Detailed preop 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.

PREOP

1. Determine Resectability

2. Intra-axial tumors

3. Extra-axial tumors

4. ANESTHESIA

5. APPROACH SELECTION

6. SURGICAL PRINCIPLES

7. Position

8. Monitoring

9. Mapping of eloquent cortex

10. Brain relaxation

11. Operative corridor

12. Blood supply

13. Tumor resection

14. Extent of tumor resection

15. Tumor fencing

16. Ventricular entry

17. Intraoperative MRI (iMRI, ioMRI)

18. Fluorescence-guided resection (s. chemonavigation)

19. Fluorescent sodium

20. 5-aminolevulinic acid (5-ALA)

21. Closure

22. Postoperative

23. Steroids

24. AED

25. Symbolic measures

26. Postoperative imaging

27. COMPLICATIONS

28. SKULL BASE TUMORS

29. ANTERIOR SKULL BASE

30. CAVITARY TUMORS AND MELIDE FOSSA

31. PINXAL REGION TUMORS

32. POSTERIOR FOSSA TUMORS

33. CEREBELLOPONTINE ANGLE, 4TH VENTRICLE

34. BRAINSTEM TUMORS

35. CEREBELLAR TUMORS

36. HEMANGIOBLASTOMA

37. THIRD VENTRICLE

38. Endoscopic transventricular resection of 3rd ventricle colloid cyst.


40. Transchoroidal (subchoroidal or supachoroidal) approach.

41. Intraventricular approach

42. LATERAL VENTRICULAR MASS

43. PREOPERATIVE

44. OPERATIVE TECHNIQUE

45. Temporal Lobe

46. Parietal Lobe

47. Occipital Lobe

48. Frontal Lobe

49. Corpus Callosum (transcallosal interhemispheric approach)

50. Indications

51. Procedure

52. Complications

53. Combined approaches (transcallosal + transcortical)

54. POSTOPERATIVE DEFECTS

55. MENINGIOMAS

56. PREOPERATIVE

57. Principles in meningioma resection

58. Simpson Grades

59. MENINGIOMA INVOLVING BONE

60. VERY LARGE MENINGIOMA

61. OPAcITY GROUP MENINGIOMA

62. ANTERIOR CLINOID REGION MENINGIOMA

63. CONVEXITY MENINGIOMA

64. PARASEGITAL/ PARAFALANGE MENINGIOMA

65. SPHENOID WING MENINGIOMA

66. CAVITARY SINUS MENINGIOMA

67. PETROUS APICA MENINGIOMA

68. CEREBELLOPONTINE ANGLE MENINGIOMAS

69. CLIVAL AND PETROCLIVIC MENINGIOMAS

70. TENTORIAL AND VERMICULAR MENINGIOMAS

71. CHORDOMY DETAIS - see p. Op300

72. VESTIBULAR SCHWANNOMA - see p. Otx02

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!

1. ENH for cortical mapping (BOLD - 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 will see how safely approach tumor).
**INTRA-AXIAL TUMORS**
- not always curable due 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 even of malignant gliomas has some benefit (cytoreduction).
- solitary brain metastasis is indication for surgical resection (depending on systemic medical status).
see p. Omn232.**
  - 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.

**EXTRA-AXIAL 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 ICP.
  - increasing number of resections in dominant hemisphere are done under local anesthesia for purpose of speech mapping.
- Mannitol (1 g/kg) + Hyperventilation (PeCO2 25-30 mmHg) for definitive ICP reduction in preparation for brain resection; 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 manitol to start working and those 30 minutes are with increased rheological bleeding; manitol peak effect lasts 30 hours”).
- **c) 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 (IV during induction of anesthesia) - tumor labeling on fixed tissue postoperatively.

**APPROACH SELECTION**
For craniotomy details see p. Op310.**

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

Subcortical tumors are approached through:
- a) deep sulci (vs. gyral crown) avoiding eloquent areas (e.g. approaching lesion obliquely).
- b) anterior corpus callosum (causes minimal, if any, deficit).
- c) dilated ventricles (causes minimal, if any, deficit).
- d) localized resection of subcortical tumors:
  - a) intraoperative ultrasonography
  - b) frameless MRI-guided navigation (markers on patient's scalp).

**Skull base tumors**
Amnot skull base:
- a) tumor behind orbit (incl. tumors of gasserian ganglion and cavernous sinus) → **orbitalzygomatic approach** (osteotomy through zygoma and orbital roof).
- b) tumors in sella turcica → **trans-sphenoidal approach**.
- c) tumors of upper one third of clivus, lesions of odontoid process → transoral or transpalatal approach (may be extended by osteotomy of mandible).
- d) tumors of pterional sinuses and upper one third of clivus → **transfacial approach** to expose mandible for osteotomy, 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**
- a) extreme lateral approach - exposes lower third of clivus, cerebellopontine angle, and petrous surface temporal bone.
- b) lesions of cerebellopontine angle → **retromastoid craniotomy**.
- c) lesions of petrous surface of temporal bone → **suboccipital craniotomy**.

**SURGICAL PRINCIPLES**
For craniotomy details see p. Op310.**

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 an embolism, less comfortable for operating physician, but field is much better because drainage is easier.
- head is held rigidly with **pin 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).
- **intraoperative electrocorticography** (ECoG) is useful in guiding epilepsy surgery, e.g. tumor-associated epilepsy (esp. in long-standing or severe seizures).

**MAPPING OF ELOQUENT CORTEX**

-BRAIN TUMOR SURGERY- Op340 (2)
BRAIN RELAXATION

-data is opened only after brain has been softened completely by mannitol diuresis and intraparenchymal 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 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* tumor - approach from Sylvian fissure split above Sylvian vessels (up to choroidal fissure).
-2) 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)
-3) Venticles - 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)

-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. Corticotomy (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 Gelffoam) to keep fluid contained within ventricles

*makes 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.
-Initial 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.

-exanguination 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 resection of large massas (bipolar & gentle suction, CUSA): debulking tumor center – dissecting remaining shell from surrounding normal brain tissue by advancing pabrites / Yella 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) – ccesso surgery (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 surrounded by two concentric channels, one dispensing saline to solubilize fragments and another suctioning away (CUSA).

-for intraventricular tumors use Vycor / BrainPath retractors (connect to Greenberg frame) / Greenberg retractors.

-handheld retractors are less traumatic (retraction injury).

TUMOR EXTENSION:

-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. Onc109
-Low-grade gliomas – see p. Onc109

TUMOR RESECTION:

-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 strands of pia.
**VENTRICULAR ENTRY**

- during resection of high-grade gliomas (HGG):
  - https://doi.org/10.1097/01.nua.0000059382.02165.62

- higher odds of intraparenchymal migration (sOR: 3.91 [95% confidence interval (CI): 1.89-8.10]; 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)
  - increased 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, iMIR)**

- 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!
- fluoresce 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.
- 5-ALA fluorescence-guided surgery vs. conventional surgery
  - class I evidence.
    - Fluorescence-assisted surgery
    - Conventional surgery
    - Statiscal significance
    - Percentage of complete resections
      - 65% 36%
      - p < 0.0001
    - PFS (6 months)
      - 41% 21%
      - p = 0.0003

**FLUORESCIN SODIUM**

- 3–20 mg/kg IV at dual opening. 560 nm microscope filter
- contraindication – serum creatinine > 2 mg/dL

**5-AMINOLEVULINIC ACID (5-ALA)**

**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, an endogenous fluorescent bioactive intermediate 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.

**Practical**

- 1 g is taken PO 2 h before surgery.
- 5-ALA leads to accumulation of fluorescent porphyrin (protoporphyrin IX) in tumor tissue.
- target region is exposed to laser light with 405 nm wavelength (with hand-held device):
  - laser light is blue
  - tumor tissue glows red
  - surrounding infiltrated tissue glows orange.
- after operation, avoid direct sunlight for 24 hours.

**Studies**

- ALA fluorescence is a good marker of tumor presence but is not a good indicator for the absence of tumor when no fluorescence is present (negative predictive value only 37%)
  - In 11 of 12 operations, residual contrast enhancement on iMRI was found after complete resection of 5-ALA fluorescent tissue.
- Not all glioblastoma tissue exhibits 5-ALA fluorescence and not all areas of iMRI contrast enhancement represent tumor. iMRI performed after complete resection of 5-ALA fluorescent tissue shows contrast-enhancing regions suspicious for tumor in a high percentage of cases (91.6%), whereas those regions in fact contain tumor in only 64.3%.
- it is well established that even MRI-nonfluorescing low and high-grade gliomas will show fluorescence in about 20% of cases.

- Fluorescence shows more than expected from gadolinium enhancement
  - 100-200% lower enhancement than the fluorescent 5-ALA accumulation
- Fluorescence shows extreme heterogeneity: non-visible 5-ALA accumulation

- 2 cohorts of patients with GBM (n = 50), both without residual enhancement on early postoperative (1.5 T) MRI, 1 cohort with and 1 cohort without residual fluorescence; cohort without residual fluorescence survived 16 months longer.
- Volume of fluorescing tissue is about double the volume of enhancement on MRI.
- Fluorescence extends even beyond the fluoro-ethyl-tyrosine-PET zone of hypermetabolism.

**FDA approval**

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. Recommended oral dose: 20 mg/kg administered 3 hours (range 2 to 4 hours) prior to induction of anesthesia. Do not administer phototoxic drugs for 24 hours during the perioperative period. Reduce exposure to sunlight or room lights for 24 hours postoperatively.

Mechanism of Action (MOA)
ALA HCl leads to accumulation of its metabolite protoporphyrin IX (PpIX) in tumor cells. Under an operating microscope adapted with a specific blue emitting light source and filters for excitation light of wavelength 375 to 440 nm, and observation at wavelengths of 620 to 710 nm, tumor tissue is visualized as red fluorescence. Tissue lacking sufficient PpIX concentrations appears blue.

General Pharmacokinetics (PK), and Pharmacodynamics (PD)
- **Absorption:** The mean absolute bioavailability of ALA HCl following the approved recommended dose of Gleolan solution was 100%. Maximum ALA plasma concentrations were reached within a median of 8.8 hours. The Tmax for PpIX occurred within a median of 4 hours. **Protein Binding:** The mean protein binding of ALA was 12% at concentrations up to approximately 25% of the maximal concentration following the approved recommended dose of Gleolan.
- **Half-Life:** The mean half-life of ALA is approximately 1 hour. The mean elimination half-life of PpIX is 3.6 hours.
- **Metabolism:** Exogenous ALA is metabolized to PpIX, but the fraction of administered ALA that is metabolized to PpIX is unknown. The average plasma AUC of PpIX is < 6% of that of ALA.
- **Excretion:** The mean excretion of parent ALA in urine in the 12 hours following administration of the approved recommended dose of Gleolan was 34%.

Drug Interactions
Patients exposed to a photosensitizing agent may experience a phototoxic skin reaction (severe sunburn). Avoid administering phototoxic drugs (e.g., St. John's wort, griseofulvin, thiazide diuretics, sulfonylureas, phenothiazines, sulphonamides, quinolones, and tetracyclines) and topical preparations containing ALA for 24 hours before and after administration of Gleolan.

Specific Populations
The effect of renal or hepatic impairment on the PK of ALA following Gleolan administration is unknown.

Efficacy and Safety
The efficacy of 20 mg/kg ALA HCl was evaluated in three clinical studies (Studies 1-3) involving patients, ages 18 to 75 years old, who had a preoperative MRI compatible with malignant glioma and were undergoing surgical resection.

Both open-labelled studies, Study 1 included 33 patients with newly diagnosed glioma and Study 2 included 36 patients with recurrent glioma. Both studies compared fluorescence (positive/negative) to tumor status (true/false) using histopathology as the reference standard. In 4 patients with low grade glioma randomized to the ALA fluorescence arm, presence of fluorescence at a biopsy level was compared to tumor status using histopathology as the reference standard. In 4 patients with low-grade glioma who received ALA HCl, 9 out of 10 fluorescent biopsies were false negative. Determined by a central blinded read of early postoperative surgical MRI, the percentage of patients who had “completeness” of resection was 64% in the ALA arm and 38% in the white light control arm with the difference of 26% (95% CI: 16%, 36%).

A total of 295, 370, and 479 biopsies were obtained in Studies 1, 2, and 3 respectively. True positive biopsies (i.e., biopsies that were positive by histopathology and fluorescence) were 176, 342, and 312, respectively. False positive biopsies (i.e., biopsies that were negative by histopathology and positive by fluorescence) were 7, 12, and 7, respectively. True negative biopsies were 27, 3, and 30, respectively. False negative biopsies were 85, 13, and 130, respectively.

The safety of Gleolan is supported by 5 clinical studies which included 527 patients with glioma who received ALA HCl and 21 healthy volunteers. Adverse reactions that occurred in > 1% of patients in the week following surgery were pyrexia, hypotension, nausea, and vomiting. Adverse reactions occurring in < 1% of patients in the first 6 weeks after surgery were chills, phototoxic sensitivity reaction, solar dermatitis, hypotenension, abnormal liver function test, and diarrhea. One patient experienced respiratory failure due to drug overdose.

**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 cauterezation or topical gelatin foam, activated cellulose or microfibillar collagen application for control.
- Dr. Graham lays Surgicel in tumor cavity.
- 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. Onc18 >>
Resection of infiltrating lesions requires debulking of mass — when bulk of tumor has been removed, further search for additional tumor is carried out and such lines of demarcation can usually be developed between metastatic lesions and surrounding brain, aided by strips of cottonoid to wall off brain. Bridging 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**

- **exhaustion:**
  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 endovascular manipulations).

**STEREOTAXY**

Continue **anticonvulsants** for at least 5 days (to minimize surgically induced brain edema);
- if adequate surgical decompensation is achieved, sterer can be discontinued within first 1-2 weeks.
- speed of weaning depends on:
  1) postop new deficits
  2) amount of edema on postop FLAIR MRI
- indications for serum markers:
  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) steroid dependence
- corticosteroids again may be needed during or after radiation therapy. **AED**

Continue **anticonvulsants** for at least 7 days (few recommend – 1 year).
- incidence of seizures after surgery for brain tumors is low (8% [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 (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) – reduce / increase serum concentration of chemotherapeutics.
- new generation of AEDs (LAMOTRIGINE, LEVETRACETAM) are not metabolized by CYP isoenzymes.

There are studies that do not support prophylactic AED use:

- **side effects:**
  1) patients undergoing resection for brain tumors without a previous history of seizures.
  2) PHENYTOIN vs. placebo for 7 days postop.
  3) incidence of all seizures was 18% in observation group and 24% in prophylaxis group (p = 0.01).
  4) incidence of early seizures (< 30 days after surgery) was 8% in observation group vs. 10% in prophylaxis group (p = 0.62).
  5) prophylaxis group experienced significantly more adverse events (18% vs. 6%, p < 0.01).

**ANTIREZISION MEASURES**

- compression boots, subQ heparin immediately postop – early passive exercises and mobilization!!!
Cerebellar tumors are best approached along the shortest transparenchymal route to the lesion. Some authors suggest obtaining CSF at time of surgery from cisterna magna for cytologic analysis.

Vestibular schwannoma

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

- 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. See p. Onc3 >>

COMPLICATIONS

- Operative morbidity depends largely on tumor location (highest – 10-20% – in diencephalic tumors).
- Operative mortality rates are < 1%.

Further阅读:
- Postoperative hematoma: most frequent cause of death.
- Postoperative hema(to)mata:
  - Incidence of a POH requiring recraniotomy significantly correlated with the incidence of meningiomas.

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

Cerebellum

Cerebellar tumors are best approached along the shortest transparenchymal 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)
   - 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 by putting cottonoid strips into developing plane to avoid direct pressure on brain or spinal cord tissue.
   - identify feeding vessels - coagulate and cut (arterial feeders prior to draining veins!)
   - generally pack resection cavity with wet cotton balls → blood oozing stops after few minutes.
   - no need to resect capsule if it is nonenhancing on MRI.
   - 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 1” or larger 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. Transcortical 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. Interfornical approach
• experts say that it is OK to divide massa intermedia.

**ENDOSCOPIC TRANSVENTRICULAR RESECTION OF 3RD VENTRICLE COLLOID CYST**

Pending
Jandial, procedure 47

**TRANSFORMATIONAL 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; foraminal 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; 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.

• 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.
Postoperative – see p. Onc30 >>

TRANSCOROIDAL, SUBCOROIDAL, OR SUPRACOROIDAL 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 tania choiroidea, 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
- suprachoroidal approach (correct route on board exam for transchoroidal 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.

INTERFORNICEAL APPROACH
- midline division of the fornical bodies
- bilateral fomicial 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 interforncial 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>COLOID 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>Trigone of lateral ventricle</td>
</tr>
<tr>
<td>ENDOCRINOMA</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:

<table>
<thead>
<tr>
<th>Left lateral ventricle</th>
<th>Right lateral ventricle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transcallosal approach</td>
<td>Transcallosal approach</td>
</tr>
<tr>
<td>Middle frontal gyrus incision</td>
<td>Occipital lobe incision</td>
</tr>
<tr>
<td>Parietal lobe incision</td>
<td>Lateral temporal parietal incision</td>
</tr>
<tr>
<td>Occipital lobe incision</td>
<td>Transcallosal approach</td>
</tr>
<tr>
<td>Temporal horn incision</td>
<td>Middle temporal gyrus incision</td>
</tr>
<tr>
<td>Middle temporal gyrus incision</td>
<td>Occipital lobe incision</td>
</tr>
</tbody>
</table>
**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. **Temporalparietal 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**

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 (TRANSCALLOSAL 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.
  ▾ mannitol
  ▾ gravity can be used to surgeon's advantage - falk 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/Budde 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 mm 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 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.

Third ventricle
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Disorders of interhemispheric transfer of information, which may include the anterior cingulate gyrus, septum pellucidum, and fornix or by circulatory disturbances. The anterior cingulate gyrus projects fibers to the thalamus and basal ganglia, the hemisphere controlling speech and language, is a contraindication. Crossed dominance can cause alexia and visual agnosia. These patients may develop writing and speech deficits if the hemisphere speech dominant patients with left-hemisphere memory only could result in memory disorder.

b) 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

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 hemianopia).

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 (TRANSCALLOSAL + TRANSCORTICAL)

a) For masses that are too large to remove through single approach:

b) When hemisphere is displaced by tumor (rather than by CSF) → transcallosal 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.
- 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).
- **seizures** can occur in any patient (29-70% after transcortical resections; significantly lower after transcallosal surgery).
- **speech deficits** complicate surgery in dominant hemisphere.
- **subdural hematoma and hygroma** are significant problems in patients with preoperative hydrocephalus.
- **enlarged ventricles and normal ICP** may present condition analogous to NPH.
- **postoperative ventricular enlargement** is noted frequently in spite of total tumor resection; 35% patients require shunt.
- **incomplete resection** occurs in 33-50% cases.
- **MORTALITY** for surgery on lateral ventricular 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 microspheres (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 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 cauterize dural surface.**
**SIMPSON GRADES**

<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 completion of dural attachment</td>
</tr>
<tr>
<td>III</td>
<td>macroscopically complete without resection or re-attachment of dural attachment or of its extradural extensions (e.g. hypertrophic 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**

- Complete resection with dural margin: 9%
- Complete resection with removal of dura: 19%
- Complete resection (no treatment of dura): 29%
- Partial removal leaving tumor in situ: 40%
- Decompression: NA

**Recurrence rate**

D. Simpson 1957

**Likehood 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>Hypophyseal</td>
<td>47</td>
<td>96%</td>
</tr>
<tr>
<td>Olfactory</td>
<td>5</td>
<td>80%</td>
</tr>
<tr>
<td>Spinal</td>
<td>18</td>
<td>78%</td>
</tr>
<tr>
<td>Olfactory Gyrus</td>
<td>22</td>
<td>77%</td>
</tr>
<tr>
<td>Paranasal Aces/Fish</td>
<td>38</td>
<td>76%</td>
</tr>
<tr>
<td>Paraseptic Region</td>
<td>26</td>
<td>57%</td>
</tr>
<tr>
<td>Posterior Fossa</td>
<td>31</td>
<td>32%</td>
</tr>
<tr>
<td>Spinalis Ridge</td>
<td>56</td>
<td>28%</td>
</tr>
</tbody>
</table>

**TOTAL**

225 64%

**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)
  - 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 prosthesis / 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 craniectomy duraotomy 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
- C. Frontal interhemispheric approach (ligating anterior portion of superior sagittal sinus)

*unilateral approach is usually sufficient

- microscope (Dr. JRC – yes; Dr. Broaddus – no).

- 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 frontal 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
  - no need to reattach falx at the end of surgery

- attempt to preserve at least one of olfactory nerves.
— olfactory bulbs and tracts are often displaced laterally by tumor and may be preserved.

— these tumors often invade ethmoid sinuses and, at times, sphenoid sinus. 

— care should be taken to identify and preserve both optic nerves. Note that usual relationship between optic nerves and carotid arteries might not hold true owing to displacement of these vital structures by tumor. 

ANTERIOR CLINOID REGION MENINGIOMAS

— Preoperative imaging of clinoideal region meningiomas can accurately predict the presence or absence of tumor involvement of the clinoideal in only 75% of cases. In light of the fact that a quarter of patients with radiographically negative clinoideal will have tumor present on pathological analysis, recommend a clinoidealctomy for all clinoideal 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 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 flag of bone immediately adjacent to tumor, separated from larger second flag 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 boring. If removal is more extensive, bone flap may be autocalved 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 hypotrophy 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 arachnoidal layer. This layer may not be complete at dura. 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 arachnoidal plane and dissect it gently. 

— placing circumferential around tumor allows quick identification of this crucial plane at later time. 

— coagulate surface of tumor, then core it and invaginate outer layer to allow further circumferential dissection. 

— pressure from meningioma can produce marked atrophy of compressed and devitalized cortex; epilepsy may result. Removal of atrophic cortex using techniques ordinarily applied to seizure surgery should be considered. 

— perform dural grafting.

PARASAGGITAL / PARAFAaméliorer 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 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 ignited. 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 obliterating more SSS. If sinus is occluded gradually by tumor, venous drainage will be diverted over time through paranasal veins. 

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

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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 insinuates itself 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. 

— inner-third tumors arise from anterior clinoideal process and compress optic nerve and encur 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 preoral to fronto-temporo-zygomatic craniotomy – see p. Op300 >> 

— removing zygoma and orbit allows wider exposure of sphenoid wing, middle cranial fossa, anterior cranial fossa, and anterior clinoideal. 

— remove temporal floor and sphenoid wing 

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

— careful when bifurcating dura on temporal floor – trigeminal ganglion underneath (sensory loss)
issue of meningiomas involving cavernous sinuses is currently a 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 anterosuperiorly 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). 

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CEREBELLOPONTINE ANGLE MENINGIOMAS

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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 petroclival (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. 

— definite 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 sinuses may permit resection of involved sinus. The size of sinus, however, at times may permit reconstruction of sinuses after removal of one wall from which tumor extends into lumen. 

— anterolateral (AL) incisural meningioma - middle third of the tentorial free margin: ptorial, subtemporal, and retromastoid approaches. 

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