) O-arm automatic registration.
- sitting position - risk of air embolism, less comfortable for operating physician, but field is much clearer because drainage is easier.
- head is held rigidly with pins fixation to minimize movement (for infants, use soft rings - pins can perforate infant's skull or cause depressed fracture; may use pediatric pins).

MONITORING

- intraoperative cranial nerve monitoring alerts surgeon when nerves are at risk of damage: cranial nerves II-XII can be monitored intraoperatively (e.g. CN7 monitored with EMG, CN8 monitored with BEAR).

- intraoperative electrocorticography (ECoG) is useful in guiding epilepsy surgery, e.g. tumor-associated epilepsy (esp. in long-standing or severe seizures).

* Partial removal...
BRAIN RELAXATION

- “Wake cranioatony” in p. Op100

1. Use natural corridor:

   1) Tumors (do not violate normal cortex); e.g. medial temporal tumor - approach from Sylvian fissure split above Sylvian vessels (which nourish choroidal plexus).
   - *medial temporal region (memory) is phylogenetically different than lateral (Wernicke, auditory); tumors do not spread between these regions.
   2) SUFI (e.g. BrainPath circular retractor – atrumatic transsural approach)

2. Intralesional approach:

   - *intralesional approach is best used for posterior circulations tumors.
   - *incisions through cortex or corpus callosum should be covered with absorbable hemostatic barrier* (such as Surgicel or Gelfoam) to keep fluid contained within ventricles
   - *make sure material does not fall into ventricle to cause obstruction.

SULCAL APPROACH

- *deliver lesion into field of view without excessive retraction (requires patience)* for intraventricular tumors.

CORTICOTOMY

- *most likely at cortex closest to tumor surface* - coagulate with bipolar + cut with microscissors / spread with bipolar probes (or sucker tip).
- *innominate cortectomy (memory)*
- *disturb minimally).
- *disturb minimally).

BLOOD SUPPLY

- *quickly likely because of earlier reports of high mortality in infants with choroidal plexus papillomas.*
- *preserve vessels (they may be en passage - violating them will cause stroke); if both arterial and venous supplies of structure are to be sacrificed, arterial supply should be interrupted first* (to avoid congestion, bleeding, and swelling).

TUMOR RESECTION

1. Piecemeal removal of large masses (bipolar & gentle suction, CUSAT), debulking tumor center → dissecting remaining shell from surrounding normal brain tissue by advancing parys / Teila into interface (i.e.: resecting tumors from inside out so that surrounding normal white matter is disturbed minimally).
- N.B. resist temptation to pull the tumor en bloc - there could be a critical vessel attached to tumor base (where you cannot see and can be avulsed); also tumor base can be attached to dural sinus wall, etc.
- *may use saline spray with blunt needle tip to open plane.
- *piecemeal resections will result in bleeding, and many times this cannot be avoided.
- *intraoperative bleeding* – protect foramen of Monro with cotton square (to avoid obscurance of this structure and to protect brain elements) → preserved irrigation (risk of postoperative ventricular obstruction and probably postoperative headache).
- *if foramen of Monro cannot be cleared of obstruction, open window in septum pellucidum (almost routinely).
- *early reports of lateral ventricular tumors that display entire lesion as gross pathologic specimen clearly demonstrate why surgery caused profound neurological deficits and high mortality.*
- *removal of firm, adherent, or calcified tumor is simplified by Cavitron ultrasonic aspirator (CUA)* - tip vibrates at 22,000 Hz - ultrasomically disrupts tumor; tip is surrounded by two concentric channels, one dispensing saline to solubilize fragments and another suctioning away (almost routinely).
- *allows for internal debulking of large tumors and reduces amount of brain retraction needed for tumor removal.*
- *in limited access locations, CO2 laser can vaporize tumor tissue with hands-off technique (such tumor removal is slow).*
- *for low grade gliomas – remove entire tumor using subpial dissection - hold edge of pia with pickup and suck parenchyma with sucker along pial interface (such tumor removal is slow).*

2. Total resection should be goal of surgery.
- *glistening prominent white matter is seen easily through microscope as tumor's margin is reached* - at this interface resection is stopped.
- *incomplete resection may be preferable when site of attachment invades into deep structures such as thalamus (goal is debulking when mass effect is cause of symptoms).*

3. Intralesional piecemeal vs. circumferential piecemeal (en bloc) resection

- *intralesional piecemeal contrast enhancement of portion of the tumor is entered, and the tumor is removed from the center toward the edges.*
- *perilesional fashion:*
  - *intraventricular ultrasound and stereotactic image guidance identify the cortical margins of the tumor and its subcortical extension.*
  - *because the tumor is not “compressed”, shift does not happen and computer-assisted surgical guidance is relatively well maintained throughout the case.

MAPPING OF ELOCUTENOUS CORTEX

- “Awake cranioatony” in p. Op100

OPERATIVE CORRIDOR

- *deliver lesion into field of view without excessive retraction (requires patience)* for intraventricular tumors.

- *deliver lesion into field of view without excessive retraction (requires patience)* for intraventricular tumors.
perilesional tumor resection was associated with a significantly higher rate of GTR than intralesional resection (81% vs 62%, multivariate odds ratio = 2.5).

among tumors in eloquent cortex, perilesional resection had a higher rate of GTR (79% vs 58%, respectively, P < 0.001) and a lower rate of neurological complications (11% vs 20%, P = 0.018).

**EXTENT OF TUMOR RESECTION**

- **Goal:** resection of maximal amount of tumor consistent with functional preservation

- gross total resection may extend survival from around 11 to 14 months in glioblastoma and from 60 to 90 months in low grade glioma (Sanai 2009).

- High-grade gliomas – see p. Onc10 >>

- Low-grade gliomas – see p. Onc10 >>

**TUMOR ENCIRCLING**

- inserting along tumor perimeter (using navigation, before tumor resection – to avoid shift) Becker ventricular catheters (cut flush to brain surface but still tend to fall out – so suture to dura edges) or strings of patties.

During tumor resection keep going until encounter “fence poles” – serve also as depth guides (not just perimeter guides).

**VENTRICULAR ENTRY**

- during resection of high-grade gliomas (HGG):
  - Cancer Dissemination, Hydrocephalus, and Survival After Cerebral Ventricular Entry During High-Grade Glioma Surgery: A Meta-Analysis Akshitkumar M Mistry, MD Patrick D Kelly, MD Reid C Thompson, MD Lola B Chambless, MD Neurosurgery, nyy202, https://doi.org/10.1093/neuros/nyy202 Published: 22 May 2018

  - higher odds of leptomeningeal dissemination (sOR: 3.91 [95% confidence interval (CI): 1.89-8.81]; P = .0002; 86/410 vs 57/847 patients in 9 studies)
  - higher odds of hydrocephalus (sOR: 7.78 [95% CI: 3.77-16.05]; P < .0001; 58/431 vs 11/565 patients in 11 studies).
  - decreased survival (median survival: 16.8 vs 19.1 mo; 413 vs 322 patients in 10 studies; hazard ratio: 1.25 [95% CI: 1.05-1.48], P = .01).

**Intraoperative MRI (iMRI, ioMRI)**
• be aware of thin rim enhancement along the surface of the resection cavity artifact caused by surgeon’s mechanical disruption to BBB - may be difficult to distinguish from tumor-specific enhancement (esp. when a low-resolution 0.15 T magnet is used).

**FLUORESCENCE-GUIDED RESECTION (S. CHEMONAVIGATION)**

- 5-ALA and iMRI work synergistically!
- fluorescence gives 2-D real-time surface information and may sometimes be hidden behind overhanging edges or obscured by blood, can be used to wisely augment the capabilities of more complex and non-real-time iMRI, which gives 3-D information, to safely optimize resections.

**FLUORESCENT NODULE**

- 3-20 mg/kg IV at dural opening, 560 nm microscope filter.
- contraindication – serum creatinine > 2 mg/dL.
- labeling mechanism is based on BBB leakage (during surgery BBB gets damaged anyways – false positive labeling).

**5-MANLEVULINIC ACID (5-ALA)**

- FDA approval (first drug approved in US based only on European trials).
- June 6, 2017 - FDA has approved Gleolan™ (aminolevulinic acid hydrochloride (ALA HCl)) as an optical imaging agent indicated in patients with gliomas (suspected World Health Organization Grades III or IV on preoperative imaging) as an adjunct for the visualization of malignant tissue during surgery.
- commercially in US became available in October 2018.

**Mechanism of action**

- 5-ALA is metabolized to protoporphyrin IX, an endogenous fluorescent bioproduct, as part of the heme biosynthesis pathway.
- in malignant glioma cells, but not in healthy brain cells, exposure to 5-ALA results in tumor-specific accumulation of protoporphyrin IX as a result of alterations in enzymes and cell transporters involved in heme biosynthesis - useful for the intraoperative discrimination of tumor and normal tissue in the operating room, as well as 5-ALA – based photodynamic therapy.

### Pivotal Efficacy Studies: Biopsy-Based Diagnostic Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Study 1* (Primary)</th>
<th>Study 2 (Recurrent)</th>
<th>Study 3 (Primary)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPV</td>
<td>96.2</td>
<td>96.6</td>
<td>97.8</td>
</tr>
<tr>
<td>NPV</td>
<td>24.1</td>
<td>18.8</td>
<td>18.8</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>67.7</td>
<td>96.3</td>
<td>70.6</td>
</tr>
<tr>
<td>Specificity</td>
<td>79.4</td>
<td>20.0</td>
<td>81.1</td>
</tr>
</tbody>
</table>

*Fluorescence-guided resection of high-grade gliomas (suspected WHO grades III-IV on preoperative imaging).

- **Contraindication:** photosensitivity.
- **20 mg/kg (1 vial, 2700$ = 1 vial) wrapped in yellow bag.**
- **Drink room temperature** before use.
- **vial wrapped in yellow bag.**
- **Mean absolute bioavailability:** 100%.
- **Maximum ALA plasma concentration:** within a median of 0.8 hour.
- **Max fluorescence time is 5 hours.**
- **False positive labeling.**
- **Positive predictive value - 95%.**
- **False negative:**
  - necrotic tissue will not fluoresce.
  - intensity of fluorescence will diminish as a function of the focal distance of the microscope beyond 300 mm from the tumor, which is the point at which it becomes increasingly difficult to adequately visualize tumor fluorescence - fluorescence energy declines by the 4th power of the focal distance.
  - fluorescence intensity will diminish with time of light excitation due to photobleaching upon exposure to light.
- **Target region is exposed to blue laser light with 405 (375-440 nm) peak wavelength (with handheld device or microscope):**
  - there is a phantom available to test microscope (blue light source must be replaced every 250 hours).
  - turn OR lights away from the patient until fully draped.
  - tumor tissue glows red (620-710 nm); operative video >>

**Fluorescence enhancement:**

- surrounding infiltrated tissue glows orange.
- tissue lacking sufficient PpIX concentrations appears blue.
- reduce exposure to sunlight or room lights for 48 hours postoperatively (place wristband on the patient indicating the time when this 48-h period will end).
- do not administer photosensitizing agent for 24 hours pre and 24 hours postoperatively - photosensitization skin reaction (severe sunburn) may result.
- St. John’s wort, griseofulvin, thiazide diuretics, sulfonylureas, phenothiazines, sulphonamides, quinolones, and tetracyclines.

**Fluorescence-guided resection of high-grade gliomas (suspected WHO grades III-IV on preoperative imaging):**

- dose room temperature.
- vial wrapped in yellow bag.
- mean absolute bioavailability - 100%.
- maximum ALA plasma concentration - within a median of 0.8 hour.
- **TV: 1 hour.**
Adverse reactions (> 1% of patients in the week following surgery): pyrexia, hypotension, nausea, and vomiting.

- no liver failure cases reported (but LPs may become elevated up to 10-fold in 11-15% of patients in a first week, and remain elevated at 6 weeks in 2-7% of patients).

Studies

5-ALA fluorescence-assisted surgery vs. conventional surgery


- class I evidence.

Gadolinium is better than 5-ALA

- ALA fluorescence is a method of tumor presence but is not a good indicator for the absence of tumor when no fluorescence is present (negative predictive value only 37%)


- percentage of complete resection

<table>
<thead>
<tr>
<th>Fluorescence-assisted surgery</th>
<th>Conventional surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of complete resection</td>
<td></td>
</tr>
<tr>
<td>1%</td>
<td>45%</td>
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<tr>
<td>P5 (months)</td>
<td></td>
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<tr>
<td></td>
<td>0.0117</td>
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<td></td>
<td>0.0003</td>
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</tbody>
</table>

Fluorescence shows more than expected from gadolinium enhancement

5-ALA% Intracranial gliomas show visible 5-ALA accumulation

- in a first week, and remain elevated at 6 weeks in 20% of cases.

Fluorescence shows more than expected from gadolinium enhancement

16.20% Intracranial gliomas show visible 5-ALA accumulation

- volume of fluorescing tissue is about double the volume of enhancing regions.

- fluorescence extends even beyond the fluoro-ethyl-tiroxine-PET zone of hypometabolism.

CLOSURE

- tumor cavity is then examined for bleeding points, and meticulous hemostasis (sometimes difficult but must be perfect) is secured prior to closure.

- persistent bleeding may be due to residual tumor, and it will require direct bipolar coagulation or topical gelatin foam, activated cellulose or microfibrillar collagen application for control.

- if brain swelling is worrisome at time of closure (rare situation), ICP catheter is left in subdural space.

- tumor cysts can be drained and, when possible, fenestrated into adjacent ventricle to prevent reaccumulation.

- about CSF drainage → see p. Oncl18

ALA

The pic-aroachidone is opened using bipolar coagulation along line of incision which is made by sharp dissection. It is usually safe to make subdural incision to adjacent sulcus, continuing into white matter and seeking plane between tumor and edematous brain. Some tumors present with false capsule, but such lines of demarcation are rarely delineated. Generalized brain substance is divided by suction or blunt dissection. Division of low-grade gliomas or sclerotic areas may require sharp dissection or ultrasonic aspiration. Dissection around base of tumor continues until tumor is isolated. If ventricle is opened, it should be walled out with stagnant blood from collecting within it. If cortex is reached opposite entry site, cortical vessels must be individually occluded and divided by sharp dissection. The plane of dissection can be preserved by use of continuous strips to protect brain. Planes of demarcation can usually be developed between metastatic lesions and surrounding brain, aided by strips of cottonoid to wall off brain. Bridges of vessels are divided, and separation along lines of cleavage is continued until tumor is surrounded. Many infiltrating lesions have pseudocapsules that may be well demarcated, but usually such lines of delineation fade out so that separation must continue along areas of infiltration. In other cases where infiltrating lesion is limited to lobe, standard lobectomy may be selected, dividing pia and pial vessels, and transecting lobar structures so as to include neoplasm. If cortex is reached opposite entry site, cortical vessels must be individually occluded and divided by sharp dissection. Ultrasonic aspiration may supplement suction and coagulation.

Resection of infiltrating lesions requires debulking of mass—usually by aspiration and often with ultrasonic aspiration. Generally, blood loss from highly vascular neoplasms will be less by working at edge of tumor. When this is impossible, aspiration must begin within tumor.

Care must be taken against undermining or even excessive retraction of functional cortex to be preserved. Hemostasis during dissection aids visualization of structures and identification of vessels. When bulk of tumor has been removed, further search for additional tumor is carried out and such fragments are removed. The ultrasonic aspirator is helpful in this maneuver.

POSTOPERATIVELY
**extubation:**
- a) if surgery entails significant manipulation of brain stem, patient should remain intubated for at least 2 postoperative nights and be extubated carefully once lower cranial nerve function has been assessed;
b) if brain stem involvement was minimal, patient may be extubated in operating room.

**DISCUSS**

ICU for at least 1 night; increasing trend for selective ICU admission (“ICU, unless” → “no ICU, unless”) - reduced complication rates and length of stay while keeping patients satisfied + hospital costs related to the admission have been significantly reduced.


**serum electrolyte levels and sodium levels are measured often (also to detect possible onset of SIADH or diabetes insipidus, esp. after endoventricular manipulations).**

**SIDESTEPS**

**Continuous antiepileptic drug therapy in patients undergoing supratentorial meningioma resection: a systematic analysis of efficacy.” J Neurosurg 115:483 2011.**


There are studies that do not support prophylactic AED use:

- incidence of seizures after surgery for brain tumors is low (8% [95% CI 1.3%–18.4%]) even without prophylactic AEDs, and incidence of clinically significant seizures is even lower (3%)
- even for patients with preoperative seizures, postoperatively for most seizures cease spontaneously (when patients are initially seizure free after surgery, seizure recurrence is associated with tumor progression)
- 3 mechanisms by which a seizure may occur in setting of neurosurgery for tumors:
  1) intrinsic epileptogenic nature of the tumor, particularly in certain locations such as temporal and parietal lobes
  2) surgical factors associated with craniotomy (brain retraction and cortical irritation)
  3) postoperative complications (hydrocephalus, edema, or infection).
- traditional AEDs are potent enzyme-inducing (PHENYTOIN, CARBAMAZEPINE, PHENOBARBITAL) or inhibiting (VALPROIC ACID) and reduce/interfere serum concentrations of chemotherapeutics.
- new generation of AEDs (GABAPENTIN, LEVETIRACETAM) are not metabolized by CYP isoenzymes.

There are studies that do not support prophylactic AED use:


- patients undergoing resection for brain tumors without a previous history of seizures
  - incidence of all seizures was 18% in observation group vs 24% in prophylaxis group (p = 0.62).
  - incidence of clinically significant seizures was 3% in observation group and 2% in prophylaxis group (p = 0.49).
- review of 698 patients
  - no significant differences in incidence of early or late seizures between AED and no-AED cohorts.
  - conclusions - prophylactic administration of anticonvulsants during resection of supratentorial meningiomas does not improve prevention of either early or late postoperative seizures.

**PREOPERATIVE PREPARATION**

**baseline contrast MRI within 6 weeks - to evaluate resection success (later, prominent enhancement of newvascularized reactive gliosis develops - interferes with image interpretation); absence of abnormal enhancement indicates gross total resection.**

- look at DWI and ADC - postcontrast MRI may show great tumor resection but if there is adjacent stroke it will start enhancing (as natural evolution) 3–4 weeks later and radiologist will call it “tumor progression”.
- for tumors with propensity for leptomeningeal spread (MEDULLOBLASTOMA, Ependymomas, CHOROID PLEXUS CARCINOMAS, certain PINEAL GERMINOMAS), test before further postoperative therapy:
  1) CSF cytologic examination at least 2 weeks after surgery (LP is safe ≥ 10–21 days after intracranial decompression);
  - some authors suggest obtaining CSF at time of surgery from cisterna magna for cytologic analysis.
  2) spinal MRI yearly during first 24 months (CSF exam alone is inadequate – may be false-negative in up to 20% of cases), routine spinal evaluations beyond this time may not be practical (local recurrences are far more likely). If MRI is contraindicated, CT myelography is utilized.

N.B. baseline spinal MRI is best done prior to surgery (to avoid postoperative artifacts); first postoperative spinal MRI – at least 2 weeks after surgery (spinal canal enhancement can occur in early postoperative period); if equivocal → repeat after 1–2 weeks (artifacts secondary to surgery regress while drop metastasis remain stable or increase).

**ROUTINE SURVEILLANCE** (unwarrented in asymptomatic patients following complete resection of benign tumors)

- every 3–6 months during first 2 years;
- every 6–12 months for follow-up 2–3 years

**demonstration of residual tumor from scar (region of linear, rim enhancement) is improved by gadolinium.**

N.B. true tumor progression cannot be confirmed on MRI prior to 3 months!

- differentiation of residual tumor from scar (region of linear, rim enhancement) is improved by gadolinium.
**COMPLICATIONS**

- **tumor recurrence** – consider reoperation. see p. Onc3 >>

- **operative morbidity** depends largely on tumor location (highest – 10-20% – in diencephalic tumors).

- **operative mortality** rates are < 1%; 30-day mortality rate after brain tumor surgery is 2.2-2.9% - postoperative hematoma is the most frequent cause of death.


  o incidence of a POH requiring a recraniotomy was 2.09%
  
  o among recraniotomy patients, 12.5% died within 30 days of the first surgery.

  o incidence of recraniotomy significantly correlated with the incidence of a hemangioblastoma, infratentorial tumors, and a prolonged operative time (>10 h).

**SKULL BASE TUMORS**


**ANTERIOR SKULL BASE**

See also p. Op300 >>

**CAVERNOUS SINUS AND MIDDLE FOSSA**

**PINEAL REGION TUMORS**


**POSTERIOR FOSSA TUMORS**

- EVD can be placed frontally prior to positioning or occipitally once the patient has been positioned

- place EVD in OR prior to craniotomy (or at least prep for occipital Frazer bur hole)

- important to avoid hypertension immediately postop – risk of bleeding into posterior fossa!

**CEREBELLOPONTINE ANGLE, 4TH VENTRICLE**

Vestibular schwannoma → p. Onc62 >>

**BRAINSTEM TUMORS**

**CEREBELLAR TUMORS**

- navigation is not necessary but useful!

- prone on chest rolls or white Wilson frame; head in Mayfield frame.

- open cisterna magna (by opening arachnoid) – will drop cerebellum by gravity.

- mark floor of 4th ventricle – by advancing Telfa / patty / cut finger of glove into 4th ventricle from below (start between cerebellar tonsils) – or will fail Oral Boards!

Cerebellar tumors are best approached along the shortest transparentchymal route to the lesion
A. Superior hemispheric lesions - via the supracerebellar cistern and by incising the cerebellum at the closest point to the tumor - requires a high suboccipital craniotomy with exposure of the transverse sinus.

B. Inferior cerebellar tumors require opening of the foramen magnum.

C. Midline tumors can be resected after splitting the inferior vermis.

D. Lateral hemispheric lesions - directly from a posterior trajectory; entering the paracerebellar cisterns is generally not necessary, thus avoiding exposure of the cranial nerves; split hemispheric pia horizontally (parallel to widened folia):

- postoperative deficits:
  1. Cranial nerve deficits
  2. CEREBELLAR MUTISM (anatomic origin - deep cerebellar nuclei) - one of most commonly cited complications.

HEMANGIOBLASTOMA

A. Cerebellar lesions - via suboccipital craniectomy; Hydrocephalus → external ventricular drain prior to tumor resection! (hydrocephalus resolves in > 90% patients postop)

B. Spinal lesions - via laminectomy:
  - no syrinx → remove upper ones (tumors);
  - syrinx present – remove largest one (tumor) – syrinx resolves in 1-3 months (if not – means residual tumor)

- target - mural nodule (otherwise, cyst will recur); no need to resect capsule if it is nonenhancing on MRI
  - cyst wall is not removed unless there is evidence of tumor within the cyst wall on MRI (typically thick-walled cysts) or visually at the time of surgery (5-ALA fluorescence may aid in visual localization of small hemangioblastomas within the cyst wall).

- surgical principles similar to those used in treating AVMs:
  - pre-operative embolization may help reduce the vascularity.
  - identify feeding vessels → coagulate and cut (arterial feeders prior to draining veins!)
  - do not remove in piecemeal fashion - significant bleeding may ensue!
coagulate tumor surface (to shrink the tumor) with wide bipolar forceps (avoid penetration of tumor itself due to its extreme vascularity and difficulties with hemostasis).

- dissect tumor circumferentially by careful devascularizing blood supply (coagulation and cutting small feeding vessels), releasing adhesions between tumor and surrounding tissue by putting cottonoid strips into developing plane to avoid direct pressure on brain or spinal cord tissue.

- need for permanent shunt is determined by response to EVD clamping.

- all patients must be screened for PHEOCHROMOCYTOMAS preop (may cause perioperative hypertensive crisis induced by anesthetic or analgesic agents) - 24-hour urine free cortisol or plasma concentrations of metanephrine and normetanephrine $\Rightarrow$ CT; if evaluation reveals pheochromocytoma $\Rightarrow$ resect pheo first (if resection is prohibitive, preoperative $\alpha$-blockade with $\beta$-blockade begun only after $\alpha$-blockade to avoid unopposed $\alpha$-activity)

**THIRD VENTRICLE**

pending read:

Approaches to the Third Ventricle - Interhemispheric Transcallosal

A. Transcortical approach - facilitated by ventriculomegaly
B. Transcallosal (interhemispheric) approach - equally effective in reaching foramen of Monro with large or small ventricles $\Rightarrow$

A. Transforaminal approach
B. Transchoroidal approach
C. Interforniceal approach
for lesions that are soft or cystic, it is often appropriate to resect and deliver the lesion through the foramen of Monro.

lesions with significant mass effect sometimes already have caused dilation of the foramen, facilitating the surgical approach; foraminial patency can be assessed with the use of forceps or with probing with a Silastic shunt tube.

N.B. dilating the foramen can lead to postoperative memory deficits due to fornix injury! Also lateral side of foramen of Monro is made of genu of internal capsule!

dexamethasone, mannitol, no AED.

frontal parasagittal craniotomy: — supine position with head in Mayfield headholder — lazy-S incision in transverse fashion over midline, just in front of coronal suture (two thirds anterior and one third posterior to coronal suture; there are no bridging veins near coronal suture) — 2 bur holes (4 cm apart) with Acorn drill bit over superior sagittal sinus; vein near coronal suture may be necessary to cauterize one side just parasagittal, other side 3 cm from midline — dura reflected towards sagittal sinus — Greenberg/Budde retractor, microscope — gentle retraction of frontal lobe away from falx — separate both cingulate gyri — bilateral pericallosal arteries gently separated — 1-2 cm midline callosotomy using microsuction tip (verify with navigation trajectory) — N.B. corpus callosum is very shiny brightly white!

enter lateral ventricle — venous angle and choroid plexus lead into foramen of Monro. incision into tumor capsule and attempt debulking with pituitary retractor, microscope — very gentle tumor rocking allow — ary rongeur — the posterior component of fornices.

transventricular colloid cyst approach: - entering either above or below the choroid plexus in the body of the lateral ventricle — access into the third ventricle through the velum interpositum, which serves as the roof for the third ventricle.

subchoroidal approach - incision is made in the taenia choroidica, and the choroid plexus is reflected upward; may be necessary to cauterize one of the thalamostriate veins, which may be a limiting factor in the untethering of the choroid — potential consequences of sacrificing a unilateral striate vein include hemiplegia, mutism, and drowsiness.

*these postoperative morbidities may not occur, however, because of collateralization by superficial cortical, posterior medullary, and galenic venous systems.

superchoroidal approach (correct route on board exam for transchoroidal approach) - incision is made above and medial to the choroid plexus in the taenia fimbriata, and the choroid is deflected inferiorly - approach requires less manipulation of the superficial thalamic and caudate veins - safer.

interforaminal approach: - midline division of the fimbriated bodies — bilateral fimbriated injury can occur through manipulation (→ devastating memory impairment) - approach is reserved for cases in which there is significant mass effect that distends the roof of the third ventricle.

during development of a dissection plane in the interforaminal approach, remain cognizant of the hippocampal commissure in the posterior component of fimbriata.

preserve and retract gently the internal cerebral veins (appearance may mimic colloid cyst)
most commonly encountered postoperative problem is transient amnesia of recent events (30% of cases), most striking 24 to 72 hours postoperatively and resolves completely within 21 days.

LATERAL VENTRICULAR MASSES

Relatively high risk for mortality and neurological morbidity.

Masses in this location:
- Often are benign tumors - grow at slow rate - reach very large size before identified.
- Cause hydrocephalus (headache, poor balance, difficulty with memory).
- Localizing findings (aphasia, agnosia, hemiparesis, etc) are rarely present – mostly occur with entrapment of occipital and temporal horns.

Etiologies:

<table>
<thead>
<tr>
<th>Tumor</th>
<th>Typical site</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLOID CYST</td>
<td>Foramen of Monro / 3rd ventricle</td>
</tr>
<tr>
<td>SEGMA</td>
<td>Foramen of Monro</td>
</tr>
<tr>
<td>MENINGIOMA</td>
<td>Trigone of lateral ventricle</td>
</tr>
<tr>
<td>CHOROID PLEXUS PAPILLOMA</td>
<td>4th ventricle</td>
</tr>
<tr>
<td>EPENDYMOMA</td>
<td>Lateral ventricle (more common in children), 4th ventricle</td>
</tr>
<tr>
<td>NEUROCYTOMA*</td>
<td>Lateral ventricles involving septum pellucidum</td>
</tr>
<tr>
<td>METASTASES</td>
<td>Lateral ventricles, ependyma and choroid plexus</td>
</tr>
</tbody>
</table>

* Most common lateral ventricle tumor in young adults

PREOPERATIVE

- Routine EVD

OPERATIVE TECHNIQUE

Also see above for principles >>

Surgical approaches:
- TEMPORAL LOBE
  - Incisions provide access to temporal horn (least likely site for mass lesion).
temporal approaches provide early access to anterior choroidal artery but poor visualization of posterior choroidal vessels (until lesion is almost completely resected).

If mastoid air cells are entered – close with generous use of bone wax.

normally temporal horn is approximately 3.5 cm from temporal tip.

Safest temporal corticotomy is ANTERIOR INFERIOR TEMPORAL GYRUS (middle temporal gyrus might be OK on nondominant side)

Access to temporal horn

A. Temporoparietal junction:

1) traverse angular gyrus – dyslexia, agraphestia, acalculia, idiomotor apraxia in dominant hemisphere (in nondominant hemisphere - impaired visual memory, construction deficits, neglect).

2) cross optic tracts – visual field deficit

B. Middle-temporal gyrus – high-risk of damage to speech cortex in dominant hemisphere (H: cortical stimulation); in nondominant hemisphere is it acceptable route!

C. Transtemporal horn occipitotemporal gyrus (originally developed for resection of hippocampus in treatment of intractable seizures) - provides exposure to temporal horn and atrium

• may result in superior quadrant field deficit.

PIERIAL Lobe

• incisions contraindicated in dominant hemisphere (→ speech deficits).

• vascular supply is away from surgeon’s line of vision.

Access to

A. Transtemporal horn occipitotemporal gyrus – see above

B. Occipital lobe incision / lobectomy – see below

C. Transcallosal approach – see below

D. Superior parietal lobule incision (first choice approach per Dr. Graham) – most commonly used approach; avoid significant retraction → risk of apraxia and agnosia (dominant hemisphere), visual-spatial processing problems, homonymous hemianopia and hemiparesis.

• incision should be sufficiently large to permit use of 2-cm retractor blade without tension.

• when ventricle is opened, retraction should be minimized on lateral white matter by gently elevating brain rather than pushing it out of way.

OCCIPITAL Lobe

Occipital lobectomy can provide access to entire ipsilateral ventricle.

• causes permanent loss of homonymous visual field (may be acceptable, if present preoperatively).

• does not permit early access to choroidal vessels – prepare for considerable blood loss.

FRONTAL Lobe

Access to anterior ventricle

A. Transcallosal approach – see below

B. Middle frontal gyrus incisions:

• particularly helpful for tumors with broad ependymal attachment in frontal horn.

• incision in middle frontal gyrus at level of coronal suture (3.5 cm from midline, 1 cm anterior to coronal suture) – direct approach to frontal horn and foramen of Monro.

• significant speech problems may occur even when Broca’s area is undisturbed.

• incisions in either hemisphere can result in attention deficits.

CORPUS CALLOSUM (TRANSICALLOSAL INTERHEMISHERIC APPROACH)

Used literature: R. Jandial “Core Techniques in Operative Neurosurgery” (2011), procedure 8

Pending:

Lab Demo – Transcallosal Approach to Lateral & Third Ventricle >>

INDICATIONS

1. Third ventricular tumors
2. Lateral ventricular tumors - relatively safe access to all areas except temporal horn and posterior occipital horn H: transcortical approach.

PROCEDURE

• Brain relaxation is particularly important.

    — gravity can be used to surgeon’s advantage - patient in lateral decubitus position with involved hemisphere dependent - falls acts as retractor to hold contralateral hemisphere while involved hemisphere is gently retracted – greater risk of midline disorientation; other experts (Dr. Graham) prefer straight supine position (neck flexed 45 degrees) – easiest for orientation but it is difficult to work with both hands (instruments above each other).

    — long and narrow craniotomy (to parallel interhemispheric corridor).

    — arachnoid adhesions can be dense near ACAs – risk of pericallosal arteries damage!

    — slight change in angle can result in opening wrong lateral ventricle (H: identify septum, pellucidum and redirect surgical angle).

    — superior portion of mass should be delivered into surgeon’s line of view rather than retracting hemisphere to expose it.

    — most difficult area to see – inferior lateral corner (roof of basal ganglia, thalamus).
• use microscope and Greenberg/Buddle with 3/8 retractor blades.
• access to corpus callosum requires preservation of medial (bridging) draining veins (but still provide space for 3-cm retractor blade) - look at preop imaging (MRV/CTV up to formal catheter angiography) for large vessels that may preclude entry.
  – “Dr. Graham’s area” – from 3-5 cm anterior to coronal suture to just (max 2 cm) behind it
  – paucity of bridging veins – best area for craniotomy.
  – most often there are 2-3 large veins that serve medial hemisphere, but there is no clear rule on which may be sacrificed (smallest anterior vein usually can be coagulated and transected if necessary).
  – dissect veins from their pial attachment to reduce tension.
  – near coronal suture there are no bridging veins!
  – open along nondominant (usually right) side

• use navigation to limit extent of callosotomy just over tumor
• dissect and retract ACA (pericallosal arteries – place cotton balls to keep those arteries retracted from each other)
• corpus callosum can be identified easily because of its very bright glistening and relatively hypovascular aspect

  N.B. with ventricular masses, there may be midline distortion of corpus callosum (review preoperative imaging).
• callosotomy is done with suction tip; limit AP extent (usually 1-2 cm is enough) – rather go side-to-side (opening corridor by taking already sectioned fibers)
• retractor is gradually (to prevent venous infarction secondary to overretraction, limit retraction to < 2 cm along any part of the corridor, pauses of 2 to 3 minutes should be observed after every advancement of the retractor blade down the interhemispheric fissure (pause allows for the ventricular pressures to equilibrate in the face of forces exerted by the retractor itself).
• if the foramen of Monro is open, a physical barrier should immediately be placed at its entry to prevent blood from pooling into the third ventricle.
• if contralateral ventricle is entered, fenestration or excision of the septum pellucidum can open access into the ipsilateral lateral ventricle; fenestration of the septum also allows for the alternative pathway for CSF flow.
• fornices travel across the base of the septum and must be preserved.
• following the thalamostriate vein, septal vein, fornices, or choroid plexus reliably guides the surgeon to the foramen of Monro.
• ependymal surface adjacent to the callosotomy and abraded medial and paramedial cortical surface are particularly susceptible to postoperative hemorrhage.
• EVD should be left in the lateral ventricle for about 48 hours postoperatively.
• if expect that redo will be needed in the future, leave gel film in the interhemispheric fissure to prevent adhesions.

Transcallosal exposure of lateral ventricle – choroid plexus entering foramen of Monro:
COMPLICATIONS

- disconnection of hemispheres, esp. in patients with anomalous cortical organization (H. Wada test prior to transcallosal surgery):
  - mutism, akinesia, apathy, unilateral weakness (leg > arm), forced grasping, fixed gaze, disinhibition, incontinence, right-left confusion.
  - sectioning of splenium in patients with dominant hemisphere homonymous hemianopia will cause alexia and visual agnosia.
  - transcallosal surgery in left-handed, left-hemisphere speech-dominant and right-handed and right-hemisphere speech dominant patients can cause agraphia and speech impairment.
  - certain early childhood injuries can cause reorganization of cerebral function such that interhemispheric communication becomes critical (both hemispheres contribute to speech or unilateral motor function); callosal disconnection → altered speech and motor function.

Crossed dominance, wherein the hemisphere controlling the dominant hand is contralateral to the hemisphere controlling speech and language, is a contraindication. Crossed dominance can arise after cerebral injury during childhood that resulted in cortical functional reorganization. These patients may develop writing and speech deficits postoperatively. Special consideration should be given to cases in which a more posterior callosotomy (splenium) is required, increasing the risks of cognitive dysfunction (e.g., alexia), particularly in patients with established preoperative visual field cuts (e.g., homonymous hemianopsia).

Limited incision of the callosal trunk usually leads to minimal physiologic complications. An acute syndrome of decreased speech spontaneity, ranging from mild slowness of speech initiation to frank mutism, with onset in the hours and days after surgery and possibly persisting for several months, has been described after transcallosal injury. Although longer callosal incisions (2 to 3 cm compared with 0.8 to 2 cm) may be associated with this syndrome, other manifestations of this acute syndrome, including lower extremity paresis, incontinence, emotional disturbance, and seizures, suggest that additional neural structures are likely involved. Mutism may also be caused either by direct retraction of the anterior cingulate gyrus, septum pellucidum, and fornix or by circulatory disturbances of the supplementary motor area, thalamus, and basal ganglia.

Disorders of interhemispheric transfer of information, which can include visuospatial and tactile information and bimanual motor learning, are another potential complication. Although the exact deficits depend on the topographic relationship within the corpus callosum, several studies have suggested that interhemispheric transfer should be preserved as long as the splenium is intact.

- leg motor cortex injury - venous infarction or retraction injury.
- short term memory deficits – from fornix manipulation

COMBINED APPROACHES (TRANS CALLOSAL + TRANS COR TICAL)
a) for masses that are too large to remove through single approach:
b) when hemisphere is distended by tumor (rather than by CSF) → transcortical incision and partial decompression to obtain sufficient relaxation → interhemispheric dissection for callosotomy.
c) portions of tumor with broad ependymal attachment along superior portion of frontal horn may not be accessible from interhemispheric approach.

- combined cortical incision and callosotomy can be performed safely in adults.
- transcortical incision usually goes first → safer interhemispheric dissection with relaxed hemisphere.

Case illustration:
POSTOPERATIVE DEFICITS

- visual field loss is one of most common focal deficits.
- hemiparesis is frequently observed during immediate postoperative period.
- speech deficits complicate surgery in dominant hemisphere.
- seizures can occur in any patient (90-99% after transcortical resections; significantly lower after transcallosal surgery).
- memory deficits if damaged fornices (e.g. colloid cyst resection).
- subdural hematoma and hygroma are significant problems in patients with preoperative hydrocephalus.
- avoids excessive CSF drainage via EVD.
- incomplete resection occurs in 33-50% cases.
- mortality for surgery on lateral ventricular mass lesion ranges 12-75% (massive brain swelling or intraventricular hemorrhage were most common causes).
- in one series of meningiomas, all deaths occurred when tumor was removed en bloc.

MENINGIOMAS

- Although meningiomas are benign and potentially curable, total removal may be impossible without unacceptable destruction of normal structures because of location, compression of vital structures, and vascularity.
- leaving some tumor behind is often better than risking neurologic function for sake of complete removal.

PREOPERATIVE

- preoperative endovascular embolization of vascular feeders from external circulation is beneficial in extremely vascular meningiomas → resection 0-96 hrs after embolization (to decrease likelihood of revascularization).
- embolization facilitates surgery by reducing blood loss (esp. when blood supply is on other side of tumor vis-à-vis surgeon’s line of sight).
- embolization may help to achieve gross-total resection of both skull base and large supratentorial meningiomas.
- increasing interest in intraoperative direct needle puncture intratumoral embolization.

- corticosteroids (preoperatively and postoperatively) significantly decrease mortality & morbidity.
- antiepileptics are started preoperatively in supratentorial surgery and continued postoperatively for no less than 3 months.

PRINCIPLES IN MENINGIOMA RESECTION

- tumor removing technique → using bipolar / Penfield #1, disconnect tumor at base from dura (disconnects blood supply).
- always start by coagulating arterial feeders to meningioma.
- if preop MRI shows no or little adjacent brain edema → expect no or minimal leptomeningeal feeders (easy development of tumor-brain plane).
- involved dura as well as dural rim free from tumor should be resected (↔ duraplasty*), dural tails (apparent on MRI) are best removed.
- from best to worst results: pericranium > fascia lata > commercial dural substitutes.
- if meningioma cannot be removed completely → try (if safe) detaching tumor from its dural origin and therefore from its predominant blood supply, then may also canterize dural surface.

SIMPSON GRADING

<table>
<thead>
<tr>
<th>Grade</th>
<th>Degree of removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>macroscopically complete removal with excision of dural attachment and abnormal bone (including sinus resection when involved)</td>
</tr>
<tr>
<td>II</td>
<td>macroscopically complete with endocraniectomy coagulation (Bovie, or laser) of dural attachment</td>
</tr>
<tr>
<td>III</td>
<td>macroscopically complete without resection or coagulation of dural attachment or of its extradural extensions (e.g. hypertensive bone)</td>
</tr>
<tr>
<td>IV</td>
<td>partial removal leaving tumor in situ</td>
</tr>
<tr>
<td>V</td>
<td>simple decompression (± biopsy)</td>
</tr>
</tbody>
</table>

Table 21-25. Simpson grading system for removal of meningiomas
### Degree of Resection vs. Recurrence Rate

<table>
<thead>
<tr>
<th>Degree of Resection</th>
<th>Recurrence Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete resection with dural margin</td>
<td>9%</td>
</tr>
<tr>
<td>Complete resection with coagulation of dura</td>
<td>19%</td>
</tr>
<tr>
<td>Complete resection (no treatment of dura)</td>
<td>29%</td>
</tr>
<tr>
<td>Partial removal leaving tumor in situ</td>
<td>40%</td>
</tr>
<tr>
<td>Decompression</td>
<td>NA</td>
</tr>
</tbody>
</table>

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### Meningioma Involving Bone

- **all involved / hyperostotic bone** should be removed
  - some centers use 5-ALA to guide bone resection (or avoid extensive resections if bone is nonfluorescent and thus likely just with reactive changes)
  - 20 mg/kg of 5-ALA orally 2-4 hours before surgery
  - 5-ALA has sensitivity of 89.06% and specificity of 100% in detecting bone invasion, while positive and negative predictive values are 100% and 82.93%.
  - sometimes surgery is done cosmetically just for involved bone, then replace bone flap with prosthetic cosmetically-acceptable flap; historically, attempts were to boil bone flap in OR while removing meningioma (autoclaving is worse – destroys cells and bone matrix)
  - remove bone flap → intraoperative bone flap irradiation (e.g. 100 Gy)
  - if there is more affected bone – drill it off with diamond drill bit (useful to have CT loaded for navigation).
  - only after bone work is finished, open dura to remove tumor (most likely will be able to excise with whole dural base which needs to be repaired with Dura-Guard)

### Very Large Meningioma

- consider **preoperative embolization** (space closely with resective surgery as tumor recruits new vessels very fast, plus, tumor swells due to necrosis and patient may deteriorate).
- tumor might be invading brain cortex – better to default (make craniate dureotomy over tumor center to start debulking) but leave tiny rim of tumor on cortex → postop radiation (it will take long time until tumor grows back to fill original volume again).

### Olfactory Groove Meningioma

- Preoperative imaging of clinoid region meningiomas can accurately predict the presence or absence of tumor involvement of the clinoid in only 75% of cases. In light of the fact that a quarter of patients with radiographically negative clinoids will have tumor present on pathological analysis, recommend a clinoidectomy for all clinoid region meningiomas.

#### Endoscopic approach:

- Preoperative imaging of clinical region meningiomas can accurately predict the presence or absence of tumor involvement of the clinoid in only 75% of cases. In light of the fact that a quarter of patients with radiographically negative clinoids will have tumor present on pathological analysis, recommend a clinoidectomy for all clinoid region meningiomas.
Lateral see-through illustration of a typical meningioma of the tuberculum sellae. The extent of bone removal underlying the typical dural attachment is highlighted in blue. Note the anterior extension along the planum sphenoidale and the inferior extension into the sella turcica. Inset: Superslateral view demonstrating the typical planum attachment, optical canal invasion, and displacement of the optic apparatus and surrounding vasculature.

Upper: Anterior endoscopic view of the posterior wall of the sphenoid sinus after removal of the mucosa revealing the relevant bony anatomy. Note the anterior sellar wall centrally, bilateral opticocarotid recesses laterally, and the suprasellar notch superiorly. The area of bone removal is shaded and outlined. Lower: Lateral view demonstrating superoinferior extent of bone removal and trajectory of endoscope and high-speed drill.

CONVEXITY MENINGIOMA

- Although large tumor, presents little problem in removal.
- Large bone flap is made around tumor, dural incision circumscribes tumor, and dura attached to tumor is used to retract tumor from brain as microdissection frees adhesions between tumor and surrounding brain.
  - In dealing with convexity tumor invading dura and cranium, elevation of bone flap in usual manner may damage underlying brain. One plan is to form free flap of bone immediately adjacent to tumor, separated from larger second flap that encompasses entire area. The second flap may be elevated to expose dura surrounding tumor and invaded dura and bone. The tumor may be separated from brain by careful dissection of arachnoid and separation of tumor from brain, preferably using magnification. The brain should be protected by cottonoid or Telfa strips.
  - Invaded bone may be discarded. If invasion involves inner table only, this may be removed by burring. If removal is more extensive, bone flap may be autoclaved and replaced. A defect left by discarded flap may be corrected by prosthesis at same, or at later, operation.
- Opening scalp and skull may be bloody because of hypertrophy of blood vessels originating from external circulation.
- Dural blood vessels should be coagulated before opening dura to decrease tumor vascularity.
- Usually tumor is separated from underlying brain parenchyma by arachnoid layer. This layer may not be complete at depth of tumor. In this location, separating tumor from brain may be difficult.
PARASAGGITAL / PARAFALCINE MENINGIOMA

Foremost consideration in surgically treating parasagittal meningiomas is to decide what to do with SSS (MRV is not yet sensitive enough to confirm unequivocally complete occlusion of SSS; diagnostic test of choice is still endovascular angiography with late venous images to look for possible delayed filling of involved portion of SSS). If SSS is completely obliterated by tumor, it can be ligated safely and excised. The surgeon should be careful not to injure veins that run anteriorly and posteriorly to tumor. These veins may provide crucial collateral circulation for venous drainage of cerebrum and should be preserved at all costs.

B) If SSS is only partially involved, decision of whether to sacrifice it depends on involved segment.

1) anterior third of SSS (i.e. anterior to central (rolandic) veins) can usually be sacrificed with impunity; middle third, sacrificed at times; and posterior third, never ligated. In this author's experience, SSS is never sacrificed beyond anterior third.

2) some surgeons resect partially involved sinus and reconstruct it later (either with vein or prosthetic graft).

3) author's opinion is that explaining to patient that some tumor was left behind that may need further resection at later date is better than taking undue risk of neurological deficit by obliterating more of SSS. If sinus is occluded gradually by tumor, venous drainage will be diverted over time through parasagittal veins.

N.B: recurrence – MRV – if SSS patent → radiosurgery (resection is contraindicated)

SPHENOID WING MENINGIOMA

sphenoid-wing meningiomas present either as en plaque meningiomas or as globular masses.

sphenoid ridge meningiomas vary in approach, depending on whether they occupy outer, middle, or inner third of sphenoid bone. 1) outer-third tumors can be problem purely of tumor mass, purely of massive temporal hyperostosis from en plaque tumor invading bone, or combination of both. When it is present, tumor mass is not insinuated in sylvian tissue, and its removal through frontotemporal craniotomy is complicated by tumor's adherence (on its medial aspect) to sylvian veins.

Surgical cure is not possible.

2) middle-third tumors grow into both frontal and temporal fossae in globular fashion. The approach is through frontotemporal craniotomy, with base of tumor approached first to eliminate blood supply. Surgical cure is likely.

3) inner-third tumors from anterior clinoid process and compress optic nerve and encase carotid and middle cerebral arteries. In addition, medial sphenoidal meningiomas can grow diffusely into cavernous sinus and optic canal. Only in those situations where tumor presents early because of optic nerve compression is total removal even feasible. Most commonly, complete resection is not possible, and surgeon stops when risk of surgery exceeds potential benefits.

need to replace to fronto-temporo-zygomatic craniotomy – see p. Op330 1)

– removing zygoma and orbital rim allows wider exposure of sphenoid wing, middle cranial fossa, anterior cranial fossa, and anterior clinoid.

– expose temporal floor and sphenoid wing

– tumor capsule incision at where tumor comes to surface → debulk → dissect away from vessels.

– careful when bipolarizing dura on temporal floor – trigeminal ganglion underneath (sensory loss).

CAVERNOUS SINUS MENINGIOMA

http://www.neurosurgicalatlas.com/grand-coumad/resection-of-cavernous-sinus-meningiomas

– issue of meningiomas involving cavernous sinus is currently area of intense interest in neurosurgery. No one doubts that, in experienced hands, such meningiomas can be treated successfully.

– debate centers on 2 points: when to operate and how aggressive resection should be. The following opinion is personal reflection on matter, and diverging views may be found in literature. — Asymptomatic cavernous sinus meningiomas should not be operated but should be monitored carefully by means of repeated physical examination and serial MR.

– Symptomatic meningiomas in otherwise healthy patients should be resected by neurosurgeons who are trained for such procedures.

– avoid injuring cranial nerves or carotid artery. This author does not believe in benefit of bypassing and resecting carotid artery in these cases.

– surgeon should remember that multitude of processes may affect cavernous sinus and mimic meningioma, including sarcoidosis and infection/inflammation that lead to Tolosa-Hunt syndrome.

PETROUS APEX MENINGIOMA

– in acoustic neuromas, facial nerve usually lies anterolaterally to tumor and is encountered late in surgery. This relationship is lost in cerebellopontine angle meningiomas, because facial nerve may lie along posterior tumor edge and can be injured early in surgery (unless care is taken to identify it).

– before attempting to remove tumor, surgeon should first diminish its blood supply by coagulating its supplying arteries from dura. To do so, interface of tumor and petrous bone should be identified.

A) a partial cerebellar resection may be necessary to avoid undue retraction of brain.

B) cerebellum could be worked with cautery (adjuvant to surgery).

CLIVAL AND PETROCLIVAL MENINGIOMAS

– although partial resection is relatively straightforward, complete resection remains daunting task.
partial resection usually does not translate into any benefit for patient and only renders further surgeries more difficult; therefore, every attempt should be made to complete resection. If surgery has to be interrupted for logistical reasons, second operation should be scheduled earliest possible opportunity.

— traditional approaches such as suboccipital or subtemporal are usually insufficient to allow complete removal.
— more extensive approaches, such as petrosal (Kawase) approach, are needed. This approach consists of combined supratentorial and infratentorial craniotomies, associated with simple mastoidectomy down to solid angle (i.e. bone encasing inner ear). After tentorium is split, petroclival meningioma can be visualized in its entirety.

TENTORIAL AND TORCULAR MENINGIOMAS

- Tentorial meningiomas may be supplied by multitude of vessels that arise from tentorial leaf. These should be coagulated thoroughly before one attempts to remove tumor.
- Major supply may be Bernasconi-Cassinari artery, which arises from cavernous portion of carotid artery and runs posteriorly to supply tentorium.
- This artery is usually not apparent on normal angiograms but may be conspicuous in angiograms of tentorial meningiomas.
- Definitive attempt should be made at recognizing Bernasconi-Cassinari artery during surgery and coagulating it to decrease tumor vascularity.
- Tentorial meningiomas often grow in both infratentorial and supratentorial compartments and should be approached accordingly.
- Studying preoperative angiogram is imperative in cases of torcular meningiomas to delineate patency of different sinuses and available collateral circulation. Removing these tumors completely is often impossible because of partial involvement of venous sinuses.
- Adequate demonstrable patency of opposite lateral or sigmoid sinus may permit resection of involved sinus. The size of sinus, however, at times may permit reconstruction of sinus after removal of one wall from which tumor extends into lumen.

- Anterolateral (AL) incisural meningioma - middle third of the tentorial free margin: pterional, subtemporal, and retromastoid approaches.
- Posteromedial (PM) incisural meningioma - posterior third of the tentorial free margin: occipital or supracerebellar infratentorial approaches.