**PREOP**

1. Determine Resectability
   - Intraxial tumors
   - Extra-axial tumors

2. ANESTHESIA

3. APPROACH SELECTION

4. SURGICAL PRINCIPLES

5. Position

6. Monitoring

7. Mapping of eloquent cortex

8. Brain relaxation

9. Operative corridor

10. Blood supply

11. Tumor resection

12. Extent of tumor resection

13. Tumor fencing

14. Ventricular entry

15. Intraoperative MRI (iMRI, ioMRI)

16. Fluorescence-guided resection (s. chemonavigation)

17. Fluorescent sodium

18. 5-aminolevulinic acid (5-ALA)

19. Closure

20. Postoperative

21. Steroids

22. AED

23. Embolic measures

24. Postoperative imaging

25. Complications

26. Skull Base Tumors

   - Anterior skull base

   - Cavernous Sinus and Mezzi Fossa

27. Pineal Region Tumors

28. Posterior Fossa Tumors

29. Cerbellar-Pontine Angle, 4th Ventricle

30. Brainstem Tumors

31. Cerbellar Tumors

32. Hemangioblastomas

33. Third Ventricle

   - Endoscopic transventricular resection of 3rd ventricle colloid cyst

   - Transforaminal resection of 3rd ventricle colloid cyst

   - Transchoroidal (subchoroidal or supachoroidal) approach

34. Intraventricular approach

35. Lateral Ventricle Masses

   - Preoperative

   - Operative Techniques

   - Temporal Lobe

   - Parietal Lobe

   - Occipital Lobe

   - Frontal Lobe

   - Corpus Callosum (transcallosal interhemispheric approach)

36. Indications

37. Procedure

38. Complications

39. Combined approaches (transcallosal + transcortical)

40. Postoperative Deficits

41. Meningiomas

   - Principles in meningioma resection

   - Simpson Grades

42. Meningioma involving bone

43. Very large meningioma

44. Olfactory groove meningioma

45. Anterior clinoid region meningioma

46. Convexity meningioma

47. Parasagittal/ Para-falcial meningioma

48. Spheoidal wing meningioma

49. Cavernous sinus meningioma

50. Petrous apex meningioma

51. Cerbellar-Pontine angle meningioma

52. Clival and Petroclival meningioma

53. Tentorial and vesicular meningioma

54. ChandotomY details – see p. Op300 >

55. Vestibular schwannoma – see p. Onc62 >

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**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 MENINGIOMAS or ACOUTIC NEUROMIAS) 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 cytoreductive resection); how can it be improved:
  1. iMRI for cortical mapping (BIOLD - shows increased venous drainage [not electrical activity of neurons] from active cortex).
  2. DTI (tractography) for subcortical structures - to see not if tract is involved (usually that can tell clinically) but where eloquent tract is displaced by tumor (so we will see how safely approach tumor).
III. AXIAL TUMORS

- not amenable to RADIICAL surgical resection;  
  - most gliomas lack microsopic 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 even of malignant gliomas has some benefit (cytoreduction).
- solitary brain metastasis is indication for surgical resection (depending on systemic medical status).

- lateral approaches
  - Anterior skull base: tumors of upper one third of clivus, lesions of odontoid process → transoral approach; tumors in sella turcica → transsphenoidal approach (osteotomy through zygoma and orbital roof).
  - middle skull base: tumors behind orbit (incl. tumors of gasserian ganglion and cavernous sinus) → transpetrosal or presigmoid approach (may be extended by osteotomy of mandible).
  - extreme lateral approach: tumors generally grow by expansion.
- tumor behind orbit (incl. tumors of gasserian ganglion and cavernous sinus) → transpetrosal or presigmoid approach (may be extended by osteotomy of mandible).
- MANITOL: (1 g/kg) + hyperventilation (PeCO₂ 25-30 mmHg) for definitive ICP 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. Broadus “It takes 10 minutes for mannitol to start working and those 30 minutes are with increased rheological bleeding; mannitol peak effect lasts several hours”).
- BRAINSTEM: 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 bromsulphthalein IV (during induction of anesthesia) - tumor labeling on fixed tissue postoperatively.
- craniotomy at that site.
- skull base tumors
  - Anterior skull base: a) tumor behind orbit (incl. tumors of gasserian ganglion and cavernous sinus) → orbitozygomatic approach (ostectomy through zygoma and orbital roof). 
  - tumors in sella turcica → transphenoidal approach.
  - tumors of upper one third of clivus, lesions of odontoid process → transoral or transpalatal approach (may be extended by ostectomy of mandible).
  - tumors of pontine sulci and upper one third of clivus → transfacial approach (to expose mandible for ostectomy, midface can be degloved).
- 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 → retrosigmoid craniotomy.
  - lesions of petrous surface of temporal bone → suboccipital craniotomy.

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 ICP.
- increasing number of resections in dominant hemisphere are done under local anesthesia for purpose of speech mapping.
- MANITOL: (1 g/kg) + hyperventilation (PeCO₂ 25-30 mmHg) for definitive ICP 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. Broadus “It takes 10 minutes for mannitol to start working and those 30 minutes are with increased rheological bleeding; mannitol peak effect lasts several hours”).

POSTION

- 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 an embolism, less comfortable for operating physician, but field is much larger 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. C7N monitored with EMG, CN8 monitored with BEAR), cortex incision is ≈ 3 cm in length.
- lesions of cerebellopontine angle → retrosigmoid craniotomy.

SURGICAL PRINCIPLES

- skull base tumors
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MAPPING OF ELOQUENT CORTEX

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

-data is opened only after brain has been softened completely by mammitid diathermy and intraprofusor hyperventilation (sometimes few minutes' wait is necessary - this brief pause can be critical to success).

OPERATIVE CORRIDOR

1. Sulcal approach to limit cortical manipulation (need to access large lesions in deep in brain may make this too confining).
-No gyrus should be entered, unless it is involved in tumor.

2. Use natural corridors:
1) Fissures (do not violate normal cortex); e.g. medial temporal* approach from Sylvian fissure split above Sylvian vessels (up to choroidal fissure).
   -tumor involves temporal region (memory) is phylogenetically different than lateral (Wernicke, auditory); tumors do not spread between these regions.

2) sulci (e.g. BrainPath circular retractor – atrumatic transsulcal approach)

3) ventricles - to operate endoscopically (through ventricles); need large hydrocephalus (e.g. clamp EVD at midnight - enlarged ventricles can be used to surgeon's advantage in planning access)
   -Optimal corridor to ventricles should not compromise neurological function through direct manipulation of eloquent cortical structures (shortest pathway to lesion is not necessarily best option).
   -Deliver lesion into field of view without excessive retraction (requires patience)
     -One of most common causes of postoperative neurological deficits is excessive retraction (to expose mass or to stop bleeding).

3. Corticostomy (most likely at cortex closest to tumor surface) - coagulate with bipolar + cut with microscissors / spread with bipolar prongs (on sucker tip)
   -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.

4. Retractors - Greenberg retractors.
   -For intraventricular tumors use Vycor / BrainPath retractors (connect to Greenberg frame) / Greenberg retractors.
   -Handheld retractors are less traumatic (retraction injury).

BLOOD SUPPLY

Early access to blood supply - obtain proximal control.

-Partial portions of tumor resection should be directed toward gaining access to vascular supply.

-Intraventricular tumors may receive blood supply from choroidal vessels of both anterior and posterior circulations.

-Exsanguination is likely cause of earlier reports of high mortality in infants with choroid 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 mass (bipolar & gentle suction, CUSA): debulking tumor center → dissecting remaining shell from surrounding normal brain tissue by advancing patty / Tefa into interface (i.e. resection proceeds from inside out so that surrounding normal white matter is disturbed minimally).

-May use saline spray with blunt needle tip to open plane.

-Piecemeal resections will result in bleeding, and many times this cannot be avoided.

-Intraventricular bleeding → protect foramen of Monro with cotton square (to avoid obscuration of this structure and to prevent blood from pooling in ventricles) → copious 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 pathological 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 (CUSA) - tip vibrates at 22,000 Hz - ultrasonically disrupts tumor, tip is surrounding by two concentric channels, one dispensing saline to solubilize fragments and another suctioning away fluid or intraventricular tumors use.

*Goal - removal of maximal amount of tumor consistent with functional preservation

-Total resection should be goal of surgery.

-Gliding peritumoral white matter is seen easily through microscope as tumor's margin is reached
   -At this interface resection is stopped.

-Incomplete removal may be preferable when site of attachment invades into deep structures such as thalamus (goal is debulking when mass effect is cause of symptoms).

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 RESECTION

-Inserting along tumor perimeter (using navigation, before tumor resection – to avoid shift) Becker

-ventricle catheters (cut flush to brain surface but still tend to fall out – so suture to dura edges) or strings of patties.
Practical

Indication: high-grade glioma (suspected WHO grades III-IV on preoperative imaging).

Contraindication: porphyria.

Dosage: 56 mg/kg (1 vial, 2700 $ = 1 vial, 2700 mg) is taken PO 3 hours (range 2 to 4 hours) prior to induction of anesthesia.

5-ALA leads to accumulation of fluorescent porphyrins (protoporphyrin IX) in tumor tissue.

Max fluorescence time is 5-8 hours.

False positive – metastases, inflammation.

Positive predictive value – 95%.

Negative – necrotic tissue will not fluoresce.

Intensity of fluorescence will diminish as a function of the focal distance of the microscope filter.

N.B. there is no data on redosing! Must be reconstituted 1500 mg/50 mL of water per vial.

5-ALA is metabolized to protoporphyrin IX, an endogenous fluorescent bioproduc

Mechanism of action

5-ALA is metabolized to protoporphyrin IX, an endogenous fluorescent bioproduc
opened, it should be walled off to prevent blood from collecting within it. If cortex is reached opposite sonic aspiration. Dissection around base of tumor continues until tumor is isolated. If ventricle is such lines of demarcation are usually delimited. Generally, brain substance is divided by suction or dissection. It is usually safe to make subpial dissection to adjacent sulcus, continuing into white matter.

Pharmacokinetics (PK), Pharmacodynamics (PD)
- drink room temperature.
- vial wrapped in yellow bag.
- mean absolute bioavailability - 100%.
- maximum ALA plasma concentration - within a median of 0.8 hour.
- T1- 1 hour.
- Tmax for PpIX - 4 hours.
- T1/2 of PpIX - 3.6 hours.
- the fraction of administered ALA that is metabolized to PpIX is unknown.
- the effect of renal or hepatic impairment is unknown.

Adverse reactions
- one patient experienced respiratory failure due to drug overdose.
- no liver failure cases reported (but LFTs 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).
When bulk of tumor has been removed, further search for additional tumor is carried out and such preserved. Hemostasis during dissection aids visualization of structures and identification of vessels. Care must be taken against undermining or excessive retraction of functional cortex to be interfered. anticonvulsants again may be needed during or after radiation therapy.

**POSTOPERATIVELY**

- **extubation**: a) if surgery entails significant manipulation of brain stem, patient should remain intubated for first postoperative night 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.
- **ICU** for at least 1 night. 
- serum electrolyte levels and osmolality are measured often (also to detect possible onset of SIADH or diabetes insipidus, esp. after endoventricular manipulations).

**STEREOTAXY**

Continued DEXAMETHASONE for at least 5 days (to minimize surgically induced brain edema);
- if adequate surgical decompression is achieved, steroid can be discontinued within 1-2 weeks.
- speed of weaning depends on:
  1. postop new deficits 
  2. amount of edema on post FLAIR MRI
- **indications for steroid maintenance**:
  1) large volume of tumor remains, large edema → check on postop MRI
  2) unexpected (likely from edema) new / worsening postoperative deficits
  3) tumor in brainstem or spinal cord
  4) stereodend
- corticosteroids again may be needed during or after radiation therapy.

**AED**

Continued anticonvulsants for at least 7 days (few recommend - 1 year).
- incidences of seizures after surgery for brain tumors is low (5% [95% CI 3%–18%]) 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 (while patients are initially seizure free after surgery, seizure recurrence is associated with tumor progression).
- **3 mechanism** 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 infections (hydrocephalus, edema, or infection)
- traditional AEDs are potent enzyme-inducing (PHENYTOIN, CARBAMAZEPINE, PHENOBARBITAL) or inhibiting (VALPROIC ACID) → reduce / increase serum concentration of chemotherapeutics.
- new generation of AEDs (GABAPENTIN, LEVETRAXACTETAM) 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.
- PHENYTOIN vs. placebo for 7 days postop.
- incidence of all seizures was 18% in observation group and 24% in prophylaxis group (p = 0.51).
- incidence of early seizures (≤ 30 days after surgery) was 8% in observation group vs. 10% in prophylaxis group (p = 1.0).
- incidence of clinically significant early seizures was 3% in observation group and 2% in prophylaxis group (p = 0.62).
- prophylaxis group experienced significantly more adverse events (18% vs. 0%, p < 0.01).

- 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 provides no benefit in prevention of either early or late postoperative seizures.

**ANTIBIOTIC MEASURES**

- compression boots, subQ heparin immediately postop → early passive exercises and mobilization!!!

**POSTOPERATIVE IMAGING**

- baseline contrast MRI within 48 hours - to evaluate resection success (late, prominent enhancement of resection cavity is a predictive sign); (no routine imaging); 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 (MEDULLOBLASTOMAS, Ependymomas, CHORDOMAS, CHOROID PLEXUS CARCINOMAS, certain PINEAL GLIOMAS), 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 closely during first 24 months (CSF exam alone is inadequate – may be false negative in up to 50% 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: (unwarranted in asymptomatic patients following complete resection of benign tumors): every 3-6 months during first 2 years; every 6-12 months for following 2-3 years (to detect late events such as radiation-induced meningiomas).

- residual or recurrent contrast enhancement ≥ 3 months after surgery suggests recurrence.

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.

- tumor recurrence – consider reoperation.

COMPLICATIONS

- 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. Treatment Kageji et al. Postoperative Hematoma Requiring Recraniotomy in 1149 Consecutive Patients With Intracranial Tumors. Oper Neurosurg (Hagerstown) (2017) 13 (3): 392-397

- incidence of a POH requiring a recraniotomy was 2.09%.

- among recraniotomy patients, 12.5% died within 30 days of the first surgery.

- 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 transparent/synaptic 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
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 laminctomy:

no syrinx → remove upper ones (tumors);

syrinx present → remove largest one (tumor) → syrinx resolves in 1-3 months (if not - means residual tumor)

- coagulate tumor surface with wide bipolar forceps (avoid penetration of tumor itself due to its extreme vascularity and difficulties with hemostasis).

- dissect tumor circumferentially by careful coagulation and cutting small feeding vessels and adhesions between tumor and surrounding tissue to avoid direct pressure on brain or spinal cord tissue.

- identify feeding vessels → coagulate and cut (arterial feeders prior to draining veins!)

- gently pack resection cavity with wet cotton balls → blood oozing stops after few minutes.

- identify feeding vessel → coagulate and cut (arterial feeders prior to draining veins!)

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

N.B. 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 → CT; if evaluation reveals pheochromocytoma → resection of pheo first (if resection is prohibitive, preoperative α-blockade with β-blockade begun only after α-blockade to avoid unopposed α-activity)

From Greenberg, p. 672

Surgical treatment may be curative in cases of sporadic HGB, not in VHL. Pre-operative embolization may help reduce the vascularity. Cystic HGBs require removal of mural nodule (otherwise, cyst will recur). The 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. Solid HGBs tend to be more difficult to remove. They are treated like AVMs (avoid piecemeal removal), working along margin and devascularizing blood supply. A helpful technique is to shrink the tumor by laying a length of bipolar forceps along tumor surface and coagulating. HGBs with attachment to floor of 4th ventricle may be hazardous to remove (cardio-respiratory complications). Multiple lesions: if > 0.8-1 cm diameter: may treat as in solitary lesion. Smaller and deeper lesions may be difficult to locate at time of surgery.

THIRD VENTRICLE

Pending read:

Approaches to the Third Ventricle - Interhemispheric Transcallosal

A. Transectorial approach - facilitated by ventriculomegaly

B. Transcallosal (interhemispheric) approach - equally effective in reaching foramen of Monro with large or small ventricles >>

A. Transforaminal approach

B. Transchoroidal approach

C. Interforniceal approach
**Experts say that it is OK to divide massa intermedia.**

**Endoscopic Transventricular Resection of 3rd Ventricle Colloid Cyst**

**Pending**

Jandial, procedure 47

**Transforaminal Resection of 3rd Ventricle Colloid Cyst**

- Lesions in the anterior portion of the third ventricle are often easily accessible through the foramen of Monro and sometimes even expand and protrude through the foramen.

- 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 Monroe 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; time should be taken to dissect the dura carefully from the inner table working away from the sagittal sinus; connect bur holes with footplate – 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 rongeur (may fail due to rubbery nature of cyst contents).
  - Very gentle tumor rocking allows tumor delivery into lateral ventricle via foramen of Monro.
TRANSCOROIDAL, SUBCOROIDAL OR SUPRACHOROIDAL 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 choroidea, 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.
- suprachoroidal approach - incision is made above and medial to the choroid plexus in the taenia fomica, and the choroid is deflected inferiorly - approach requires less manipulation of the superficial thalamic and caudate veins.- safer.
- interforneical approach - midline division of the forniceal bodies
- bilateral fomicidal 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 interforneical approach, remain cognizant of the hippocampal commissure in the posterior component of fornices.
- 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>Colloid cyst</td>
<td>Foramen of Monro / 3rd ventricle</td>
</tr>
<tr>
<td>SEGMA</td>
<td>Foramen of Monro</td>
</tr>
<tr>
<td>Choroid plexus papilloma</td>
<td>Trigon of lateral ventricle</td>
</tr>
<tr>
<td>Epidermoidoma</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.

**Access to temporal horn**

A. Temporoparietal junction:
   1) traverse angular gyrus → dyslexia, agraphia, acalculia, ideomotor apraxia in dominant hemisphere (in nondominant hemisphere - impaired visual memory, construction deficits, neglect).
   2) cross optic radiations → visual field deficit

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

**PARietAL LOBE**

- incisions contraindicated in dominant hemisphere (→ speech deficits).
- vascular supply is away from surgeon's line of vision.

**Access to occipital lobe**

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 acalculia and apraxia (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 incision / 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 (Transcallosal Interhemispheric 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.
  - Mannitol can be used to surgeon's advantage - patient in lateral decubitus position with involved hemisphere dependent - fall 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) – easier 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/Budde with 3/8 retractor blades.

- View 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 hemispheres, 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).

- Callousomy 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 advanced to expose the lateral ventricular anatomy.

- 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.
Case illustration:

- 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 enters fissure of Monro:

**COMPLICATIONS**

- disconnection of hemispheres, esp. in patients with anomalous cortical organization (H. Wada test prior to transcallosal surgery):
  - mutism, akinnesia, aphasia, 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.
  - transcallosal surgery in left-hemisphere speech-dominant patients with right-hemisphere memory only or right-hemisphere speech dominant patients with left-hemisphere memory only could result in memory disorder.
  - 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 involved. Mutism may also be caused either by direct retraction of the anterior cingulate gyrus, septum pellucidum, and fornix or by circulatory disturbances to the fornices or choroid plexus reliably guides the surgeon to the foramen of Monro.

**APPROACHES**

- **TRANSCALLOSAL + TRANSCORTICAL**
  - for masses that are too large to remove through single approach.
  - when hemisphere is disrupted by tumor (rather than by CSF) → transcallosal incision and partial decompression to obtain sufficient relaxation → interhemispheric dissection for callosotomy.
  - 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.
  - transcallosal 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.
- seizures can occur in any patient (29-70% 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.
- 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).

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.

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 tumor 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
- embolization is performed using polyvinyl alcohol microparticles (PVA) 150-300 μm; smaller particles (Gelfoam powder) or liquid agents (Onyx, phenytoin, Lipiodol) may provide deeper tumor penetration but increased risk of side effects; other agents: porous cellulose beads, hydroxyapatite, trisacryl gelatin (TAG) microspheres.
- 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 planes).
- involved dura as well as dural rim free from tumor should be resected (**duralplasty**), dural tails (apparent on MRI) are best removed.

---

*leaving some tumor behind is often better than risking neurologic function for sake of complete removal*
BRAIN TUMOR SURGERY

D. Simpson 1957

**Table 21-25. Simpson grading system for removal of meningiomas**[3,10]

<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 uncinectomy conglutination (Bow, or loss of) of dural attachment</td>
</tr>
<tr>
<td>III</td>
<td>macroscopically complete without excision or conglutination of dural attachment or of its extradural extensions (e.g. hyperostotic bone)</td>
</tr>
<tr>
<td>IV</td>
<td>partial removal leaving tumor in situ</td>
</tr>
<tr>
<td>V</td>
<td>simple decompression (a biopsy)</td>
</tr>
</tbody>
</table>

**Degree of Resection**

<table>
<thead>
<tr>
<th>Recurrence rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete resection with conglutination of dura</td>
</tr>
<tr>
<td>Complete resection</td>
</tr>
<tr>
<td>(no treatment of dura)</td>
</tr>
<tr>
<td>Partial removal leaving tumor in situ</td>
</tr>
</tbody>
</table>

**Decompression**

NA

**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%
- Some times 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 debulk (make cruciate durotomy 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**

- Transnasal endoscopic resection – for small tumors. See p. Op300 >>
- (Unilateral)*
  - Subfrontal craniotomy ± orbital osteotomy
  - Frontal interhemispheric approach (ligating anterior portion of superior sagittal sinus)
    - Unilateral approach is usually sufficient
- Tumor arterial supply and perforator arteries to hypothalamus must be differentiated because both arise from anterior circulation.
- These tumors receive their blood supply through various sources:
  1) Ethmoidal arteries (branches of ophthalmic arteries)
  2) Branches from middle meningeal artery
  3) Carotid arteries.
- To avoid undue retraction of frontal lobes, these tumors are best approached through low fontal craniotomy entering frontal sinus (up to removing supraorbital rim).
  - Dr. Graham likes for large tumors opening dura higher (than for subfrontal approach) and using interhemispheric approach.
  - To allow adequate visualization, falx should be completely sectioned after 2-0 silk suture ligating most anterior aspect of SSS.
  - Do not use ligating suture for falx retraction.
  - Attempt to preserve at least one of olfactory nerves.

**Likelihood of Total Excision**

(MGH, n=225)

<table>
<thead>
<tr>
<th>Tumor Location</th>
<th>n</th>
<th>% Total Excisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cranial sinus</td>
<td>47</td>
<td>96%</td>
</tr>
<tr>
<td>Osteitis</td>
<td>5</td>
<td>80%</td>
</tr>
<tr>
<td>Sinus</td>
<td>18</td>
<td>76%</td>
</tr>
<tr>
<td>Olfactory groove</td>
<td>22</td>
<td>77%</td>
</tr>
<tr>
<td>Paracentral area/Fish</td>
<td>38</td>
<td>76%</td>
</tr>
<tr>
<td>Paramedian Region</td>
<td>26</td>
<td>57%</td>
</tr>
<tr>
<td>Posterior fissure</td>
<td>21</td>
<td>57%</td>
</tr>
<tr>
<td>Sphenoid ridge</td>
<td>26</td>
<td>58%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>225</td>
<td>64%</td>
</tr>
</tbody>
</table>

ANTERIOR CLINOID REGION MENINGIOMAS

- 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 clinectomy for all clinoid region meningiomas.

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 fines 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 flag 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. If the brain should be protected by contoured 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 autologized and replaced. A defect left by discarded flap may be corrected by acrylic 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 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 dural incision. In this location, separating tumor from brain may be difficult.
- Unless tumor is small and can be removed in 1 piece, best strategy for excising convexity meningiomas is to find arachnoid plane and dissect it gently.
- Placing sutures circumferentially around tumor allows quick identification of this crucial plane at later time.

PARASAGITTAL / PARAFACIAL 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).
- a) 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 inner tumor segments that should be preserved at all costs.
- b) If SSS is only partially involved, decision of whether to sacrifice it depends on involved segment.
  - 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.
  - Some surgeons resect partially involved sinus and reconstruct it later (either with vein or prosthetic graft).
  - 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 obliteration more of sinus. If sinus is occluded gradually by tumor, venous drainage will be diverted over time through parasagittal veins.

Cavernous Sinus Meningioma

- The cavernous sinus is accessible through lateral orbitotomy. The sphenoid sinus is usually opened through the ethmoid sinuses to reach the cavernous sinus.
- The temporal lobe is retracted away from the cavernous sinus, and the optic nerves and oculomotor nerves are protected.
- The cavernous sinus is entered through a transcarotid approach.

SPHENOID WING MENINGIOMA

- Sphenoid-wing meningiomas present either as 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 insinuates itself in sylvian tissue, and its removal through frontotemporal craniotomy is complete tumor (excluding tumor's adherent peripoiculus) aspect to sylvian veins. Surgical cure is not possible.
  2) Middle-third tumors grow into both frontal and temporal fossae. Surgical cure is possible.
  3) Inner-third tumors arise from anterior clinoidal 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 surgery serves only to remove of risk of surgery exceeds potential benefits.

Cavernous Sinus Meningioma

- Hereditary meningioma syndrome
- Multiple meningiomas
- Malignant transformation
- Recurrence

Caverno's Sinus Meningioma

http://www.neurosurgicalatlas.com/grand-rouind/resection-of-cavernous-sinus-meningiomas
issue of meningiomas involving cavernous sinuses is currently an 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 MRI.

— 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 cavernous carotid artery in these cases.

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

PETROUS APEX MENINGIOMAS

— in acoustic neuromas, facial nerve usually lies anterosuperior 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 followed. A partial cerebellar resection may be necessary to avoid undue retraction of brain.

— SRS is a good alternative or 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.

— multitude of approaches has been devised for these tumors.

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

— SRS is a good alternative or adjuvant to surgery.

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 the Bernasconi-Cassinari arch, which arises from cavernous portion of carotid artery and runs posteriorly to supply tumor.

— this arch is usually not apparent on normal angiograms but may be conspicuous in angiograms of tentorial meningiomas.

— definite attempt should be made at recognizing Bernasconi-Cassinari arch during surgery and coagulating it to decrease tumor vascularity.

— Tentorial meningiomas often prove to be 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.

— 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: ptorional, subtemporal, and retromastoid approaches.

— Posterior (PM) incisural meningioma - posterior third of the tentorial free margin: occipital or supracerebellar infratentorial approaches.