# Temporal Lobectomy

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Temporal Lobectomy

Pending sources:
Drs. Cohen-Gadol and Spencer: https://www.youtube.com/watch?v=ILDdmVqUkag
Youmans Ch. 62

RELEVANT ANATOMY

Amygdala – see p. A137 >>
Hippocampus – see p. A138 >>

TEMPORAL LOBE

See p. A138 >>

INDICATION

- temporal lobe epilepsies: see p. E9 >>

- 80% of patients with medically intractable seizures with demonstrable focus have foci in anterior temporal lobe!
- avoid loss of time - longer duration of epilepsy is associated with poorer postoperative seizure outcome and detrimental effect on cognitive functioning.

CONTRAINDICATIONS

Dominant side – always do WADA testing!
1. Dominant temporal lobe with preserved memory (on neuropsychologic testing)
   - if there is support for memory function on nondominant side (as tested by WADA),
     anteromedial temporal lobe resection (AMTR) still leads to decline in verbal memory function that is noticeable to patient.
   - if memory function is lacking on nondominant side (as tested by WADA), AMTR has theoretical risk of global amnesia.

2. Dominant temporal lobe with poor memory (on neuropsychologic testing) and no / little support for verbal memory on the nondominant side (as tested by WADA), AMTR has theoretical risk of global amnesia

3. Nonepileptic seizures - all patients should undergo noninvasive continuous audiovisual EEG monitoring even in presence of seemingly appropriate clinical and radiologic findings

Bilateral hippocampectomies affect declarative memory but persistent amnesia requires lateral damage (parahippocampal gyrus, entorhinal cortex).
Temporal Lobectomy

**TYPES**

Historically - resection only of convolutions with evidence of focus determined by maximal abnormality (apparent on electrocorticography or stimulation).

Measurements are made along **MIDDLE TEMPORAL GYRUS**:  
- **dominant temporal lobe**: up to 4-5 cm may be removed (over-resection may injure *speech centers*, which cannot be reliably localized visually)  
- **non-dominant temporal lobe**: 6-7 cm may be resected (slight over-resection → partial contralateral upper quadrant homonymous hemianopsia “pie-in-the-sky”; resection of 8-9 cm → complete quadrant anosia)

N.B. these “safe resection” values are generally considered safe, however, variations occur from patient to patient and only (intraoperative) mapping can reliably determine location of language centers.

1. **Standard en bloc anterior temporal lobectomy (ATL)** - originally advocated by Falconer and colleagues in 1955:  
   1) *superior temporal gyrus* resected 2 cm from temporal tip.  
   2) *middle* and *inferior temporal gyrus* resected 4-5 cm from tip of nondominant side and 3-4 cm of dominant side.  
   3) *amygdala* resected totally.  
   4) *hippocampus* resected to level of colliculus (3.5-4 cm of hippocampus).

2. **SPENCER anteromedial temporal lobectomy (AMTL)** - *superior temporal gyrus* is spared (important in dominant side).  

3. **Selective amygdalohippocampectomy (SAH)** - transtemporal resection of amygdala and hippocampus, leaving remainder of temporal lobe (*lateral temporal neocortex*) intact - may suffice for mesial temporal sclerosis and minimizes collateral surgical injury to important temporal neocortical structures.  
   - different approach trajectories are available. *see below >*
   - MR-guided laser ablation (LITT), SRS, RF ablation, FUS ablation – minimally invasive alternatives.

4. **Lesionectomy** (with preservation of *mesial temporal structures*) – for discrete temporal lobe lesions without mesial involvement, e.g. using laser ablation.  
   - concept about lesions (epileptogenic tumors) in temporomesial lobe: both lesion and hippocampus are often epileptogenic (even if MRI does not reveal hippocampal atrophy or sclerosis and histological examination shows normal features in majority of cases).

**PREOPERATIVE**

**WADA test**; esp. in dominant side, esp. if patient has already memory deficits (to verify if contralateral hippocampus will suffice to maintain adequate memory).
**PROCEDURE – OPEN**

**COUNSELLING**

We talked about the 60% chance of seizure freedom versus a 90% chance of seizure reduction. I explained that if this was a developmental anomaly, she may have to stay on medication because we would presume that there were additional abnormalities. We talked about the pie in the sky deficit typical with a temporal lobectomy, the temporalis muscle slumping, jaw opening difficulties, clogged hearing, headaches, fatigue, how long she would be in each component of the hospital stay, how each portion of the recovery would occur, when she could do what exercise, etc.

**ANESTHESIA**

- general anesthesia; in *dominant hemisphere*, value of operating under local anesthesia (to permit stimulation mapping and identification of speech areas) has been stressed.
- MANNITOL is commonly used – 50 g (vs. full 100 g for grid placement); steroids - not.

**POSITIONING, INCISION**

- supine ± with foam wedge or shoulder roll ipsilateral to side of surgery.
- head held in **Mayfield 3-pin holder** (vs. gel donut for intracranial grids)
- navigation should be used.
- microscope for hippocampectomy part.
- sagittal midline and axial axis of head should angle 20-30 degrees, respectively, to horizontal OR
  - head turned to contralateral side and extended* 50 degrees with vertex lowered 10 degrees
  
  *extension allows surgeon to view long axis of hippocampus with microscope
- positioned properly, **zygoma will be the highest point** of head.

Temporal Lobectomy
N.B. head is extended 50 degrees – brings hippocampus axis parallel to the line of vision (Dr. Spencer)

- Dr. Spencer – posteriorly incision is up to mastoid-vertex line.
- Dr. Holloway – alternatives:
Temporal Lobectomy
Temporal Lobectomy

- **small** "question mark" curvilinear frontal temporal incision (similar to pterional approach to circle of Willis): incision starts at zygoma anterior to tragus and curves superiorly and posteriorly; posterior margin is line drawn from mastoid tip (M) to vertex (V) (note how head is extended 50 degrees; approximate position of the Sylvian fissure (Syl) is shown):

- incision must expose enough of cranium to remove bone flap that allows for retraction of superior temporal gyrus and frontal lobe without compressing brain against skull edge; if more extensive posterior exposure is required, classic temporal craniotomy may be used

CRANIOTOMY

- **cuff of temporalis muscle** is preserved along superior temporal line for reattaching temporalis muscle during closure.
- scalp and temporalis muscle are reflected anteriorly and retracted with perforating towel clips / fish hooks attached to Leyla bar with rubber bands.

- bone flap should be based low in middle fossa, extending just above sphenoid wing but within confines of temporalis muscle fan (use rongeur / high-speed drill to enlarge bone opening towards middle fossa floor and anteriorly into sphenoid wing for several centimeters).

  *Maximal exposure of temporal tip***

- bony exposure must extend inferiorly to zygoma root and anteriorly as close to temporal tip as possible.
Temporal Lobectomy

- entry into mastoid air cells is avoided, and any opening into mastoid air cells is seal-closed with bone wax.
- epidural tack-up stitches are placed.
- dura is opened by cruciate incision to optimize temporal tip exposure and should extend about 1 cm above Sylvian fissure; alternatively, dura is opened in C shape and reflected anteriorly.
  — on opening dura, identify and protect vein of Labbé; attention to vein of Labbé is particularly important during retractor placement.

**Language Mapping**
(for tailored resections in dominant temporal lobe)  see p. E13 >>

No mapping
- disagreement exists regarding need for stimulation mapping - many surgeons feel safe in removing anterior 4.5 cm of dominant temporal lobe or resecting to junction of sylvian fissure with inferior extent of sensorimotor cortex.
  N.B. representation of language as far anterior as **2.5 cm from temporal tip** has been documented!

Mapping
  a) SEEG supplemented by intraop stim
  b) for children and uncooperative adults, better use subdural grid mapping preop - resective surgery can be performed under general anesthesia.
- if previously placed grid is in situ, trim it along proposed resection line.

**Resection of Lateral Temporal Lobe**
- of both lesion and epileptogenic focus:
  A) **piecemeal** removal.
  B) **en bloc** removal (opportunity for more extensive pathological study, but risk of injury to structures medial to temporal lobe – CN3, optic tract, posterior cerebral artery).

Safe to remove (temporal lobe from tip):
  dominant side – 3 cm (still may cause aphasia in some patients; H: language mapping)
  nondominant side – 6 cm

- it is easy part – “opening the door”
- slide Telfa strips under electrode grids to mark resection lines on the cortex
- resection is performed in **subpial plane** - to prevent injury to MCA branches.
  N.B. try to preserve all pia (at the end will trim it to leave short apron)
- to plan **posterior margin of lateral cortical resection** of middle and inferior temporal gyri, No. 4 Penfield and mosquito clamp are used to measure from temporal tip to prominent cortical vein along middle temporal gyrus approximately 3-4 cm from temporal tip - posterior limit of proposed lobectomy.
Temporal Lobectomy

- cut in pia of inferior part of STG:
- pia and cortical vessels are coagulated along superior temporal convolution and across temporal convolutions about 5 mm anterior to desired extent of excision.
- incision from inferior temporal gyrus along middle temporal gyrus superiorly to superior temporal sulcus (STS) is made; in sulcus between superior and middle temporal gyri incision is carried mesially (in coronal plane) with CUSA until temporal ventricular horn is entered (small cotton pledget is placed into ventricle to maintain orientation).
  - while searching for temporal horn, if one misses it and dissects too far superiorly, temporal stem, basal ganglia/amygdala complex, and then crus cerebri may be entered; superior to temporal horn, there is no arachnoid plane along this medial trajectory.
  - if you do not find temporal horn, use neuronavigation or resect further posteriorly and inferiorly along middle and inferior temporal gyri to identify hippocampus.
- cortical incision is extended anteriorly along STS, dissecting inferior to STS in subpial plane.
- using irrigating bipolar coagulator and sucker, middle and inferior temporal gyri are removed as single surgical specimen.
- superior temporal gyrus is removed, being careful to use subpial dissection technique and maintaining intact pia* along Sylvian fissure and basal temporal regions; superior temporal gyrus is removed to level of ventricle.
  
  * in most instances cortex will be gliotic and can be peeled away from pia using dissector.
  - protect middle cerebral vessels still covered by pia and arachnoid as temporal operculum is reflected.
• at tip of temporal horn, subpial dissection is continued inferiorly and posteriorly to free **amygdala**, which can be removed by severing its connections to temporal stem white matter.
• cortical incision is deepened, temporal horn *(TH)* is identified by following arachnoid of fusiform gyrus from inferior to superior.
  — search for temporal horn by following arachnoid of fusiform gyrus from inferior to superior.
  — temporal horn is perpendicular to cortical surface at inferior temporal sulcus.
  — remember, inferior temporal gyrus is not visible (faces temporal floor).
  — neuronavigation may be helpful for locating temporal horn.
• **place patty inside TH** (guides resection in axial plane – **do not resect above TH**, i.e. care is taken not to dissect superiorly into temporal stem; superior to TH, there is no intervening arachnoid plane if one were to dissect medially from anterior temporal lobe white matter through temporal stem and basal ganglia/amygdala complex into crus cerebri).
• remainder of inferior temporal structures is removed piecemeal mesially until parahippocampal gyrus is encountered (at this point, only mesial-temporal structures remain, and ependymal surface of hippocampus should be identified easily).

**TH and approximate location of fusiform arachnoid (FA):**


**TH is shown after resection of lateral neocortex and is opened more widely:**


**TH in anatomic specimen. CoS = collateral sulcus; ITG = inferior temporal gyrus; MTG = middle temporal gyrus; STG = superior temporal gyrus; THLV = temporal horn of lateral ventricle**
Temporal Lobectomy

- medial temporal pole is resected subpially from its anterior aspect until middle cerebral artery (MCA) is exposed, then remainder of amygdala is resected inferior to line between velum terminale* and genu of MCA at junction between the M1 and M2 segments.

  - velum terminale is union of taeniae of fimbria fornicis and stria terminalis at origin of choroid plexus; resecting inferior to this line prevents injuring basal ganglia and crus cerebri.

  N.B. if surgeon resects tissue above line between M1 and velum terminale, temporal stem, basal ganglia/amygdala complex, and crus cerebri also may be injured - patty string has been laid along this line before resection of amygdala:

- after amygdala resection, genu at M1-M2 junction and velum terminale are more easily seen:
this line on parasagittal MRI slice includes amygdala and hippocampus:

**Hippocampus Anatomy**

TP = temporal pole, MI = horizontal segment of the middle cerebral artery, AC = anterior choroidal artery. The course of the posterior cerebral artery is indicated by the double dotted line, 2 = optic nerve, 3 = third cranial nerve, HP = hippocampus, Fi = fimbria, PHG = parahippocampal gyrus, CP = cerebral peduncle. The free edge of the tentorium is indicated by the two arrow.
View of the amygdalo-hippocampal complex from the mesial surface of the temporal lobe. Important vascular structures are seen coursing through the ambiens and lateral mesencephalic cisterns and are intimately related with the mesial temporal structures. CHF=choroidal fissure, ERHS=endorhinal sulcus, Fi=fimbria, iLG=intralimbic gyrus, ISTH=isthmus, LG=lingual gyrus, PC=posterior cerebral artery, PHG=parahippocampal gyrus, RHS=rhinal sulcus, SLG=semilunar gyrus, UG=uncinate gyrus. Note branches of posterior cerebral artery entering hippocampal sulcus. AT, MT and PT = anterior, mid and posterior temporal planes. TP = transverse temporal plane:
**Resection of Hippocampus**

How much hippocampus needs to be removed – more than 2 cm (some say at least 3 cm);

Class I evidence: removing more hippocampus does not adversely affect memory but improves seizure outcomes!

- use Greenberg 3/8 retractor blades.
- use microscope.
- resect hippocampus in two parts
  - neuronal loss in CA1 has gradient from anterior to posterior (if marked cellular loss is found at most posterior extent of hippocampal resection - high correlation with persistent seizures).
- as two retractors are placed, care must be taken not to injure vein of Labbé; superior retractor gently holds superior temporal gyrus (careful – it is pointing towards brain stem):


• choroid plexus is protected underneath patty and retracted medially toward thalamus (*choroid plexus should not be coagulated* because this may lead to injury of anterior choroidal artery → ischemia of internal capsule and lateral thalamus; manipulation of choroid plexus should be minimized to prevent it from bleeding).

• posterior retractor is curved under lateral temporal cortex to elevate it gently laterally and posteriorly - allows lateral temporal neocortex to be gradually elevated, exposing entire hippocampus

  N.B. lateral temporal cortex should be elevated laterally more than retracted posteriorly

• medial occipitotemporal fasciculus is transected longitudinally from anterior hippocampus to hippocampal tail:

![Hippocampus with retractor and occipitotemporal fasciculus](image1.png)


• cadaveric dissection:

![Incision in occipitotemporal fasciculus](image2.png)


• hippocampus is lifted from pia using Penfield 4 (while patty in the other hands pulls on pia to stabilize it)
• next step is resection of anterior parahippocampus including entorhinal cortex, ambient gyrus, semilunar gyrus, uncinate gyrus, and intralimbic gyrus using ultrasonic aspiration or round dissector.
• intralimbic gyrus of parahippocampus lies lateral to peduncle of midbrain.
• photograph of anatomic specimen showing medial surface of temporal lobe: 14 and 15 are posterior uncus; 16 is parahippocampal gyrus; 13 is uncal sulcus, which is arachnoid plane in uncus where uncus folds back on itself; and 7 is velum terminale:


• as dissection proceeds, numerous small vessels emanating from PCA lie in arachnoid plane of uncal sulcus (arrows); PCA branches in uncal sulcus may return and supply thalamus. Complete dissection of uncal sulcus is crucial for distinguishing perforators that supply hippocampus from perforators that travel superiorly to thalamus; uncal sulcus is indicated by the black line; midbrain (MB) lies just medial to PCA; when fold of arachnoid is well dissected, it is sometimes easier to divide pes from body of hippocampus:

- when anterior hippocampus and pes hippocampi have been removed, medial dissection of hippocampus is started by separating fimbria of fornix from medial arachnoid and reflecting it back onto surface of hippocampus; anterior body of hippocampus then can be gently retracted laterally, exposing arachnoid that covers superior surface of parahippocampal gyrus; care is taken to avoid dividing any vessels that are not clearly going into hippocampus because occasionally thalamic perforators can be seen in this area as well:

![Image of hippocampus and fimbria](image_url)


- parahippocampal gyrus (PHG) can be entered with a bipolar cautery and suction or CUSA and dissected in longitudinal plane from anterior to posterior; dissection is carried out from medial and inferolateral approaches to PHG, with inferolateral trajectory shown here; inferior arachnoid of parahippocampal gyrus is seen superior to tentorium, and hippocampus (HC) is at superior margin of parahippocampal gyrus:
Subpial dissection and endopial aspiration of the hippocampal formation is accomplished with the ultrasonic dissector (CUSA) set at very low parameters of vibration and suction. The entrance to the hippocampal sulcus is indicated with the arrow. This sulcus and its vascular content represent a crucial landmark for the procedure. The collateral fissure (coll. fiss.) should also be identified. Sub = subiculum, Fus = fusiform or 4th temporal gyrus (T4). Note position of posterior cerebral artery indicated by a circle on the mesial side of the parahippocampal gyrus (PHG):
Temporal Lobectomy

- hippocampus is gently retracted laterally, showing tail as it curves medially; choroid plexus (CP) lies over lateral geniculate nucleus; PCA temporal branch is protected as hippocampal tail is divided:

N.B. there is no morbidity of removing more hippocampus (i.e. if memory is to be lost, it will happen no matter how much hippocampus is taken – so be radical)
- best results are obtained with removal of hippocampus to level of superior colliculus.
Alternative text:
• **hippocampus and uncus** are removed en bloc (for pathologic examination):
  — incision is made along choroidal fissure from level of posterior boundary of cerebral peduncle anteriorly until tip is reached (this serves as superior-mesial margin of resection)
  — posterior incision is made at level of posterior margin of cerebral peduncle laterally to lateral hippocampal margin and then brought anteriorly and laterally until it meets lateral resection margin
  — hippocampus is separated carefully from intact pial surface - hippocampus is rolled posteriorly, (coagulate and cut small vessels* arising from PComA and PCA without damaging vessels supplying peduncle and thalamus → traction hemiplegia and hemianopsias)
    *at choroid fissure there is arcade of 1-4 small feeding arteries passing through pia to hippocampus - these must be isolated, coagulated, and then divided (avulsion of these branches from parent vessels in incisura may result in infarction of posterior limb of internal capsule, with attendant hemiparesis).
  — with hippocampus removed, pial bank overlying tentorial incisura and cerebral peduncle should be intact; below this barrier should be cerebral peduncle, PCA, PComA, and CN3.
  — pial bleeding is controlled carefully by bipolar cautery at low setting.
  — demonstrable herniation of uncus mesially in incisura has high correlation with pathological change and with favorable outcome (but this may add to technical difficulty during removal).

• edges of transected gyri are débrided and any residual macerated cortical margins are removed.
• *postexcisional recording* is performed and, if necessary, additional tissue is removed.

Typical resection of anterior temporal lobe for seizures:
  dash line - hippocampus spared.
  solid line - removal of varying extent of hippocampus
SELECTIVE AMYGDALO-HIPPOCAMPECTOMY (SAH)

Reading:


- amygdala lies in the roof of anterior temporal horn of lateral ventricle.
A. **Transcortical-Transventricular** approach - most direct and simplest approach. >>

B. **Subtemporal** approach - through parahippocampal gyrus (entails significant retraction) >>

C. **Transsylvian** approach (Weiser and Yasargil 1982) - more restrictive and greater risk of injury to M1 portion within sylvian fissure; complete avoidance of neocortical injury - better neurocognitive outcomes (vs. subtemporal). >>

D. **Supracerebellar-transentorial** approach >>

E. **Zygomatic** approach

F. **Transorbital** endoscope-assisted approach

G. **Multiple hippocampal transection (MHT)** >>

Minimally invasive stereotactic surgical options:
   A. MR-guided laser interstitial thermal therapy (MRg-LITT) >>
B. Stereotactic radiosurgery
C. Stereotactic radiofrequency ablation
D. MR-guided focused ultrasound ablation

**INDICATIONS / CRITERIA**

**Semiology:** dyscognitive seizures consistent with mesial temporal onset, ± aura (typically smell, epigastric sensation, fear, déjà vu)

**MRI:** mesial temporal sclerosis positive (MTS+) or negative (MTS-)

**PET:** temporal lobe hypometabolism lateralized or greater on the same side as EEG

**VideoEEG:** localization to anterior temporal region (e.g., F7/T1 or F8/T2)

**Neuropsychological testing** (assume normally organized memory function):
- domain-specific memory decline present on side of anticipated ablation - SAH acceptable
- in absence of domain-specific memory decline referable to side of ablation:
  - MTS+: SAH acceptable (but if there is domain-specific memory loss on contralateral side, Wada test is considered)
  - MTS-:
    - nondominant side - SAH is acceptable (i.e. absence of visuospatial memory decline is acceptable for nondominant SAH)
    - dominant side – consider RNS (i.e. normal verbal memory is incompatible with dominant-side SAH)

Rephrasing:

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

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

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

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

**Intracranial EEG** (indicated only in setting of ambiguity as to seizure onset zone from noninvasive studies): onsets referable to ipsilateral mesial temporal lobe + absence of contralateral onsets.

- in MTS- (nondominant side), if positive PET is concordant with videoEEG, may proceed directly to SAH without iEEG, however, **maintain a low threshold for iEEG in MTS- cases**
- if icEEG is needed, use depth electrodes with orthogonal trajectory to provide lateral and mesial temporal coverage.
- if minimally invasive procedure (such as LITT or RNS) is anticipated, try to avoid macro invasive diagnostic approach (such as grids or even strips).
LTV (long-term video monitoring) = video EEG


LITT (STEREOTACTIC LASER AMYGDALOHIPPOCAMPOTOMY)

Procedure details (general) – see p. Op345 >

Resources to read:

"MRI Guided Laser Amygdalohippocampectomy" by Dr. Carter S. Gerard, Swedish Neuroscience Institute, Seattle, WA. Presented by Seattle Science Foundation. Click here to view: MRI Guided Laser Amygdalohippocampectomy

**Trajectory (Hippocampus Cannulation)**

It is hard to avoid blood vessels (use T1 with gadolinium).

Coronal – probe’s eye view (at target → moving towards entry):

Axial (along trajectory):
Drs. Gross and Sharan

Extraventricular long-axis hippocampal implantation necessitates a lateral-to-medial and cephalad-to-caudal trajectory that skirts the inferomedial border of the temporal horn.
- long-axis cannulation - greater volume of hippocampal coverage.
- extraventricular trajectory - avoids brain shift and reduces the risk of hemorrhage from ependymal breach.
- although trajectories must be individually tailored for each patient, we recommend a starting entry point approximately 5.5 cm superior to the external occipital protuberance and 5.5 cm lateral to midline.

### TECHNICAL ASPECTS (SPECIFICS)
- laser probe needs to be placed precisely in center of hippocampus or will leave some unablated (H: ablate via suboptimally positioned probe then reposition and ablate again)
- laser energy diffusion allows nice ablation of curved hippocampus (as laser light is reflected from reached ependymal surface, plus, CSF in reached ventricle acts as heatsink)
- amygdala and hippocampus are targeted moving the laser probed from deep towards the entry point – follow blue line (“killing zone”) is encompassing intended treatment volume.

**MR-Guided Laser Treatment**

In all cases, the laser fiber and cooling lines were routed from the patient to the control room and connected to the proprietary Visualase workstation, which combines a 15-W 980-nm diode laser with an image-processing workstation for real-time MRTI and modeled estimates of the thermal necrosis zone. Initially, volumetric 3-dimensional T1-weighted sequences were acquired to verify proper positioning through the hippocampus and to select appropriate imaging planes for monitoring during ablation. User-defined specific temperature safety limits were set relative to the monitoring image in the inferior lateral thalamus, basal ganglia, and lateral mesencephalon (Figure 2A) to automatically terminate laser delivery if these structures exceeded 45°C, avoiding off-target thermal injury (Figure 2B). The initial lesion was made anteriorly in the amygdalohippocampal complex (AHC) during real-time MRTI and modeling of the necrotizing zone (Figures 2C and 2D). The laser fiber was then retracted in approximately 1.0-cm increments, and as many as 5 overlapping focal ablations were created, resulting in a confluent tubular ablation zone (Figure 2F) encompassing the AHC posteriorly to at least the lateral mesencephalic sulcus (posterior landmark visualized on axial imaging) (Figure 2G).

**FIGURE 2.** Illustrative treatment cycle. A, patient 4 was stereotactically implanted from an occipital approach along the long axis of the amygdalohippocampal complex. Using the Visualase workstation, multiple points (3 shown in this plane) were demarcated for intraoperative magnetic resonance imaging thermal measurement: red circle (in the ablation zone), white square (anterior mesencephalon), and blue diamond (lateral mesencephalon). B, measurement of the temperature at the 3 points during ablation. Pink dotted line indicates ablation temperatures greater than 90°C, above which thermal spread is considered unpredictable19,20 and which triggers cycle termination by the workstation. Note that the brainstem temperature does not increase during the procedure. Real-time temperature measurements (left) and estimated ablation areas (right) at 25 seconds (C), 75 seconds (D), and 130 seconds (E). F, after retracting the laser applicator and ablating at a second site, the final estimate of the total ablated area was calculated. Immediate postoperative T1-weighted imaging with contrast highlights the borders of the lesion in the axial (G, red arrow) and coronal (H) planes. I, J, 6 months after the procedure, the amygdalohippocampal complex demonstrates well-circumscribed nonenhancing pseudocystic atrophy.
Postprocedure MRI including diffusion-weighted imaging (DWI), FLAIR, and T1 postgadolinium contrast (Figures 2G and 2H) were acquired, verifying the final lesion location and volume. Laser applicators and anchor bolts were completely removed, a titanium burr hole cover was affixed, incisions were closed with resorbable suture, and stereotactic frames were removed. Patients were typically admitted to the hospital for observation, administered dexamethasone for 24 hours, and discharged with a 1-week oral dexamethasone taper.

During the SLAH procedure, the lateral ventricle appeared to have an insulating heat sink effect, with ablation zones generally spreading to conform to the superior surface of the hippocampus without thermal spread across cerebrospinal fluid spaces (temporal horn, transverse cerebral fissure, or ambient cistern), sparing medial structures (basal ganglia, thalamus, optic tract, or midbrain). Moreover, ablation zones (as confirmed by immediate postprocedure FLAIR, DWI, and contrast-enhanced T1 signal intensity) tended to incorporate large portions of the hippocampus, medial to lateral, at any given coronal location, forming an eccentric volume with respect to the laser assembly, apparently delimited by the ependymal lining (superiorly and laterally), the transverse cerebral fissure (medially), and, more variably, the hippocampal sulcus or subiculum (inferiorly). Indeed, safety limit set points, which were user defined in the software interface to terminate laser delivery if any point on the brainstem, optic apparatus, and/or thalamus exceeded 45°C, never changed from baseline temperatures (Figures 2A and 2B). Individual cycles were terminated when on-target temperatures reached 90°C, thus avoiding the risk of char and thermal gassing in target tissues.
**RF**

- low cost
- temperature monitored only at tip
- best results with string electrode (not available in United States)

**Stereotactic Radiosurgery (SRS)**

- noninvasive
- delayed benefit after initial increase in seizures/risk of sudden unexpected death from epilepsy
- potential radiation injury, dose limitations
- high cost

**TRANSCORTICAL- TRANSVENTRICULAR APPROACH**

Image guidance is very helpful!

a) original Paolo Niemeyer (1958) approach through *middle temporal gyrus* providing access to the temporal horn


modification with strictly endopial resection of the hippocampal formation and amygdala:


b) approach through anterior *superior temporal gyrus.*


- disadvantages of this approach:
  1) unavoidably produces cortical injury
  2) necessity to dissect in close vicinity to optic radiation (Meyer's loop) which is located in the roof of the ventricle.

**ANESTHESIA, POSITION**

- mannitol is not used routinely.
- supine with the head rotated 90 degrees to the opposite side, parallel to the floor

**INCISION**

- linear scalp incision starting at the zygoma and curving slightly backwards
temporal muscle is split along its fibers and held with a self-retaining retractor. A burr hole and craniectomy is made through the temporalis muscle and centered over the second temporal gyrus.
Corticotomy:
- either within the depth of the first temporal sulcus* (S1) or, preferably, along the upper border of the second temporal gyrus (T2) just below the superior temporal sulcus and in front of the central sulcus (on the dominant side, the incision should be placed in front of the posterior limit of the precentral sulcus).
  *no advantage of sulcal approach - although the extent of the corridor is reduced, it turns out that the cortex is only protected by a thin layer of pia and this is more likely to cause ischemic changes in the cortex due to retraction + there is often a vein running over and parallel to the sulcus
- keyhole 2-3 cm longitudinal cortical incision through *middle temporal gyrus* centered at a point ≈ 3-4 cm posterior to temporal tip.
- note presence of a vein running over the superior temporal sulcus:
Corridor:

- ultrasonic dissector (at lowest settings - suction 12% and vibration 0.12) is used to fashion a corridor (approximately 4-5 mm in height) to the ependymal lining of temporal horn.
- more superficial extent of this corridor is created by a subpial dissection along the inferior wall of the superior sulcus which leads in the direction of the temporal horn
- opening the ependyma provides an adequate exposure of the amygdala and hippocampal complex (AG=amygdala, HP=hippocampus, Fi=fimbria, PH=parahippocampus, RHS=rhinal sulcus, P1=posterior cerebral artery, CX = cortex, TP = temporal pole):
• self-retaining retractor has been installed - dotted line indicates the intended extent of resection. SF = Sylvian fissure, T1, T2, T4, T5 = 1st, 2nd, 4th and 5th temporal gyri. T5 corresponds to the parahippocampal gyrus (PH):
a series of anatomical landmarks for the hippocampal removal should then be recognized in a stepwise fashion.

- the lateral ventricular sulcus located between the hippocampus proper and the collateral eminence on the lateral wall of the horn is identified.
- the fimbria and the apex of the uncus (intralimbic gyrus) are visualized on the inner side by lifting the choroid plexus upwards and backwards - provides exposure of the choroid fissure, especially of its anterior border which is made by the junction of the fimbria and stria terminalis.
ventricular lining must be opened sufficiently to see the bulge of the amygdala and the anterior-most extent of the horn represented by a point anterior and mesial to the hippocampus.

The choroidal fissure (chf) and choroid plexus (cp) are bordered by the fimbria (fi) and stria terminalis (st). The fimbria and stria terminalis come together at the anterior extent of the choroidal fissure at the apex of the uncus or intralimbic gyrus (a) h and b are head and body of the hippocampus. Manipulation of the choroid plexus is essential to recognize the above structures:

- enough unroofing of the ventricle must be done in order to visualize the tail of the hippocampus.
- resection proper is done by entering the parahippocampal gyrus, located underneath the hippocampus, over and along the lateral ventricular sulcus.
- endopial intragyral removal of the parahippocampal gyrus is performed along its antero-posterior extent.
- in dissecting the cortex mesially within the parahippocampal gyrus, care is taken not to injure the posterior cerebral artery which runs over its mesial border (can be visualized through the pia).
- dissection is carried out forward into the parahippocampal gyrus and the anterior portion of the uncus is entered.
- hippocampus proper is tilted laterally into the empty cavity of the parahippocampal gyrus revealing the fimbria which is resected along its length exposing the medial side of the hippocampal fissure which corresponds to the dentate gyrus.
- hippocampus proper is transected at the junction of the body and the tail and then lifted up and forward exposing the perforating arterioles arising from the hippocampal artery proper located within the hippocampal sulcus.
- hippocampal sulcus is an essential landmark and must be identified and visualized during the entire course of the procedure. Holding this sulcus with a forceps allows the surgeon to identify the various
subcompartments of the hippocampal formation namely the parahippocampal gyrus, the subiculum, the hippocampus proper and the dentate gyrus.

- vessels within the sulcus are coagulated and divided or simply teased out of the sulcus.
- fimbria is subpially resected forward into the apex of the uncus (intralimbic gyrus); at this point, the content of the anterior portion of the uncus is also resected by a subpial aspiration, care being taken not to endanger the cerebral peduncle or the third nerve which can be seen through the pia.
- entire content of the uncus is emptied, including the segment which fills the basal cisterna.
- extreme care should be taken to identify the dorso-mesial extent of the amygdala, which corresponds to the endorhinal sulcus, in order to perform a radical removal of the amygdala itself. A reliable landmark in this area is the entrance of the anterior choroidal artery into the ventricular cavity, where it fans out to form the choroidal plexus (choroidal point).
- note that the anterior choroidal artery and the optic tract run together within the endorhinal sulcus and can be seen through its pial lining. If further resection of the posterior extent of the hippocampus and parahippocampal gyrus is desired, it is done by subependymal and endopial aspiration backwards in the direction of the tectal cisterna, along the cerebral peduncle and the P2 segment of the posterior cerebral artery. The habitual posterior limit of the hippocampal formation resection corresponds to the lateral mesencephalic sulcus which runs vertically on the side of the midbrain between the cerebral peduncle and the tectum.
- resection should result in a radical resection of the amygdala i.e. of more than 4/5, the residual tissue being in the dorsal portion of the amygdala where boundaries are harder to establish. Furthermore, the junctional zone between the amygdala and hippocampus, including the ventral portion of the uncus and intralimbic gyrus (apex of uncus), should be resected. Finally, the resection of the “hippocampus” should not be limited to the hippocampus proper but must involve the dentate gyrus and the parahippocampal gyrus. Completeness of the hippocampal resection should not be evaluated in a linear fashion but also “circumferentially” around the hippocampal fissure.
- following complete hemostasis, the self-retaining retractor is removed and any devascularized area of the cortex is resected.

**PITFALLS**

- errant trajectory can lead the surgeon to miss the temporal horn in the dissection through the white matter. A too anterior trajectory will pass by the anterior extent of the ventricle and a too dorsal one could lead into the insula or temporal stem. It is best to err inferiorly and follow the grey matter of the collateral sulcus to the ventricle.
- In the endopial emptying of the parahippocampal gyrus, care must be taken to maintain the integrity of the pia to protect the structures of the ambiens cisterna and specifically the posterior cerebral artery. Similarly, in resecting the structures located medial and anterior to the hippocampal sulcus and corresponding to the dentate gyrus and velum terminale, the pia of the ambiens cisterna must be recognized and left undisturbed in order to avoid damage to the midbrain. Finally, in emptying the lower portion of the uncus below the incisura, the 3rd nerve should be recognized and left undisturbed.
- Whenever the anatomy remains or becomes unclear, the surgeon must back up and retrieve the more obvious anatomical landmarks such as the choroid plexus, the lateral sulcus or the free edge of the tentorium. By using ultrasonic dissection, hemostasis is usually not a problem and coagulation is not necessary.

**TRANSSYLVIAN APPROACH**

(Weiser and Yasargil 1982)
Wieser HG. Selective amygdalo-hippocampectomy for temporal lobe epilepsy. Epilepsia. 1988;29(suppl 2):S100–S113

- more restrictive and necessity to dissect around the Sylvian vessels (risk of injury to M1 portion within sylvian fissure).
- complete avoidance of neocortical injury - better neurocognitive outcomes (vs. subtemporal). >>
- temporal stem has to be partly disconnected.
- arachnoid over the Sylvian fissure is divided and the bottom of the circular sulcus exposed. An incision is made between two opercular temporal arteries, the temporal peduncle is transected and the ventricular horn exposed. The hippocampal formation is then resected by an extrapial approach as far laterally as the collateral fissure. The amygdala is removed by subpial aspiration.
- transsylvian approach provides an excellent overview on anterior temporomesial structures and pathologies, while dissection of the posterior part of the hippocampal formation is rendered difficult.

### SUBTEMPORAL APPROACH

- rationale is to spare temporal neocortex, to avoid incision of the temporal stem and to minimize visual field deficits.
- excellent overview on the posterior hippocampal/mesiotemporal area
- disadvantages:
  1) retraction of the temporal lobe and danger for basal veins, especially the vein of Labbé;
  2) surgical orientation where to enter the temporal lobe on its inferior surface, either through the parahippocampal gyrus, the collateral sulcus or the fusiform gyrus may be unclear;
  3) resection of the anterior aspects (uncus and amygdala) is rather difficult.

### MINIMALLY INVASIVE VIA TRANSPALPEBRAL ENDOSCOPIC-ASSISTED APPROACH


### SUPRACEREBELLAR-TRANSTENTORIAL PARAMEDIAN SAH

MTS is a disease of the hippocampal formation of the archipallium, which is separated from the neopallium by the collateral sulcus. The surgical route, which always remains on the medial side of the collateral sulcus, helps to avoid any iatrogenic damage to the neopallium and its vasculature.

Mehmet Volkan Harput et al. The Paramedian Supracerebellar- Transtentorial Selective Amygdalohippocampectomy for Mediobasal Temporal Epilepsy. Operative Neurosurgery: 23 December 2017

MULTIPLE HIPPOCAMPAL TRANSECTION (MHT)

Fady Girgis, MD Madeline E Greil, BS Philip S Fastenau, PhD Jennifer Sweet, MD Hans Lüders, MD, PhD Jonathan P Miller, MD. Resection of Temporal Neocortex During Multiple Hippocampal Transections for Mesial Temporal Lobe Epilepsy Does not Affect Seizure or Memory Outcome. Operative Neurosurgery, Volume 13, Issue 6, 1 December 2017, Pages 711–717, https://doi.org/10.1093/ons/opx031

TRANSSYLVIAN TRANSCISTERNAL AND TRANSINFERNOR INSULAR SULCUS APPROACH

Left Transsylvian Transcisternal and Transinferior Insular Sulcus Approach for Resection of Uncohippocampal Tumor: 3-Dimensional Operative Video. Juan C Fernandez-Miranda, MD. Operative Neurosurgery. Published: 07 June 2018

POSTOPERATIVE

Dr. Holloway:
MRI within 3-12 months postop.
Neuropsychiatric evaluation within 3-12 months postop

After LITT:
start on POD1: DEX 4 q 6 hours x 1 week → rapid taper

AED tapering – see below >>

COMPLICATIONS

psychiatric effects of temporal lobectomy → see p. Psy5 >>

1. Visual field deficits - most common deficits!
   a) CONTRALATERAL SUPERIOR QUADRANTANOPTIS ("pie-in-the-sky" defect) - up to 55-78% patients, but usually minor and rarely noticed by patient - from damage to Meyer loop.
      — incidence can be minimized with minimal lateral cortical and maximal medial resections.
      — incidence the same for ATL and transcortical SAH; incidence is much lower with transsylvian SAH.
      — when present, this rarely causes significant disability vocationally.
   b) HOMONOMOUS HEMIANOPTIS - from vascular damage to geniculate body or optic tract by similar mechanism as hemiparesis; risk can be minimized with careful microsurgical technique.

2. Hemiparesis (0.39-3.0%; incidence ≈ 5% in older literature) - due to damage (cauterization or tearing) of small perforating vessels to peduncle or internal capsule arising from PComA or anterior choroidal artery.
   • paralysis is present immediately and most usually is permanent to some degree.
Temporal Lobectomy

- Incidence can be minimized with careful technique and use of operating microscope for all medial resection.

3. **CN3 and CN4 palsies** still present in 5% cases (esp. after *en bloc* resections).
   - Because CN3 lies directly beneath pial surface of uncus, it can have temporary dysfunction from mild manipulation during dissection.
   - CN4 can be damaged by having current of bipolar cautery set too high when coagulating near edge of tentorium.

4. **Declarative memory problems** (esp. in patients with speech dominant temporal lobe resection – *transient dysnomia* occurs in ≈ 30-44% patients; *permanent amnesic syndrome* – in 0.6-2.0%) – related to mesial temporal structures (thus, “selective” approaches do NOT reduce this risk).
   - **Verbal memory problems** are more severe than **visual-spatial memory deficits** thought to occur after nondominant ATL.
   - Rarely, memory deficits may be so severe that patient is incapable of learning new material.
   - **Lüders area** (s. basal temporal language area) at inferior temporal gyrus – if damaged during surgery, transient (up to 6 weeks) dysnomia for kids; no deficits for adults.
   - **Risk factors:**
     - Most consistent and reliable clinical indicator – age at first seizure; if first seizure (including febrile) occurred before age 6 years, risk of increased memory problems postoperatively is slight.
     - Patients without (!) hippocampal sclerosis are at greatest risk for this complication (i.e. removal of functional hippocampus)
     - History of severe alcohol abuse → higher risk for global memory problems after ATL.
     - Surprisingly, extent of hippocampal resection is not related to poor memory outcome.

5. **Cognitive declines related to the approach** (collateral damage; absent in stereotactic approaches such as LITT) and can be impactful and permanent:
   - Impaired naming and verbal learning (dominant hemisphere)
   - Impaired object recognition and figural learning (nondominant hemisphere).

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**LITT**

LITT is better for language preservation vs. ATL or SAH

- Through investigation of connectomes involved in TLE, naming and object recognition deficits are postulated to occur through injury to the white matter in the temporal stem which tends to be damaged when approaching the mesial temporal structures during ATL and SAH.
  

- Theoretically, LITT should circumvent this complication by limiting similar damage to the white matter of the temporal stem.
  

- LITT avoids neurocognitive adverse effects of open resection on naming (dominant side) and object recognition (nondominant side).

  Cognitive declines related to the approach (collateral damage) impair naming and verbal learning (dominant hemisphere) or object recognition and figural learning (nondominant hemisphere).

Complications of stereotactic laser amygdalohippocampotomy

<table>
<thead>
<tr>
<th>Complication</th>
<th>Incidence in 49 Procedures (6 Reoperations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemorrhage</td>
<td>2 (4.1)</td>
</tr>
<tr>
<td>Visual field deficit (total)</td>
<td>4 (8.2)</td>
</tr>
<tr>
<td>Transient (superior quadrantanopia)</td>
<td>1 (2.0)</td>
</tr>
<tr>
<td>Persistent</td>
<td>3 (6.1)</td>
</tr>
<tr>
<td>Homonymous hemianopia</td>
<td>1 (2.0)</td>
</tr>
<tr>
<td>Superior quadrantanopia</td>
<td>2 (4.1)</td>
</tr>
<tr>
<td>Cranial nerve deficit (transient)</td>
<td>2 (4.1)</td>
</tr>
<tr>
<td>CN3</td>
<td>1 (2.0)</td>
</tr>
<tr>
<td>CN4</td>
<td>1 (2.0)</td>
</tr>
</tbody>
</table>


- asymptomatic visual field deficits may be present in up to 37% cases (recommend preop DTI to minimize risk).

OUTCOMES

Seizure freedom (at 1 year)
ALT – 75%
SAH – 67%
LITT ≈ 36-58% (not enough data yet)
RF – 27% (orthogonal trajectories), 78% (along hippo axis)

SURGERY

- Dr. Holloway: with a typical left temporal lobe epilepsy coming from mesial sclerosis - 90% chance of a 90% reduction in the seizures and a 60-75% chance of a cure.
Surgery vs. conservative for temporal lobe epilepsy


Surgery for temporal lobe epilepsy is not only safe but also superior to prolonged medical treatment.

– 80 patients agreed to participate with 40 randomized to each arm of the trial.
– patients randomized to medical treatment were put on a 1-year waiting list for surgery (the standard practice in the study centre).
– patients randomized to surgery were admitted for pre-operative evaluation within 48 h of randomization.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Surgery group</th>
<th>Medical group</th>
<th>Statistical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freedom from disabling seizures</td>
<td>58% free</td>
<td>8% free</td>
<td>( p &lt; 0.001 )</td>
</tr>
<tr>
<td>Freedom from all seizures</td>
<td>38% free</td>
<td>3% free</td>
<td>( p &lt; 0.001 )</td>
</tr>
<tr>
<td>Change in frequency of disabling seizures</td>
<td>100%</td>
<td>34%</td>
<td>( p &lt; 0.001 )</td>
</tr>
<tr>
<td>Mean severity of residual seizures</td>
<td>21.4</td>
<td>26.5</td>
<td>No significant difference</td>
</tr>
<tr>
<td>Mean quality of life from 3 to 12 months</td>
<td>72</td>
<td>59</td>
<td>( p &lt; 0.001 )</td>
</tr>
<tr>
<td>Percentage employed or attending school at 1 year</td>
<td>56.4</td>
<td>38.5</td>
<td>No significant difference</td>
</tr>
</tbody>
</table>

– depression occurred in 18% of patients in the surgical group and in 20% of patients in the medical group.

AED tapering

• protocol: AED withdrawal is initiated at 3 months in patients on \( \geq 2 \) drugs and at 1 year for patients on a single drug.
• seizure recurrence occurs in 28.2%* on attempted withdrawal (regardless, 86% become seizure-free and 18% become drug-free after initial recurrence).

*risk is only 17% if hx of febrile seizures, normal postoperative EEG at 1 year, and duration of epilepsy of < 20 years

SAH

Subtemporal versus transtylvian SAH


47 patients randomised to subtemporal versus transtylvian approaches.
• cognitive functions were assessed before and 1 year after surgery.
• ILAE 1a was achieved in 62% of all patients without group difference with no significant effects of approach on cognition (incl. verbal recognition memory declined irrespective of approach).
• post hoc tests: the subtemporal approach was associated with a greater memory losses (worse outcome for verbal learning and delayed free recall as well as for semantic fluency); left side of surgery was associated with decline in naming regardless of approach.
Surgically refractory MTLE

- Patients with surgically refractory medial temporal lobe epilepsy (MTLE) exhibit distinct pattern of structural network organization involving temporal lobes and extratemporal regions as seen on MRI-DTI; compared with controls, not seizure-free patients exhibit higher connectivity between structures in 1) ipsilateral medial and lateral temporal lobe, 2) ipsilateral medial temporal and parietal lobe, and 3) contralateral temporal pole and parietal lobe


- Networks involving key components of medial temporal lobe and structures traditionally not removed during surgery may be associated with seizure control after surgical treatment of MTLE

Decision tree for further surgical treatment in non–seizure-free patients after SLAH:

SRS

- SRS is investigational per CMS.

Cleveland Clinic: results unsatisfactory, CCF trial terminated due to serious adverse events.

**ROSE trial - SRS vs. surgery**

Nicholas M Barbaro et al. Radiosurgery versus open surgery for mesial temporal lobe epilepsy: The randomized, controlled ROSE trial. Epilepsia 2018 March 30

- **stereotactic radiosurgery** (24 Gy to the 50% isodose targeting mesial structures) versus standardized **anterior temporal lobectomy** for pharmacoresistant unilateral mesial temporal lobe epilepsy (MTLE).
- randomized, single-blinded, controlled trial - 14 centers in the USA, UK, and India: 58 patients (31 in SRS, 27 in ATL).
- outcomes at 36-month follow-up:
  4) seizure remission (absence of disabling seizures between 25 and 36 months): 52% SRS and 78% ATL patients achieved seizure remission (difference between ATL and SRS = 26%, upper 1-sided 95% confidence interval = 46%, P value at the 15% noninferiority margin = 0.82).
  5) verbal memory (VM): mean VM changes from baseline for 21 English-speaking, dominant-hemisphere patients did not differ between groups; consistent worsening occurred in 36% of SRS and 57% of ATL patients.
  6) quality of life (QOL): QOL improved with seizure remission.
- adverse events were anticipated cerebral edema for some SRS patients, and cerebritis, subdural hematoma, and others for ATL patients.
- conclusion: ATL has an advantage over SRS in terms of seizure remission, and both SRS and ATL appear to have effectiveness and reasonable safety as treatments for MTLE. SRS is an alternative to ATL for patients with contraindications for or with reluctance to undergo open surgery.

- 21 patients with mesial temporal epilepsy/20 evaluable.
  - 5/20 symptomatic radiation-induced mass effect, 3 hospitalized - treated with steroids in most
  - 50% new visual field defect
  - 65% seizure-free at two years.

Temporal Lobectomy

- 15 patients, > 5 yr follow-up, 24 Gy treatment.
  - 60% seizure free (on drugs)
  - 0% seizure free (off drugs)
  - mean time to effect, 12 months
  - 60% temporary mass effect
  - increase in seizures early on

- 30 patients, 17 @ 20 Gy, 13 @ 24 Gy
  - 67% seizure free @ 36 months HD.
  - 77% Seizure free @ 36 months LD.
  - 12% significant verbal memory deficit.
  - mean time to effect, 12 months.
  - increase in seizures early on.

**BIBLIOGRAPHY** for ch. “Epilepsy and Seizures” → follow this [LINK](#)

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Viktor’s Notes™ for the Neurosurgery Resident
Please visit website at www.NeurosurgeryResident.net