Temporal Lobectomy and its Modern Derivatives

Last updated: February 8, 2023

TEMPORAL LOBE EPILEPSY – see p. E9 >>

Pending sources:
http://www.neurosurgicalatlas.com/volumes/epilepsy-surgery/temporal-lobe-surgery/anteromedial-temporal-lobectomy
Drs. Cohen-Gadol and Spencer: https://www.youtube.com/watch?v=ILDdmVqUkag
Starr, Barbaro, Larson "Neurosurgical Operative Atlas - Functional Neurosurgery" 2nd ed (2009), ch. 3, 4-5
Youmans Ch. 62
A. Olivier. Temporal resections in the surgical treatment of epilepsy. Epilepsy Res Suppl, 5 (1992), pp. 175-188

RELEVANT ANATOMY

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

INDICATIONS

- temporal lobe epilepsies: see p. E9 >>

- 80% of patients with medically intractable seizures with demonstrable focus have foci in anterior temporal lobe!
- *dual pathology* - 15% of patients with extratemporal epileptogenic focus also have associated MTS (**kindling phenomenon** has been implicated in causation of MTS in this patient population).
- 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.

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).

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 3-5 cm may be removed (over-resection may injure *speech centers*, which cannot be reliably localized visually)

non-dominant temporal lobe: 3.5-7 cm may be resected (slight over-resection → *partial contralateral upper quadrant homonymous hemianopsia* "pie-in-the-sky"; resection of 8-9 cm → complete *quadrantanopsia*)

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)** - initially described by Penfield and Baldwin, in 1952.
   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)** - 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) and mesiotemporal 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. for left side resections (to verify if contralateral hippocampus will suffice to maintain adequate memory).

Certain cases need preop SEEG – see p. E13 >>

ASM

Dr. Cohen-Gadol: perioperative events and anesthetic medications lead to a drop in the serum levels of ASMs - supratherapeutic levels of ASMs are therefore advised during the perioperative period because seizures complicate recovery from surgery.

PROCEDURE – OPEN

Video (Neurosurgical Atlas) >>

COUNSELLING

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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.
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Counsel about risk for memory >>

ANESTHESIA

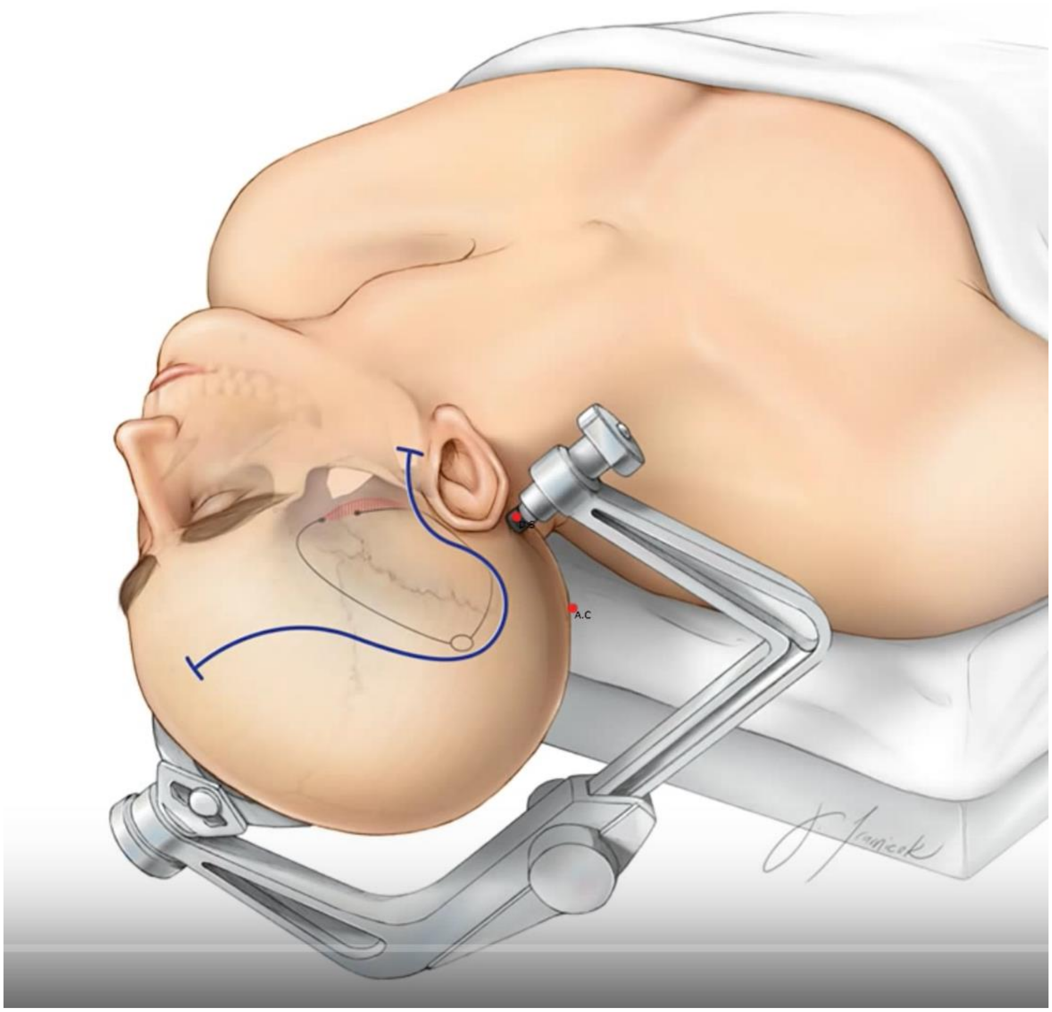
- **general anesthesia**; in ***dominant hemisphere***, value of operating under **local anesthesia** (to permit stimulation mapping and identification of speech areas) has been stressed.
- MANNITOL is commonly used – 50 g (vs. full 100 g for grid placement); steroids - not.

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.

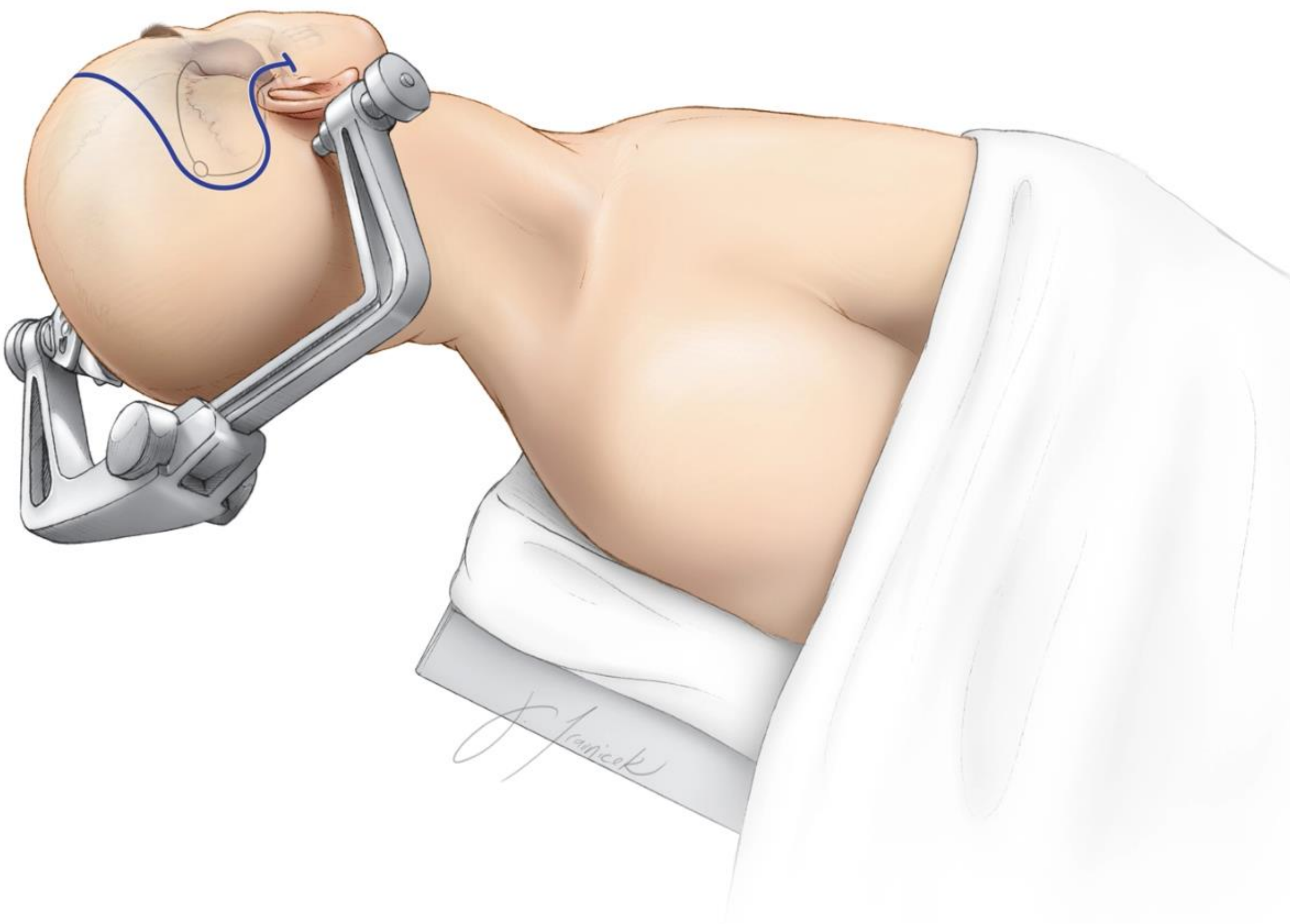
- **microscope** for hippocampectomy part.
- head turned 30 degrees to contralateral side → markedly extended* (50 degrees) toward the ipsilateral shoulder → vertex lowered 10 degrees
  *extension allows surgeon to directly view long axis of hippocampus with microscope through the temporal horn during intraventricular dissection and medial hippocampal disconnection
- positioned properly, *zygoma will be the highest point* of head.

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



Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- single pin is placed over the mastoid area to keep the arms of the skull clamp out of the operator's working zone.



Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

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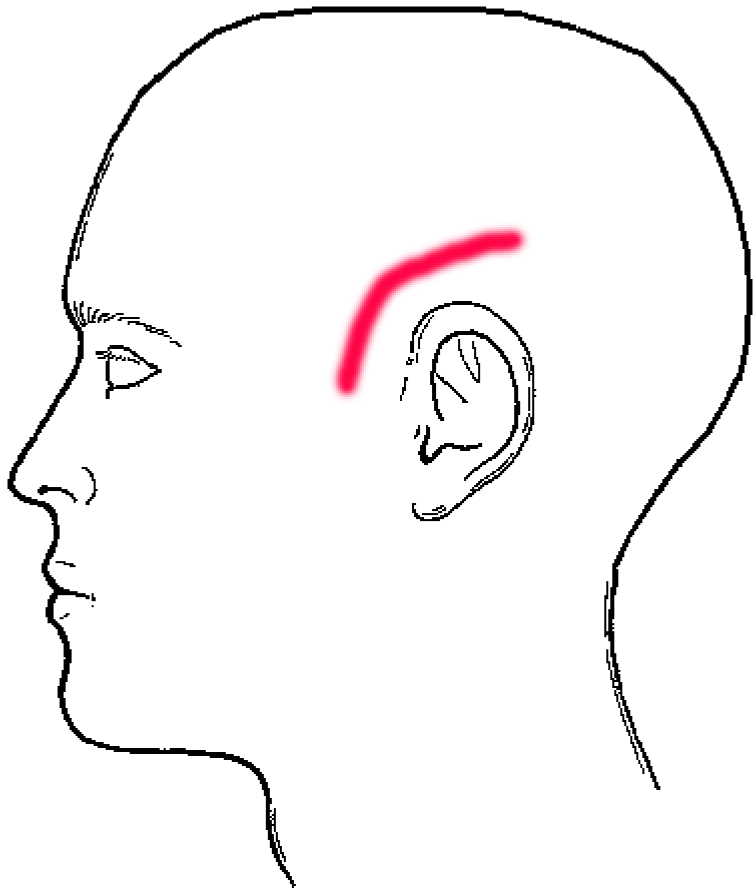
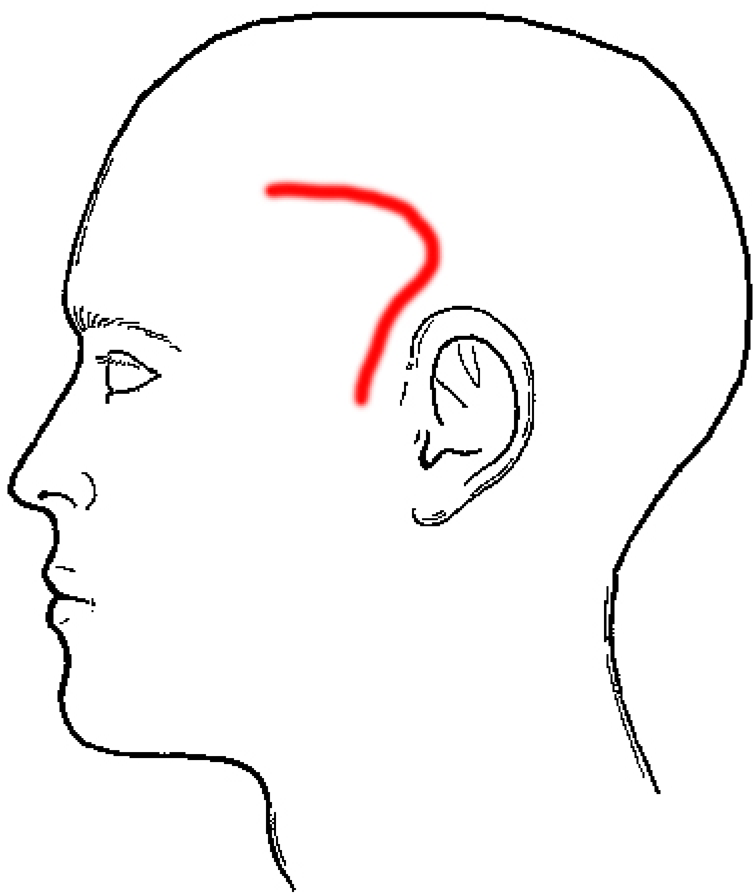
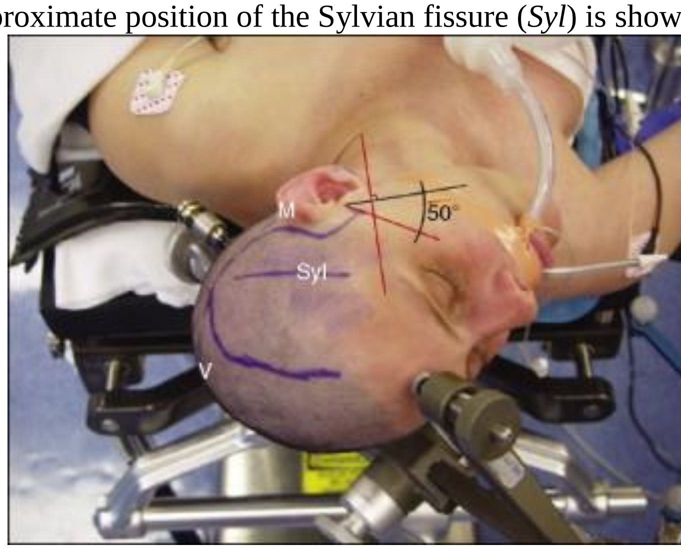
- (reverse) question mark incision begins near the zygoma and extends posteriorly behind the ear just in front of the mastoid vertex line, then curves anteriorly just above the insertion line of the temporalis muscle (superior temporal line).

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



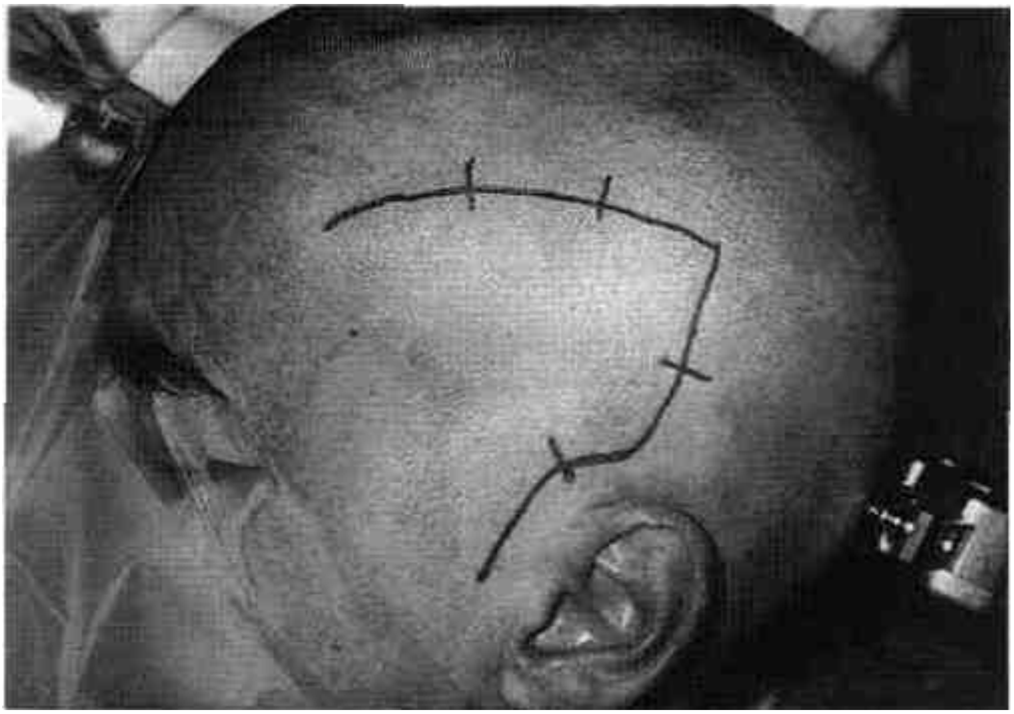



- small "question mark" curvilinear frontal temporal incision (similar to pterional approach to circle of Willis): incision starts at zygoma anterior to tragus and curves superiorly and posteriorly; posterior margin is line drawn from mastoid tip (*M*) to vertex (*V*) (note how head is extended 50 degrees;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



Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- 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



Source of picture: Marshall B. Allen, Ross H. Miller "Essentials of Neurosurgery: a guide to clinical practice", 1995; McGraw-Hill, Inc.; ISBN-13: 978-0070011168 >>

CRANIOTOMY

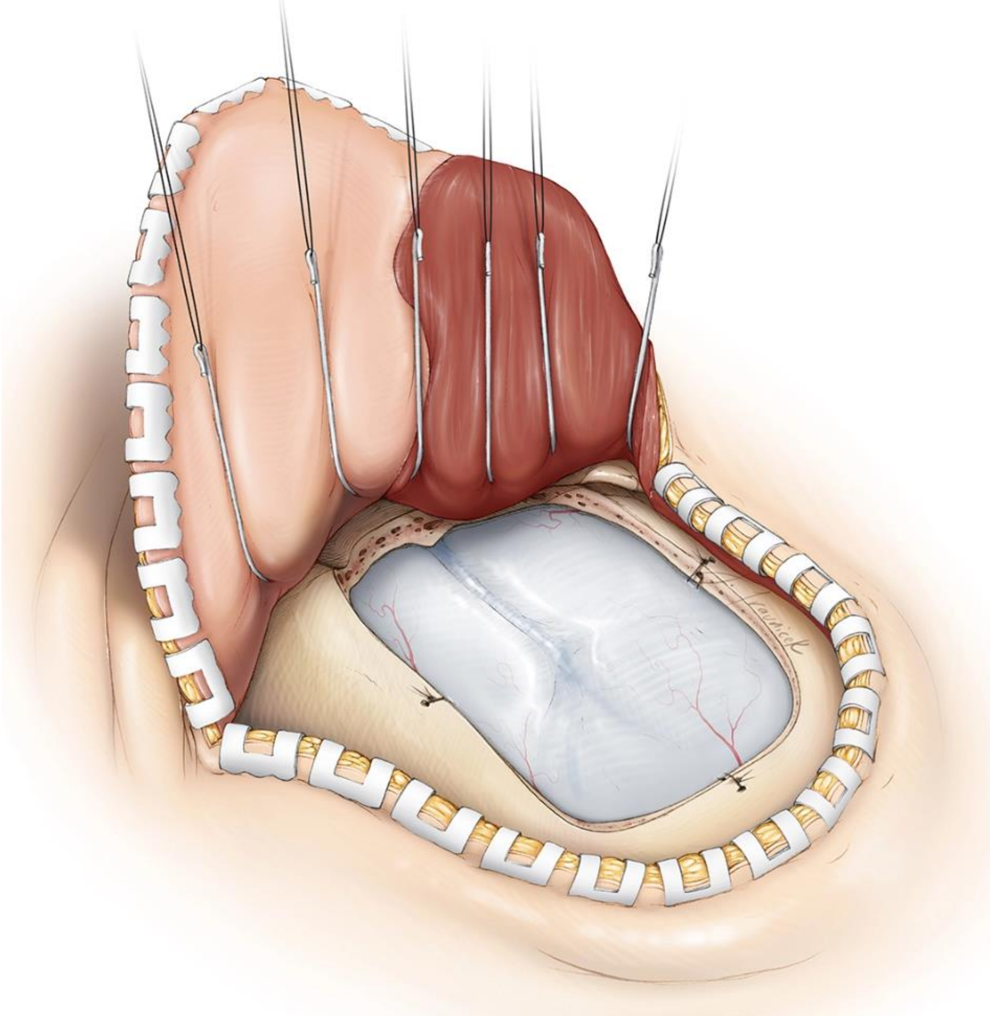
- ***cuff of temporalis muscle*** is preserved along superior temporal line for reattaching temporalis muscle during closure.
- scalp and temporalis muscle are reflected anteriorly and retracted with perforating towel clips / fish hooks attached to Leyla bar with rubber bands.

Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- myocutaneous flap is elevated and a single burr hole is placed at the root of the zygoma or just below the superior temporal line at the posterior aspect of the exposure

Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- anterior temporal craniectomy exposes the most anterior and inferior aspects of the temporal fossa – allows to direct microscope's view relatively parallel to the axis of the hippocampus during the later stages of dissection



Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- 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.
- 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.

CLEVELAND CLINIC

The skin incision has a small question mark shape, which does not cross the temporal line and it is usually sufficient for an adequate exposure. The skin incision starts posterior from the hairline, at the level of the superior temporal line and it is extended down along the anterior border of the ear to the root of the zygoma. The superficial temporal artery is avoided by making the incision along the anterior border of the ear. The skin is retracted and the fascia of the temporalis muscle is exposed. A carefully interfascial dissection of the fascia temporalis is performed in order to preserve the frontal branches of the facial nerve, obtaining better cosmetic results in the postoperatory period. The outer layer of the fascia temporalis is incised sharply just below its insertion on the superior temporal line in order to leave a small cuff of fascia for reattaching the temporal muscle. The muscle fibers are incised in T shape, exposing both the key-hole point anterior and the root of the zygoma in the basal posterior aspect of the exposure. The muscle is elevated from the bone and retracted using fish-hooks attached to springs.

Three burr-holes are performed: on the key-hole point, basal temporal bone posterior zygoma root, and a third trepanation is placed on the superior and posterior aspect of the exposure. The bone flap is then elevated, and the middle meningeal artery is identified, cauterized, and cut. The excess bone from the sphenoid wing is removed using small Leksell rongeur. The dura is opened using a horseshoe-shaped incision and retracted back over the temporalis muscle, and is protected with moist cottonoids to reduce shrinkage. At this point, the inferior frontal gyrus is partially exposed, together with 6 to 7 cm of the lateral aspect of the temporal lobe.

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!

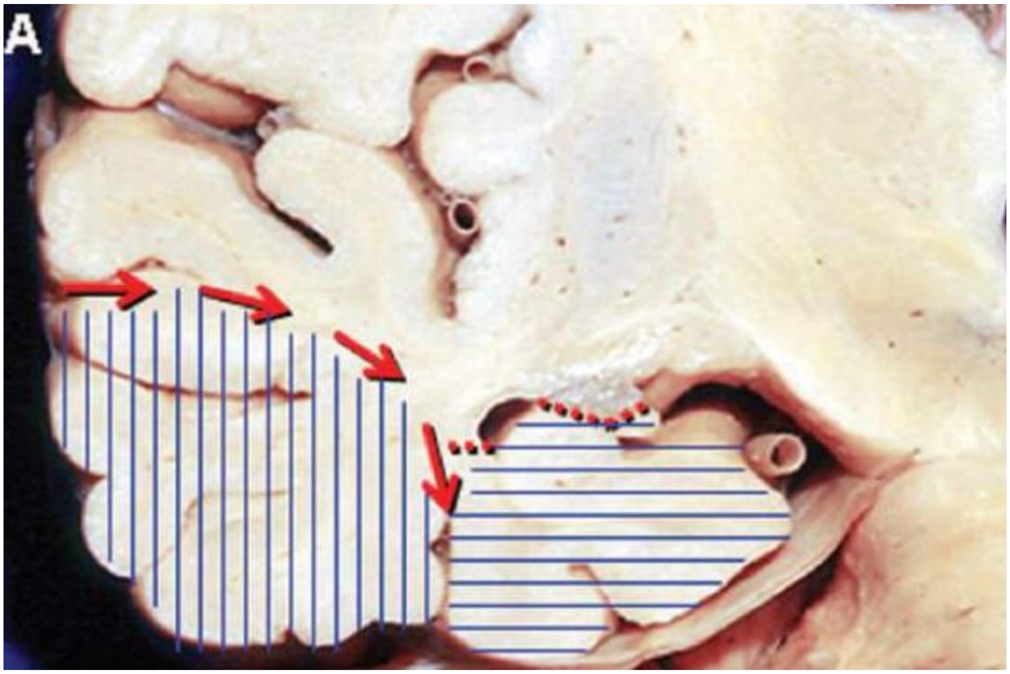
Mapping

a) intraop mapping - suboptimal strategy (better use intracranial monitoring)

b) for *children* and *uncooperative a*dults, 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 STAGES



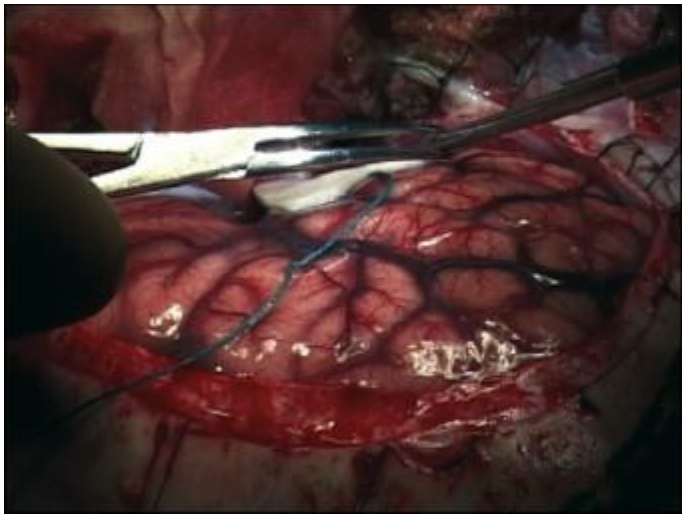
Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

RESECTION OF LATERAL TEMPORAL LOBE

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 – 3-3.5 cm (still may cause aphasia in some patients; H: language mapping)
nondominant side – 4-6 cm

- it is easy part – "opening the door"
- slide Telfa strips under electrode grids to mark resection lines on the cortex
- mark the 4.0-cm line on the instrument (e.g. Penfield #1) and then slide the instrument over the middle temporal gyrus until the tip of the instrument touches the anterior temporal fossa just below the sphenoid wing – then extent of the lobectomy from the temporal tip is marked on the cortex with an attempt to preserve the middle temporal veins located anterior to the vein of Labbe.
- 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.



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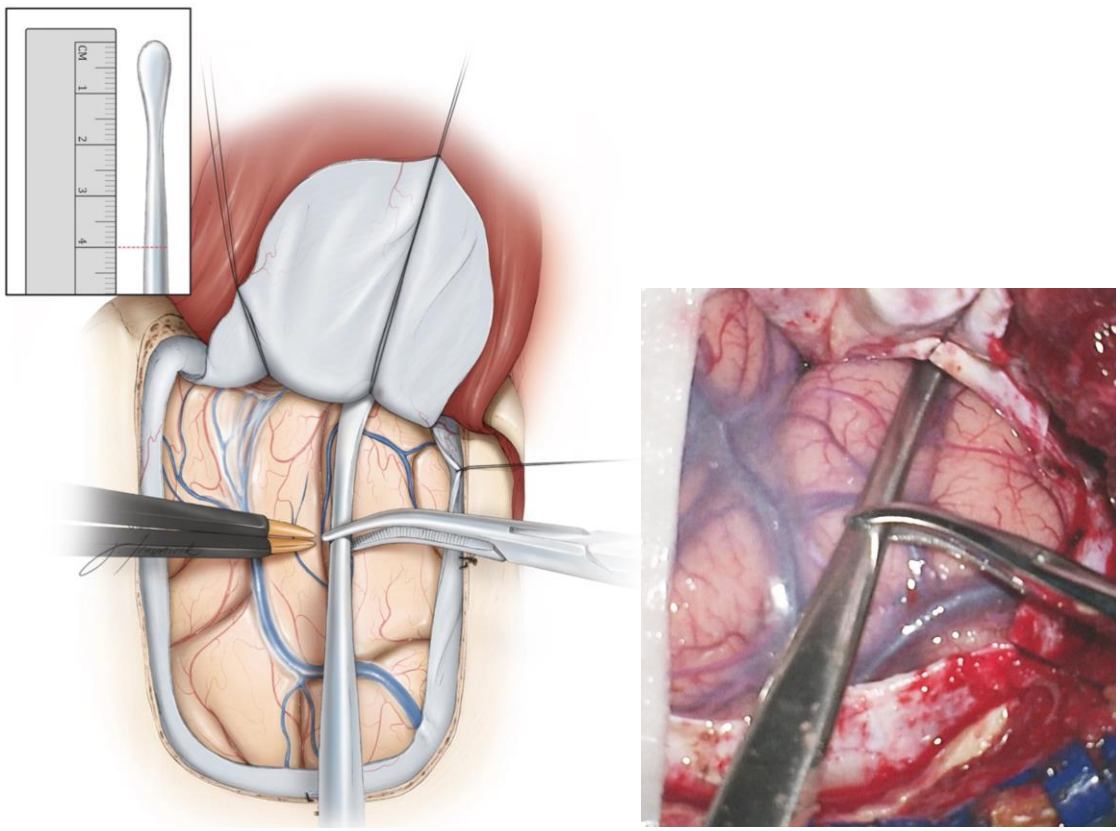
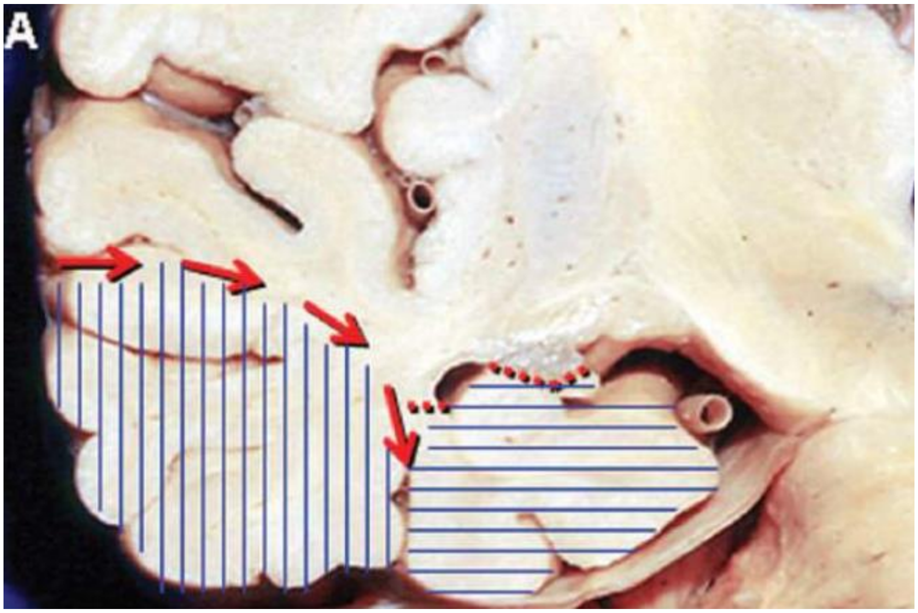


Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- 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)
- pia and cortical vessels are coagulated along superior temporal convolution and across temporal convolutions about 5 mm anterior to desired extent of excision.
- neocortical white matter dissection (*red arrows*) begins from the superior or middle temporal gyri toward the collateral sulcus → temporal horn has been uncapped to expose the choroid plexus and hippocampus:



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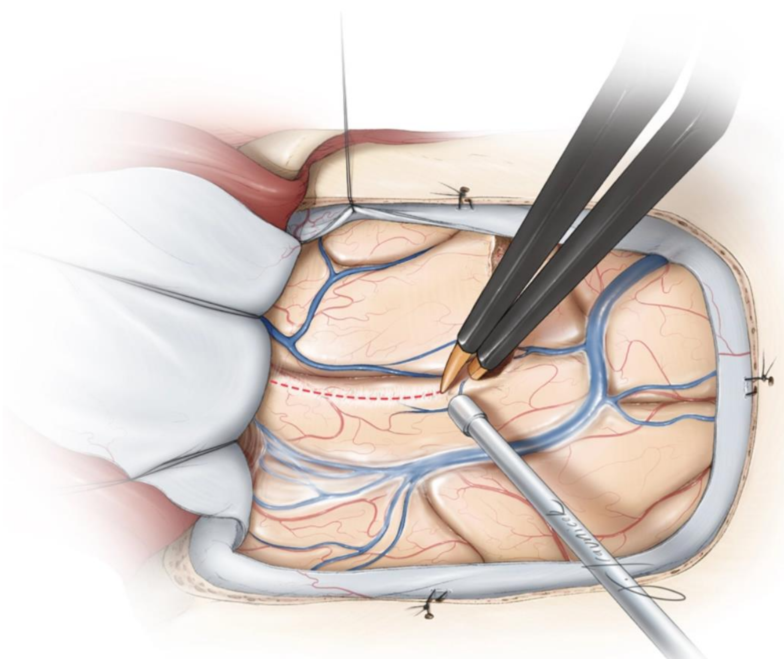
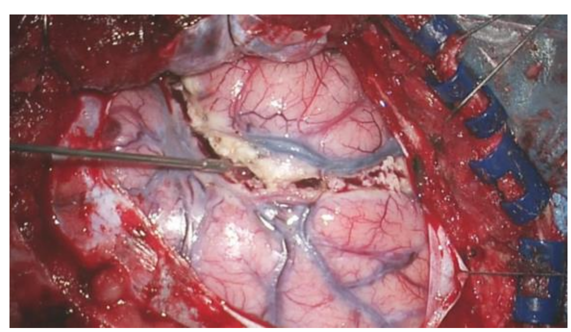
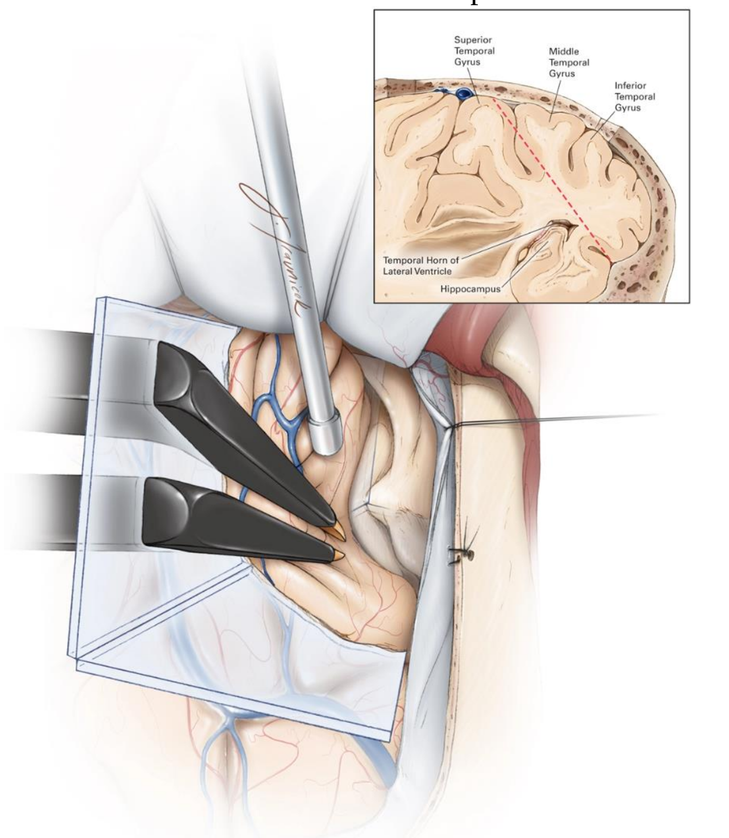
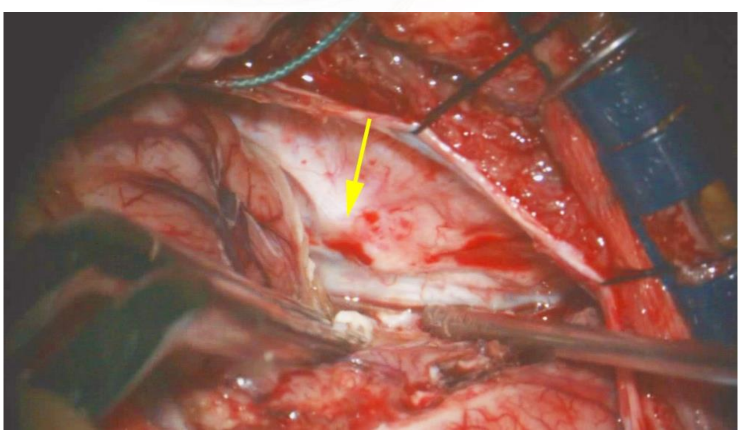
- superior corticotomy is carried out along the superior temporal sulcus, inferior part of STG (preservation of the superior temporal gyrus) → posterior corticotomy perpendicular to the long axis of the middle and inferior temporal gyri, 3.5 to 4 cm from the temporal pole.
- depth of resection is 2-3 cm and includes the fusiform gyrus (as the operator gains additional experience, the fusiform gyrus resection may be extended more medially to the level of the ventricle, simplifying exposure of the temporal horn and mobilization of the mesial structures) - navigation can guide this step!



Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- **bridging veins** (from the Sylvian fissure to the sphenoparietal sinus) are at the anterior temporal tip - retraction of the temporal lobe can cause bleeding from these veins unless they are cauterized.

- language deficits can result from interruption of the branches of the middle cerebral artery, which become more superficial at the level of the middle to the posterior portion of the sylvian fissure (within the anterior 4 cm of the temporal lobe). Also, speech deficits may occur with the disruption of the vein drainage of the basal aspect of the frontal area (particularly inferior frontal gyrus, pars opercularis and triangularis) due to damage at the level of the superficial sylvian veins).
- white matter dissection is performed to disconnect the lateral temporal neocortex.
  - there is an unnamed but anatomically consistent **bony protuberance** (*yellow arrow*) [arcuate eminence?] along middle fossa floor that can be found via gentle retraction of temporal lobe.
  - this protuberance is a useful landmark for guiding white matter dissection: planes of the superior and posterior corticotomies and white matter dissections should join at this bony protuberance – it will ensure that the operator will not violate the temporal horn prematurely or injure the vital structures located medial to this plane of dissection.



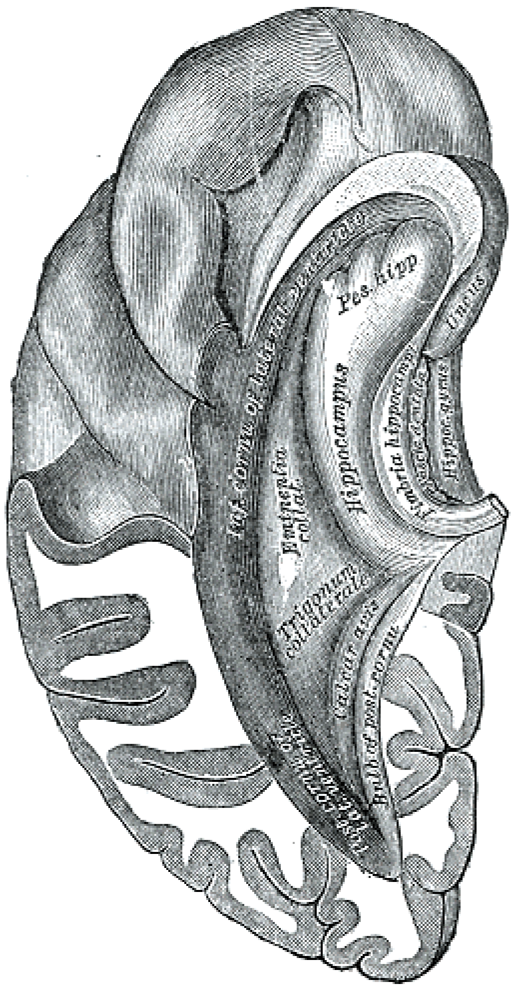


Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

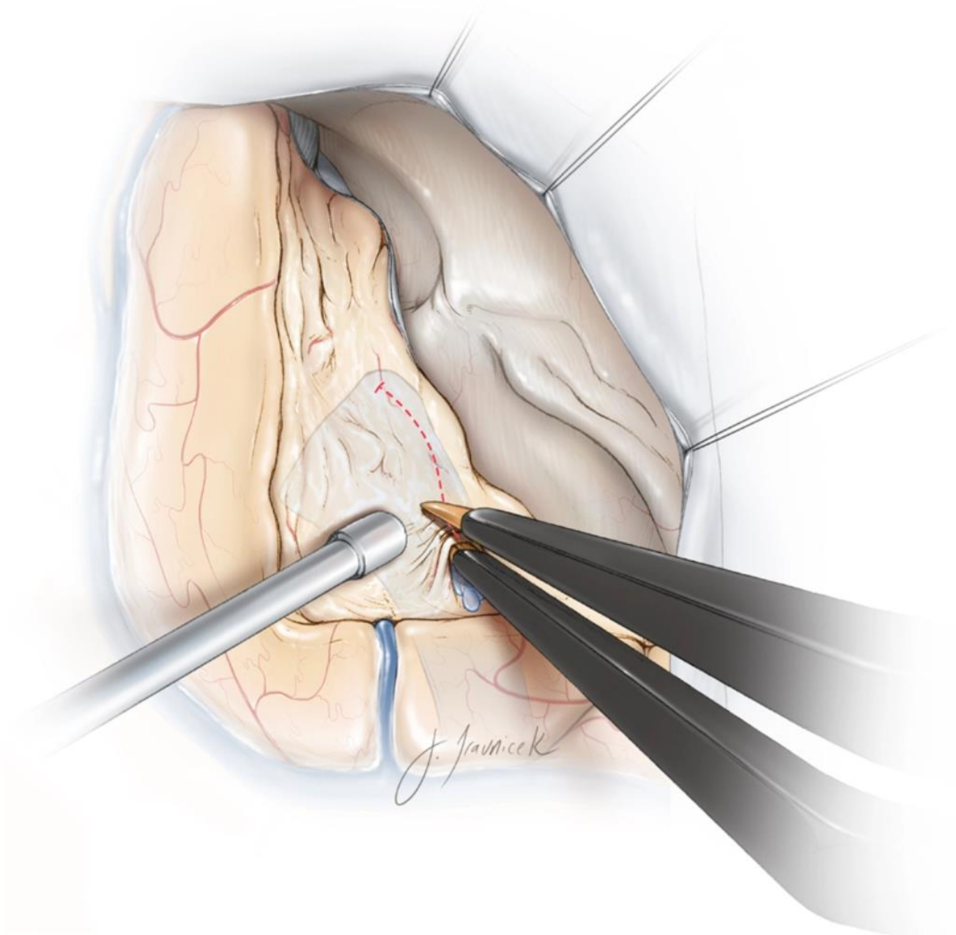
Temporal horn is the key landmark for the exposure and resection of medial structures!

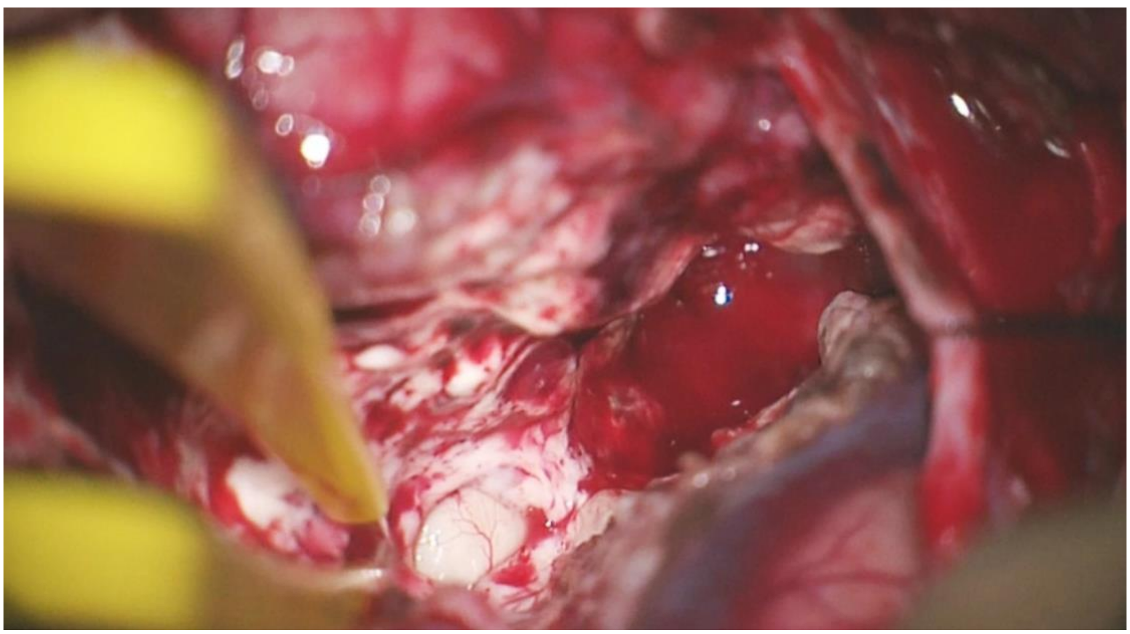
- collateral sulcus is an indirectly landmark of the temporal horn of the lateral ventricle since it indicates the position of the collateral eminence, which is located just medially to the hippocampus.

  The **collateral eminence** is an elongated swelling lying lateral to and parallel with the hippocampus. It corresponds with the medial part of the collateral fissure, and its size depends on the depth and direction of this fissure. It is continuous behind with a flattened triangular area, the trigone of the lateral ventricle, situated between the posterior and inferior cornua. It is not always present.



- underlying location of the temporal horn in relation to the deep white matter of the middle temporal gyrus is indicated - temporal horn lies deep to the white matter previously covered by the middle temporal gyrus;
  - entry into the ventricle (at the tip of bipolar forceps) is confirmed by the appearance of CSF and choroid plexus.
  - upon entering the ventricle, incise the lateral wall of the ventricle to expose the medial structures.





Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- one should recognize that ventricle is more posterior than expected due to size of amygdala (that occupies anteromedial temporal lobe); if operator is disoriented, he / she may continue medial white matter dissection and completely miss the ventricle and inadvertently enter brainstem, thalamus, or structures in the center of the hemisphere.
- 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).

N.B. identify temporal horn early – guides anatomy!

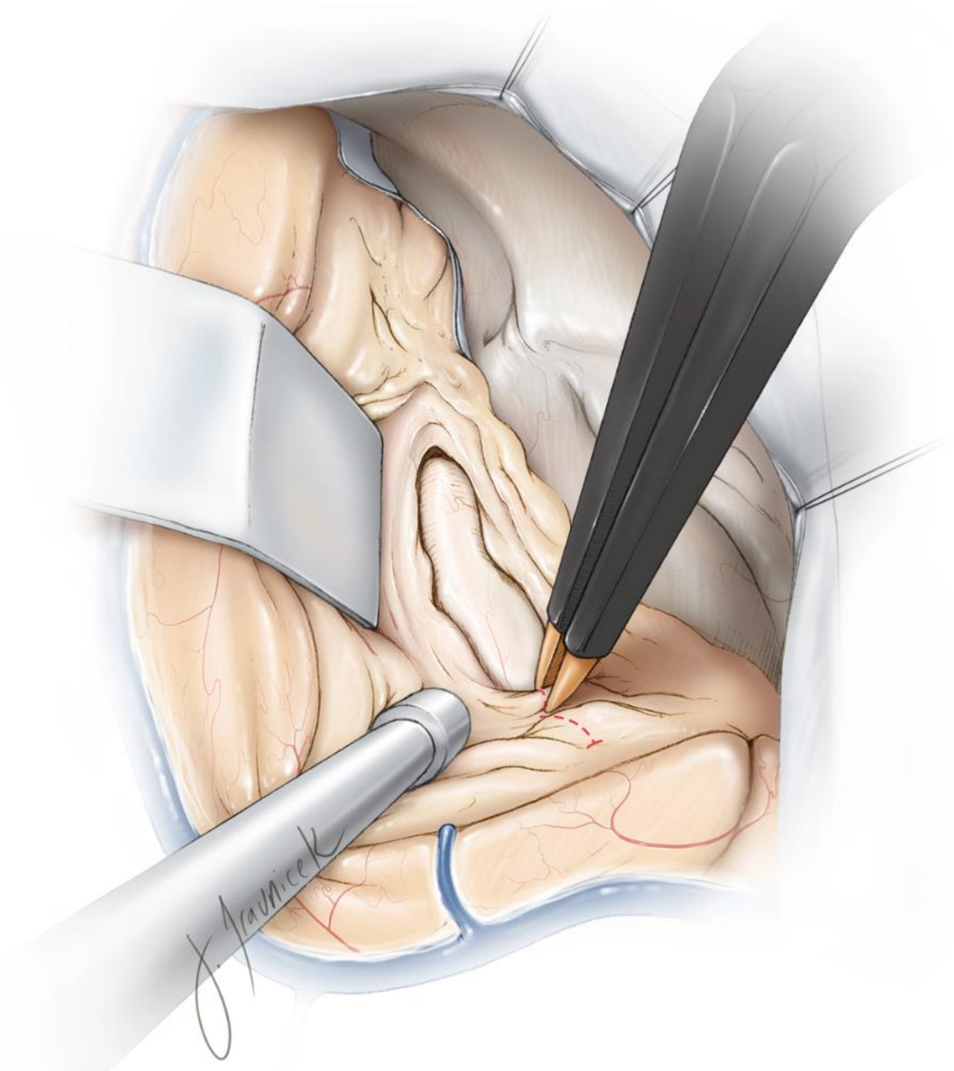
— while searching for temporal horn, if one misses it and dissects too far superiorly, temporal stem, basal ganglia/amygdala complex, and then crus cerebri may be entered; superior to temporal horn, there is no arachnoid plane along this medial trajectory.
— if you do not find temporal horn, use neuronavigation 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.
- optional - ***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.

- exposure of hippocampus is expanded by disconnection of the occipitotemporal fasciculus on the lateral wall of ventricle (parallel to the lateral edge of the hippocampus); moreover, the fusiform gyrus is incised along the occipitotemporal fasciculus until the arachnoid of the mesial occipitotemporal (parahippocampal) gyrus is identified.



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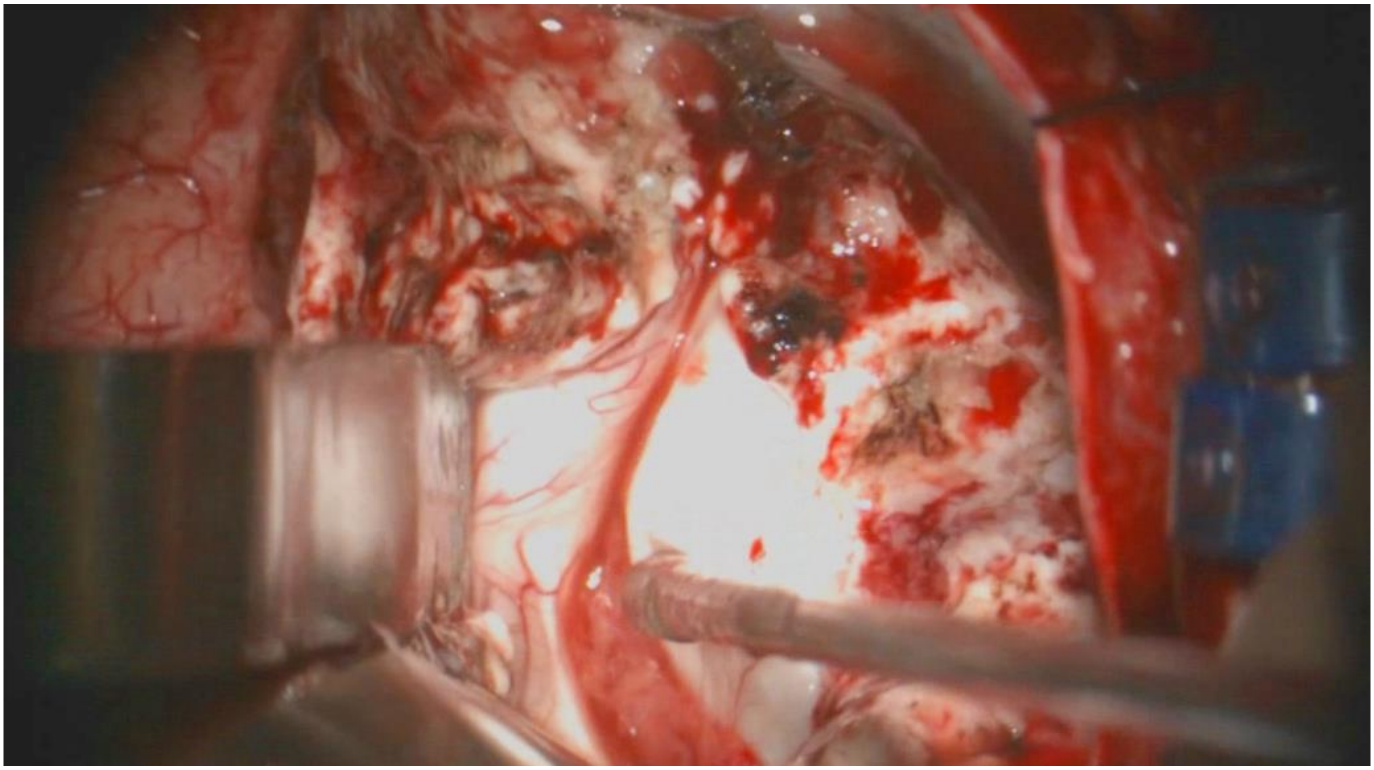
- choroid plexus is apparent at the tip of the suction device:



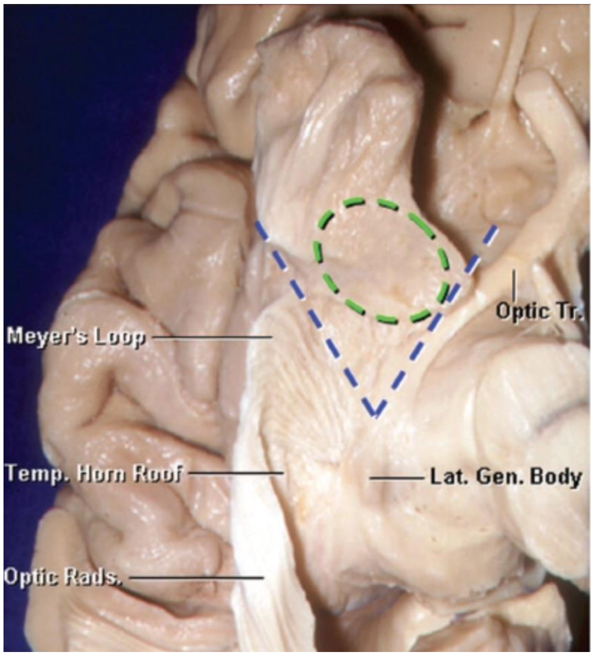
Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

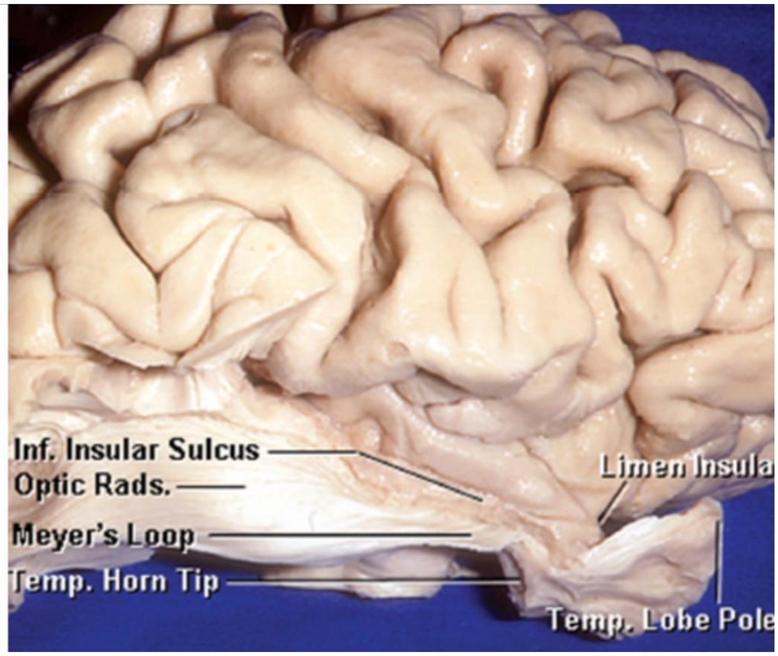
Meyer's loop courses along the roof and lateral aspects of the temporal horn.

- operator can avoid a *superior temporal quadrantanopsia* by maintaining the plane of dissection within the medial fusiform gyrus.

Inferior view of the right temporal lobe (*left image*) and lateral view (*right image*):

— gray and white matter underneath the temporal horn and optic radiations have been removed.
— optic radiations emerge from the lateral geniculate body, and loop forward on the ventricular roof toward the anterior temporal horn; radiations subsequently turn posteriorly around the roof and lateral wall of the temporal horn and atrium.
— section of the amygdala (*outlined in green*) has been included.
— *blue lines* mark the triangular area between the Meyer's loop and the optic tract with the apex at the lateral geniculate body, through which the temporal horn can be accessed via the floor of the Sylvian fissure without interrupting the optic radiations or optic tract. A la





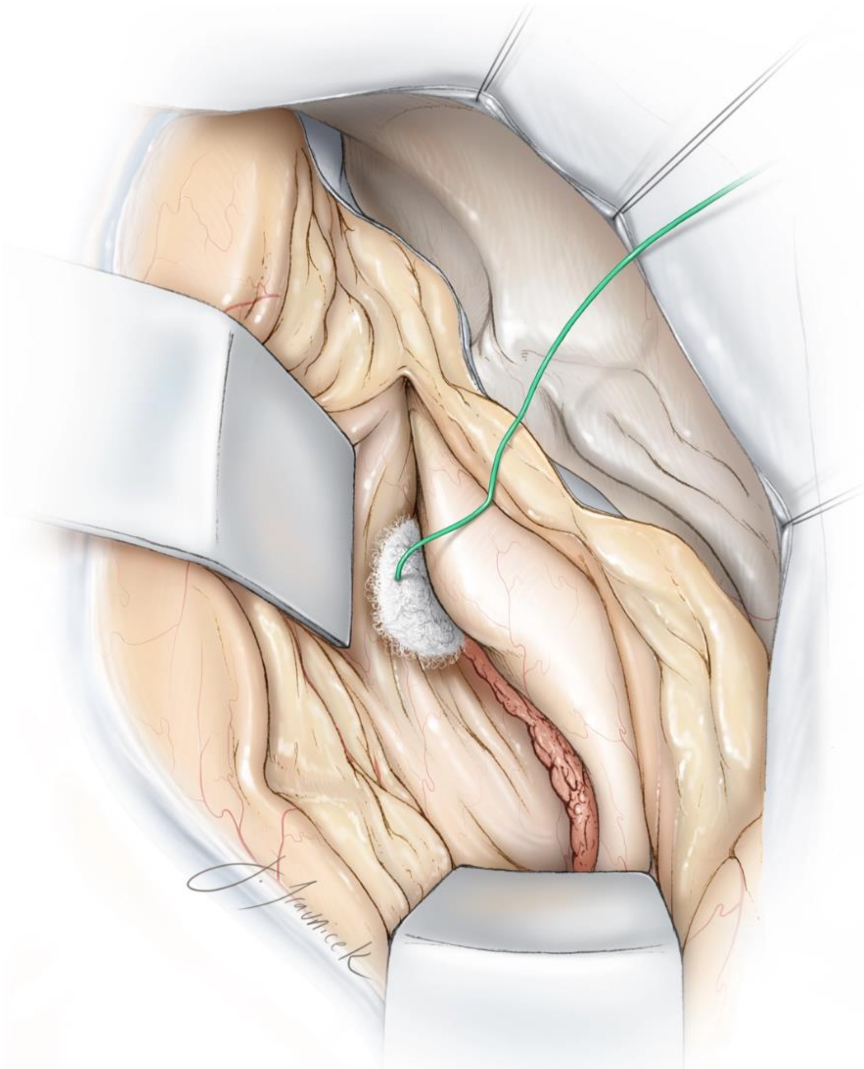
Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

Limiting the extent of occipitotemporal fasciculus dissection along the lateral hippocampus minimizes the breadth of expected visual field defects caused by injury to Meyer's loop!

- some prefer to use two fixed retractor blades:
  one to support the superior temporal gyrus - retractor elevates the roof of the temporal horn and allows identification of the choroid plexus and hippocampal structures;
  second on the cut surface of the posterior plane of resection - retractor mobilizes the remainder of the temporal neocortex laterally.

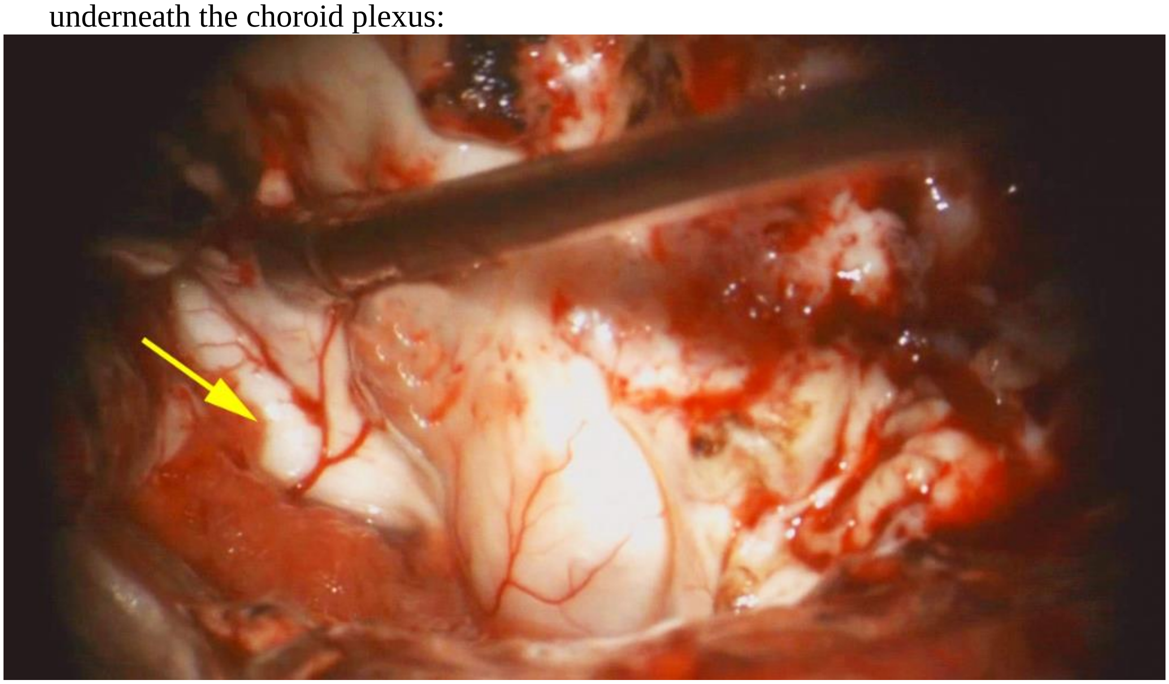
  N.B. precaution is to avoid retraction of the cranial aspect of the temporal cavity, where the basal ganglia and the internal capsule are located. Any kind of retraction is strongly disapproved in this area, with the risk of temporary or even permanent motor deficit!

- small cottonoid pledget is placed into the temporal horn and at the anterior edge of the choroid plexus so that the inferior choroidal point is easily identified.
- another pledget is placed at the tail of temporal horn - to prevent blood from entering the rest of ventricular system.



Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- yellow arrow identifies the uncinate fasciculus and the intralimbic lobe of the parahippocampus just underneath the choroid plexus:

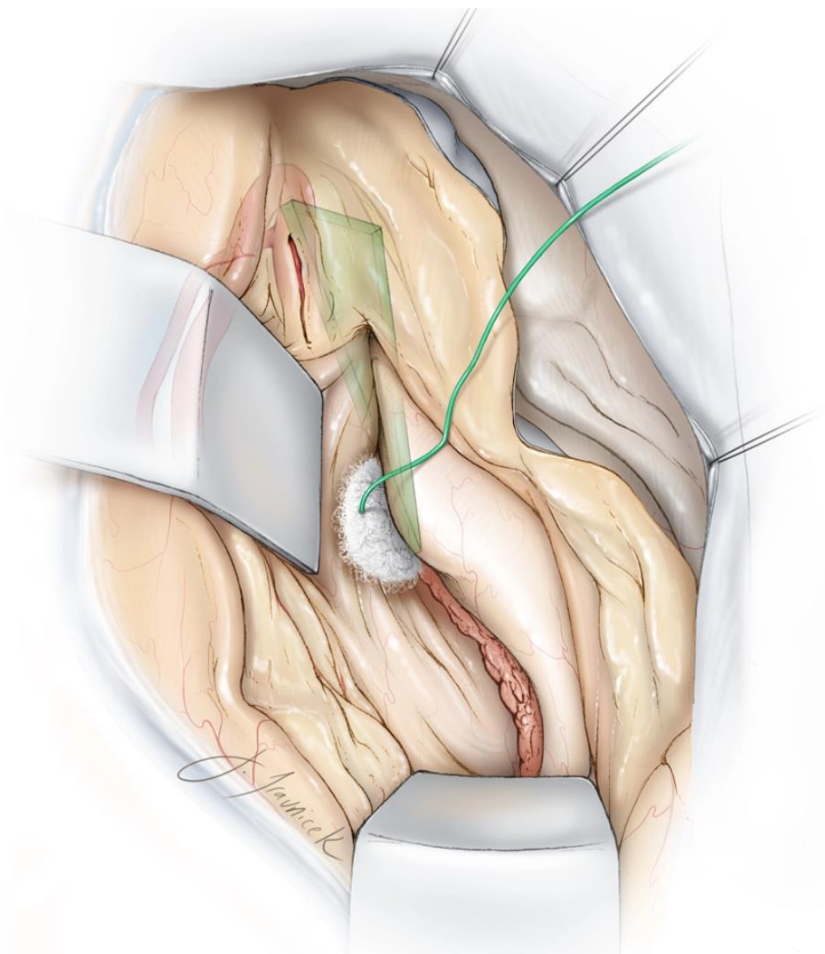


Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- compromise of the anterior choroidal artery can be avoided by minimizing bipolar cauterization and manipulation of the choroid plexus. Cottonoid patties cover the choroid plexus to avoid its direct manipulation which leads to bleeding.

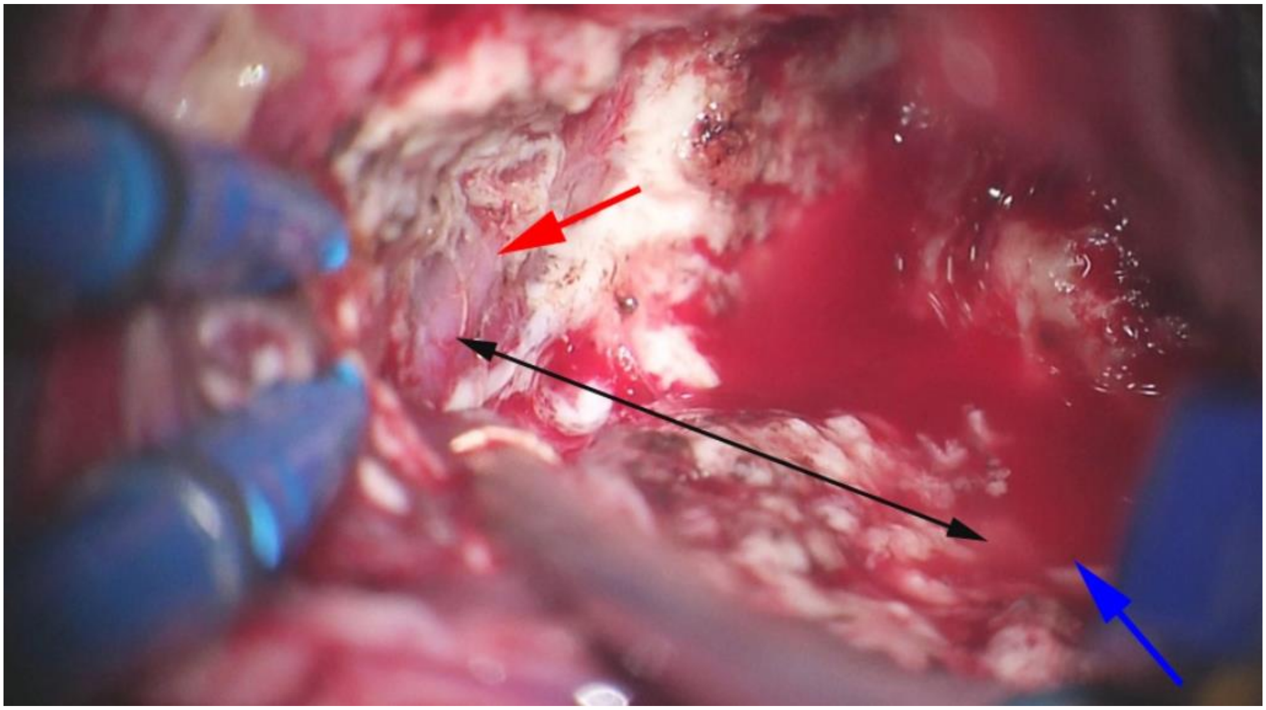
AMYGDALA RESECTION

- small portion of the medial middle temporal gyrus overlying MCA is subpially removed to expose the MCA bifurcation or the distal M1 segment that remains covered by its encasing Sylvian fissure arachnoid layers.
- line from the MCA to the inferior choroidal point (where anterior choroidal artery enters the temporal horn) defines the border (*green plane*) between amygdala and pallidum - it is important to maintain this dorsal dissection plane during amygdalectomy to avoid injuring globus pallidus.



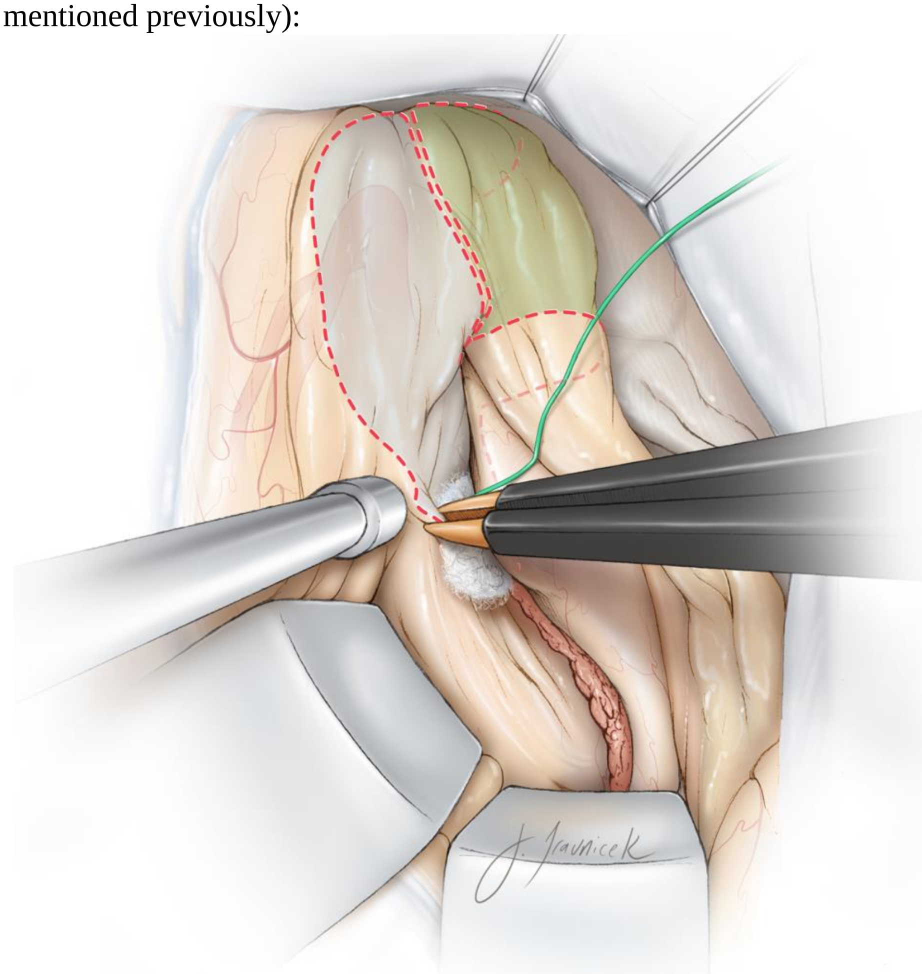
Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- intraoperative photo shows the M1 through it arachnoid band (*red arrow*) and the inferior choroidal point (*blue arrow*); *connecting black line* marks upper border of amygdala removal:



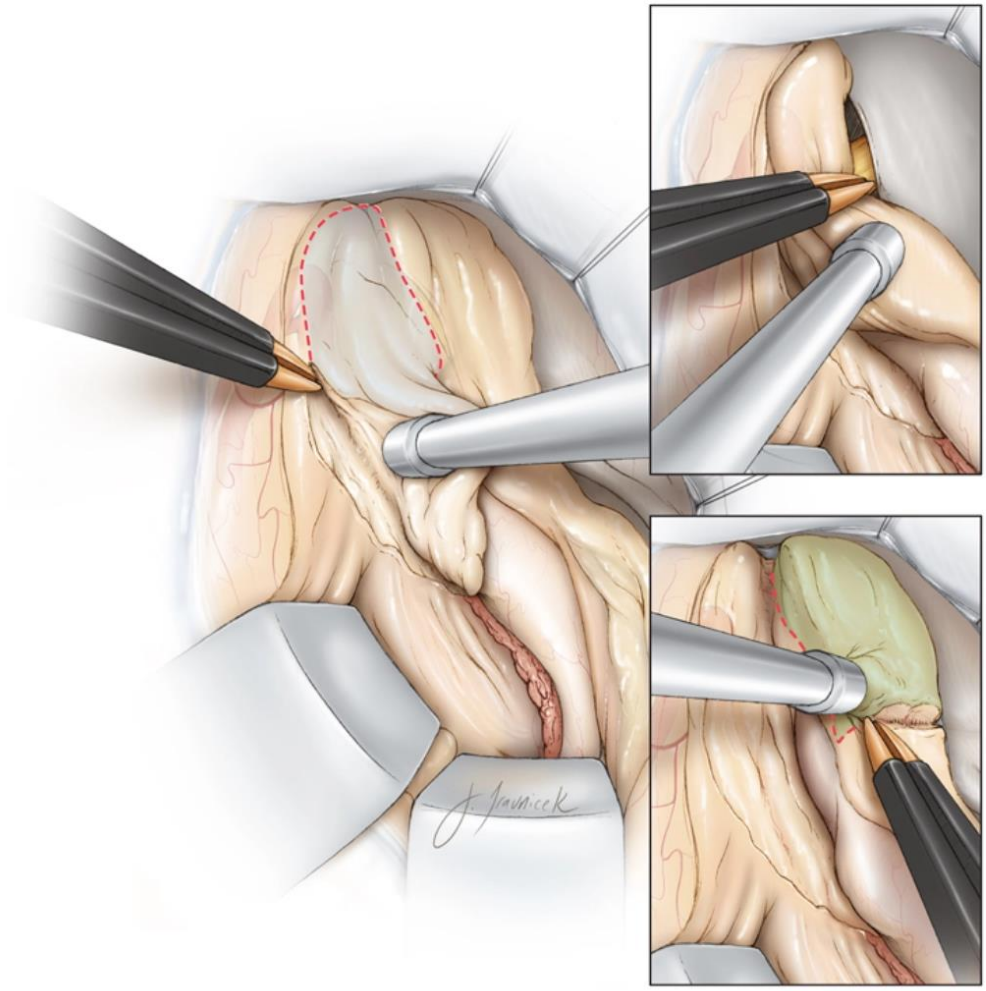
Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- inferior 2/3 of amygdala (*white*) and entire uncus (*green*) - resection of the mesial structures begins by subpial evacuation of these structures (amygdala removal is conducted utilizing the dorsal plane of dissection mentioned previously):



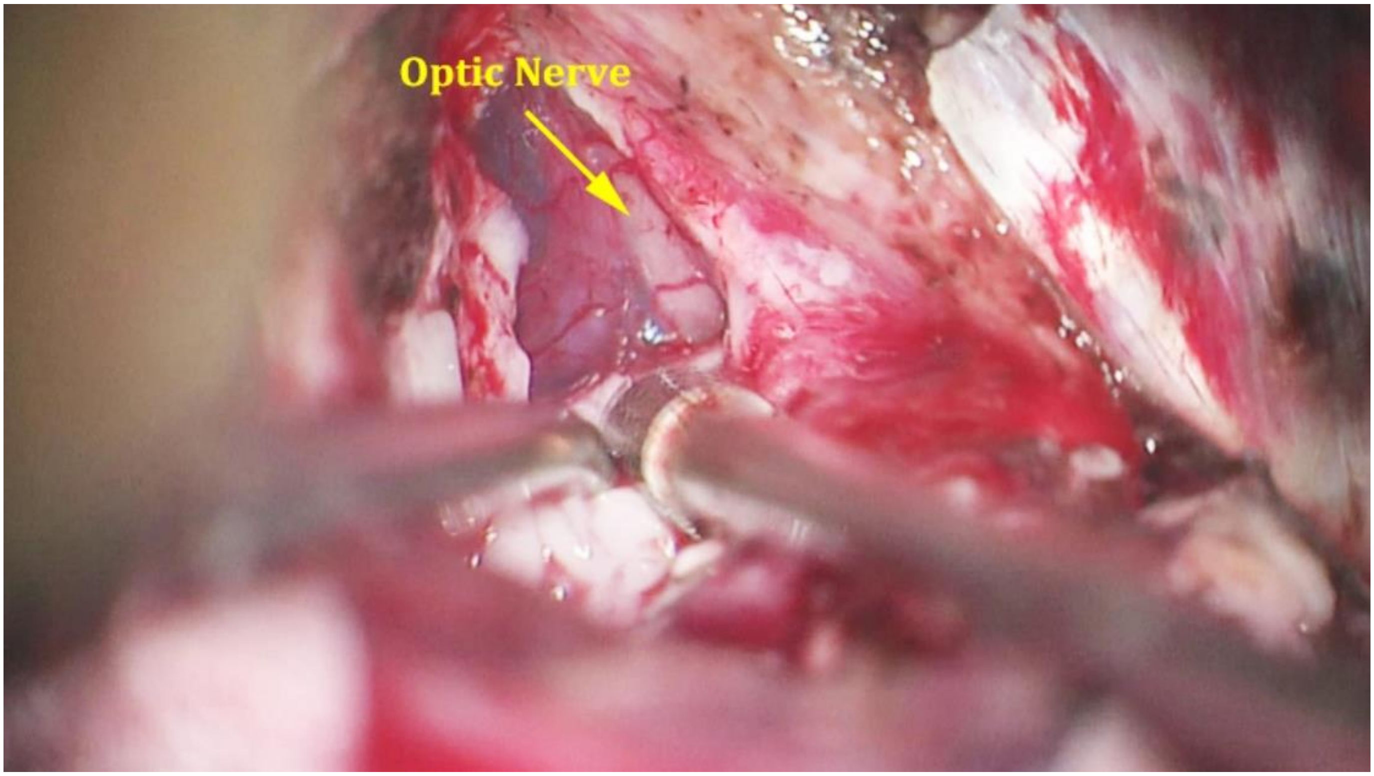
Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- en bloc amygdalectomy is feasible while maintaining the ventral plane of dissection limited to the arachnoid layers covering the basal cisterns; maintain the integrity of these arachnoid layers during the entire process of medial dissection to protect the underlying oculomotor nerve, PCA, and brainstem.
  — identification of the oculomotor nerve and the free edge of the tentorium through their corresponding arachnoid membranes confirms adequate medial removal of the uncus (*upper inset image*).
  — posterior limit of the dissection is where the uncus joins the head of the hippocampus (*lower inset image*).



Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

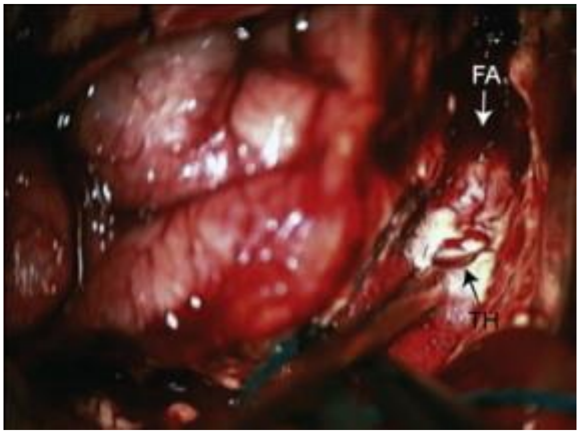
  — use a flat dissector to peel remaining thin layer of uncus off of overlying arachnoid of optic nerve (*intraoperative photo*):



Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

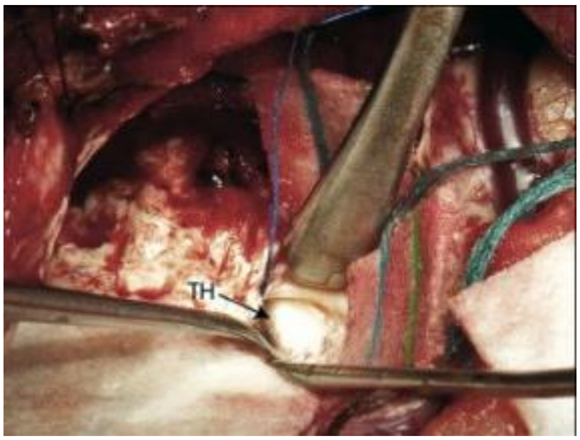
- at tip of temporal horn, subpial dissection is continued inferiorly and posteriorly to free ***amygdala***, which can be removed by severing its connections to temporal stem white matter.
- cortical incision is deepened, temporal horn (*TH*) is identified by following arachnoid of fusiform gyrus from 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).
- choroid plexus should remain attached to the thalamus.
- 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*):



Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

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



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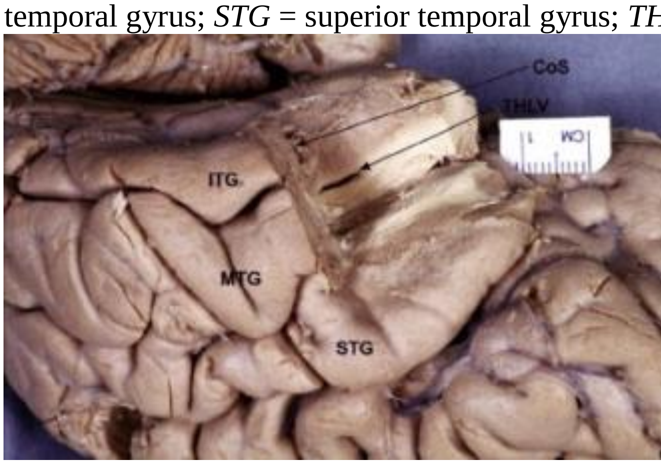
TH in anatomic specimen. *CoS* = collateral sulcus; *ITG* = inferior temporal gyrus; *MTG* = middle temporal gyrus; *STG* = superior temporal gyrus; *THLV* = temporal horn of lateral ventricle

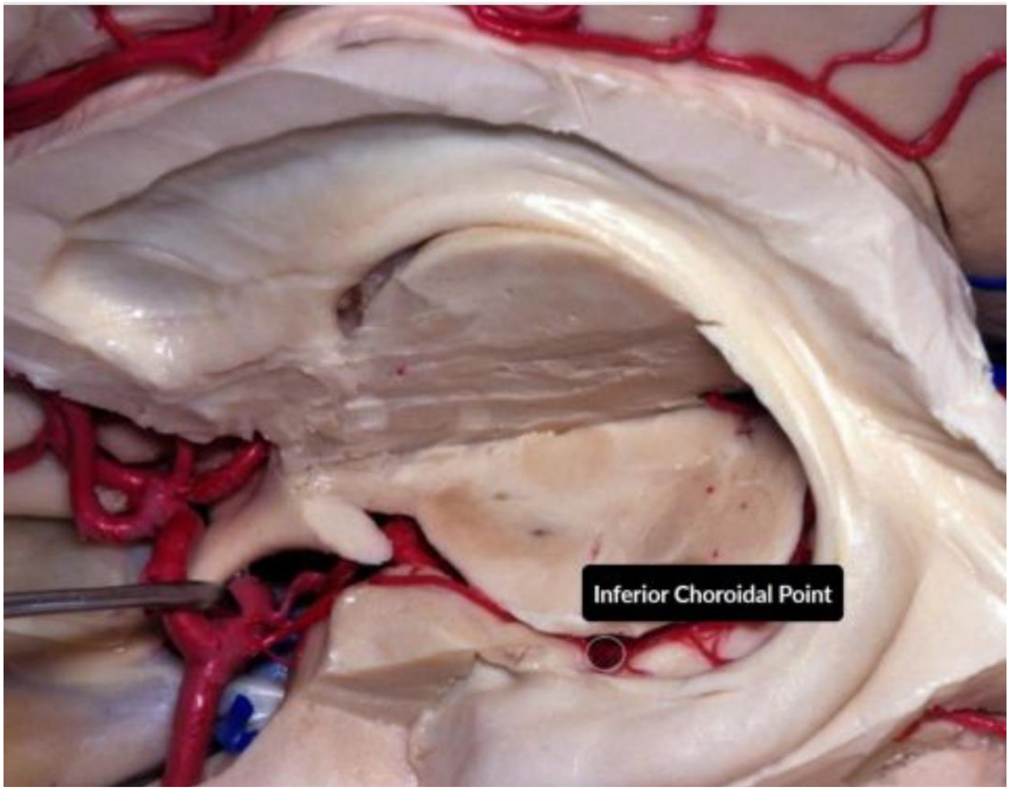


Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- 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.

*see p. A138 >>

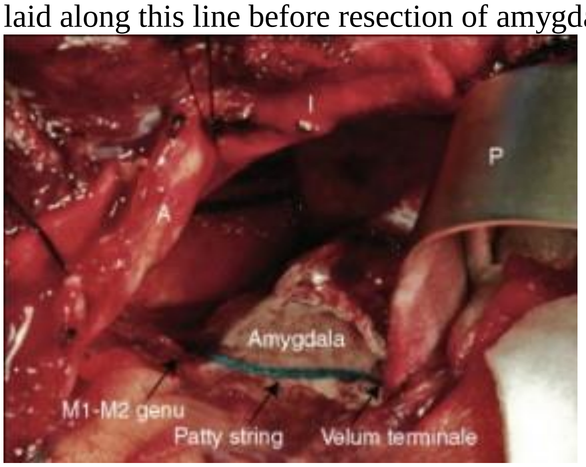
The inferior choroidal point communicates the ambient cistern with the temporal horn and is the point of entry of the anterior choroidal artery, which supplies the choroid plexus of the temporal horn, among other structures.



Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

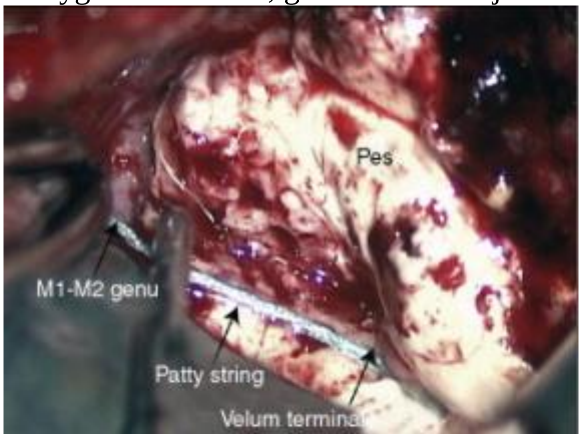
– **velum terminale (inferior choroidal point)** is union of taeniae of fimbria fornicis and stria terminalis at origin of choroid plexus; resecting inferior to this line prevents injuring basal ganglia and crus cerebri.

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



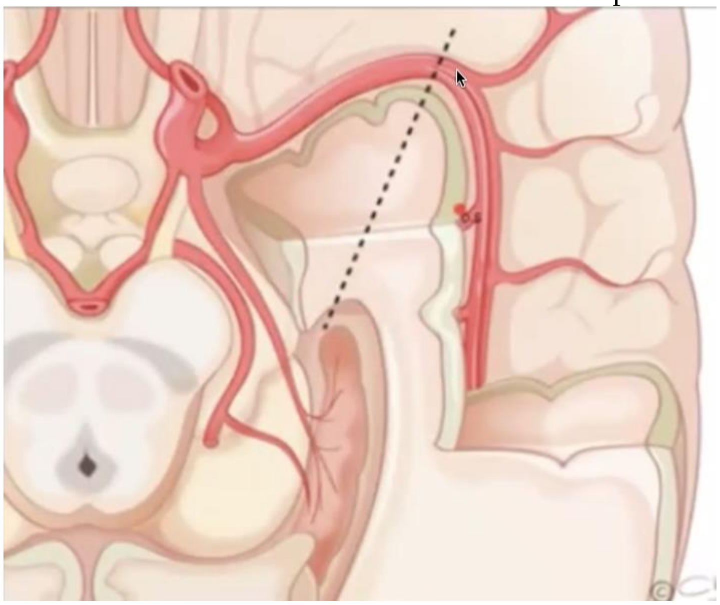
Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- after amygdala resection, genu at M1-M2 junction and velum terminale are more easily seen:

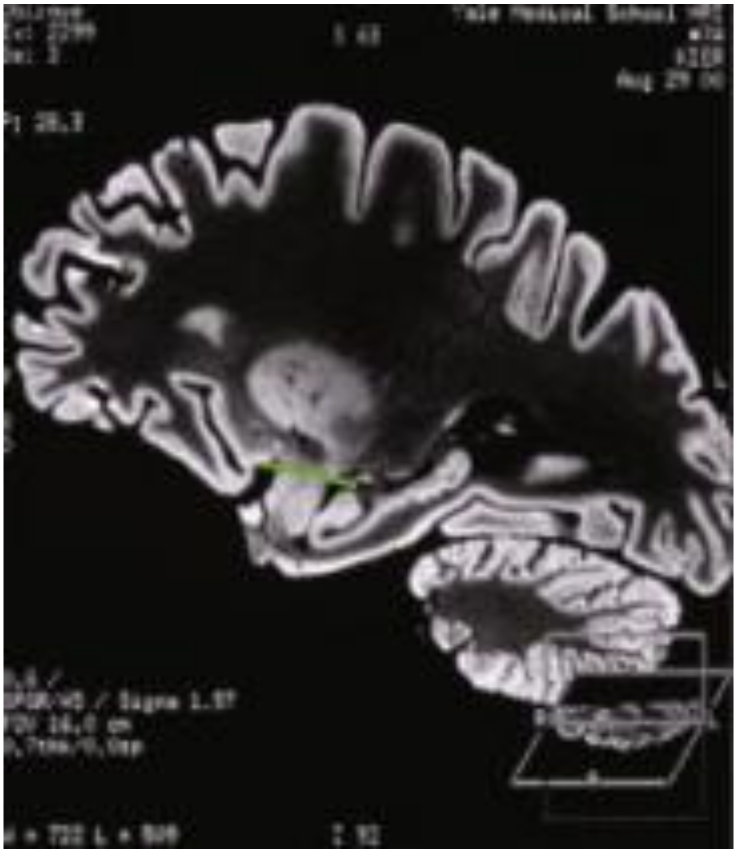


Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- resection anterior to line between choroidal point and MCA bifurcation



- this line on parasagittal MRI slice includes amygdala and hippocampus:



Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

An important concept is to understand that the whole amygdala is located within the boundaries of the uncus and that the uncus is related, at its anteromedial surface, to the internal carotid artery and the proximal half of the first segment of the middle cerebral artery (**13,16)**. Because there is no macroscopic limit between the amygdala and the globus pallidus pars interna, an artificial superior limit must be created. We believe that an imaginary line connecting the proximal middle cerebral artery and the inferior choroidal point constitute the best parameter to limit our resection, avoiding damage to the basal ganglia. The middle cerebral artery – choroidal line (MC-C line) pass in the superior aspect of the amygdala (**16)**. Under microscopic view and using microsuction, the resection is performed in the projection of the MC-C line, in a medial direction, until the pia of the mesial aspect of the temporal lobe is reached. At this point, the amygala sulcus is identified between the head of the hippocampus and inferior-lateral surface of the amygdala. The amygdala sulcus is resected along it axis, separating the amygala from the head of the hippocampus. This dissection is performed down until the mesial pia is identified. At the end of this maneuver, the amygala and the uncus will be completed disconnected from the hippocampus, parahippocampus gyrus and from the basal ganglia, only been attached to the mesial pia, which can be gently peeled off and separated from the neural tissue. It is very important to preserve the integrity of the pia, protecting the important neural and vascular structures located in the ambient cistern and also the brain. The amygadala and the uncus are finally removed to pathological analysis. It is important to mention that the amygdala removal is always incompleted, with a thin layer if tissue still connected to the basal aspect of the globus pallidus. Once we perform a complete removal of the amygala and uncus, we are able to visualize, though the pia and arachnoid membranes, the internal carotid artery and the proximal segment of the middle cerebral artery, indicating the complete removal of the anteromedial surface of the uncus; the visualization of the oculomotor nerve indicates that the inferior portion of the vertex has been removed; the removal of the inferior portion of the postero-medial surface of the uncus presents the P2A segment of the posterior cerebral artery.

RESECTION OF HIPPOCAMPUS

Hippocampus anatomy

See p. A138 >>

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

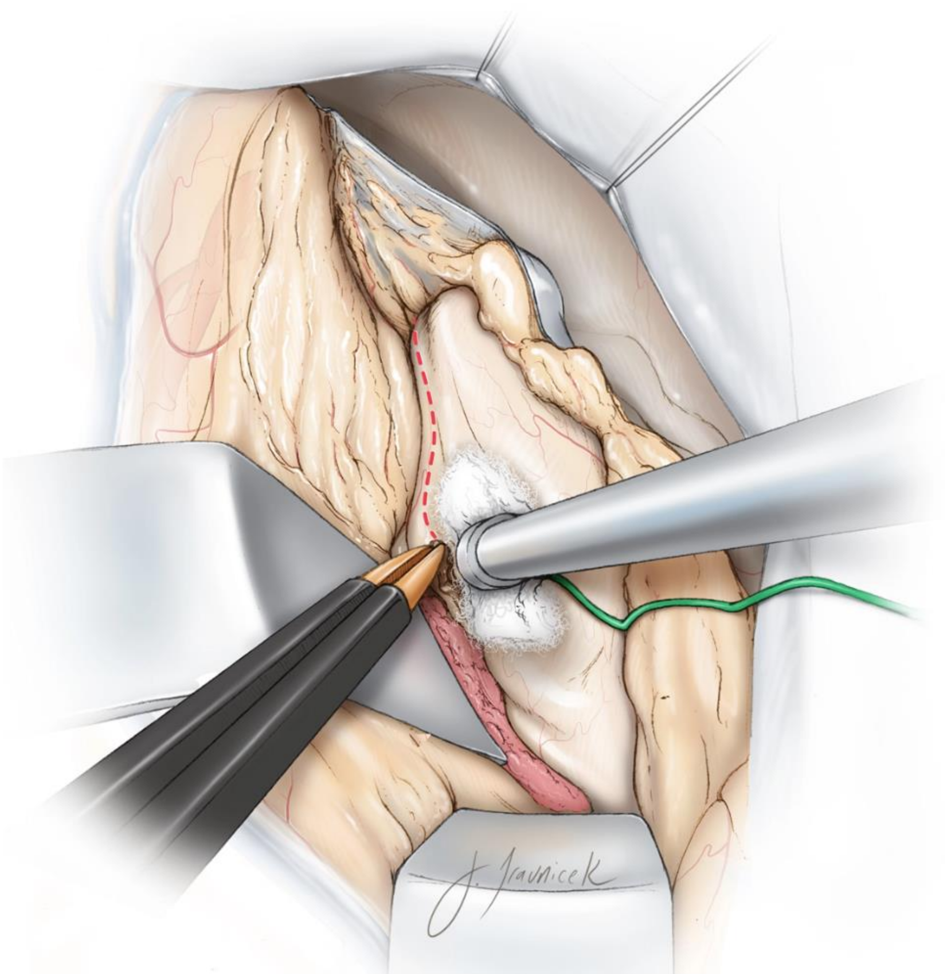
Class I evidence: removing more hippocampus does not adversely affect memory but improves seizure outcomes!

Randomized controlled surgical trial in 207 patients with TLE (Schramm et al. 2011): 2.5 cm vs. 3.5 cm resections of the hippocampus and parahippocampus - no differences in outcome with respect to complete seizure control (Engel class I).

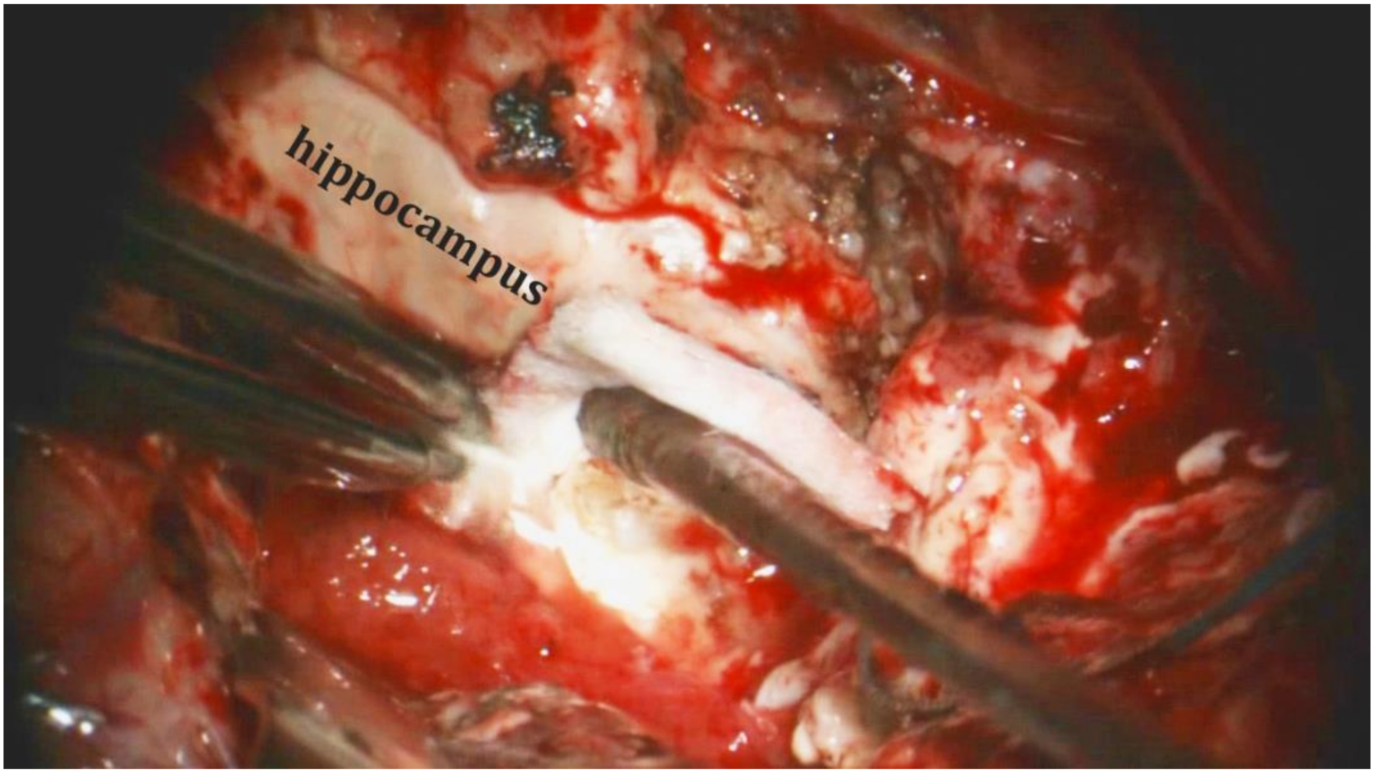
Postmortem-based neuropathology studies (Thom et al. 2012) - variation in the extent and pattern of neuronal loss along the longitudinal axis, raising the possibility that poor outcome may also relate to residual hippocampal sclerosis in the hippocampal remnant.

- use Greenberg 3/8 retractor blades.
- use microscope.

- after removal of the amygdala and uncus, the dissection through the medial hippocampus proceeds posteriorly through the uncinate fasciculus and the intralimbic lobe of the parahippocampus toward the hippocampus proper.
- disconnection of the medial part of the hippocampus remains lateral to the choroid plexus to avoid inadvertent injury to the anterior choroidal artery (a cause of hemiplegia from ATL operations).
- hippocampus is covered by a small cotton patty during its manipulation by the suction device:

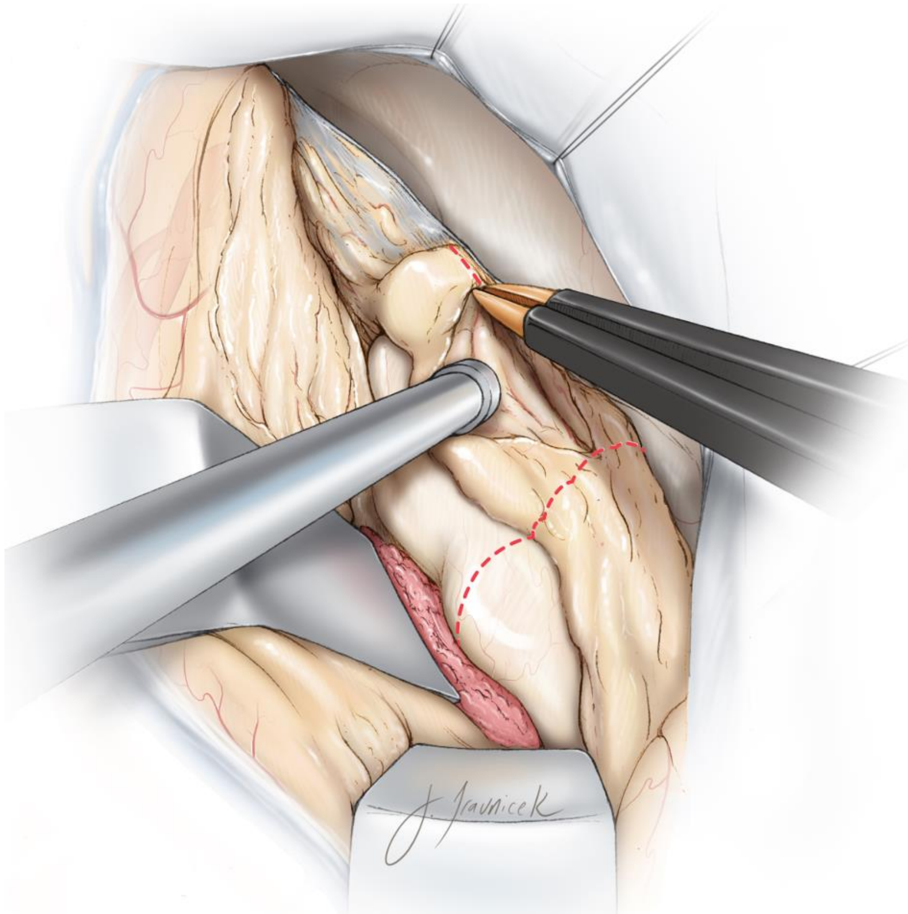


Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>



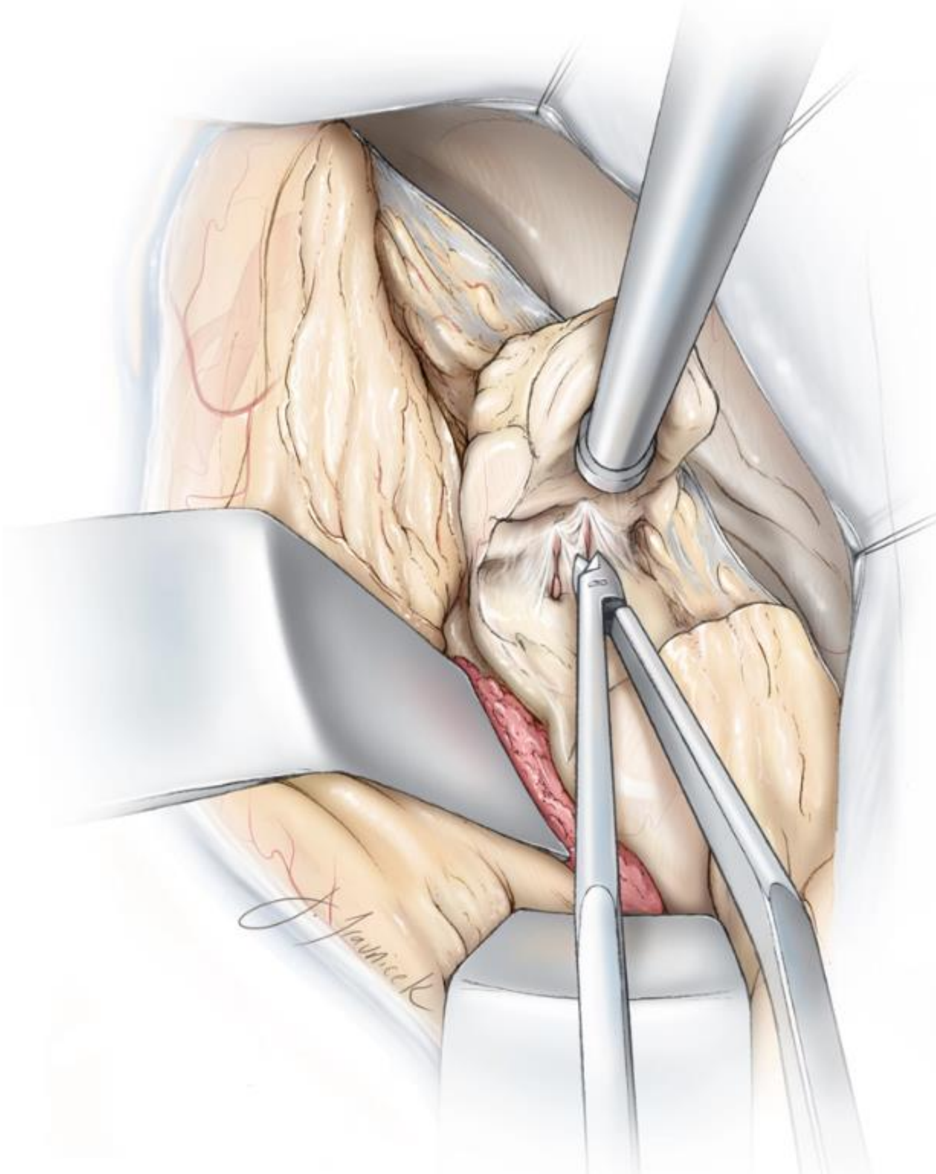
Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- arachnoid bands underneath parahippocampal gyrus are sectioned.
- **pes hippocampus (pes)** is then separated from the body of the hippocampus near the inferior choroidal point - this maneuver allows subpial elevation and anterior mobilization of the pes and parahippocampal gyrus as one unit:



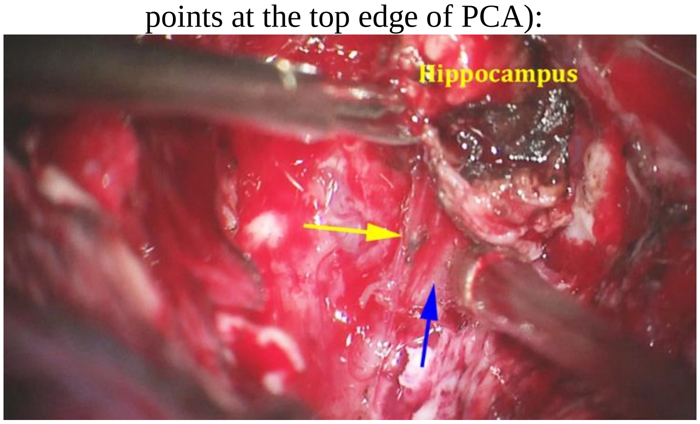
Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

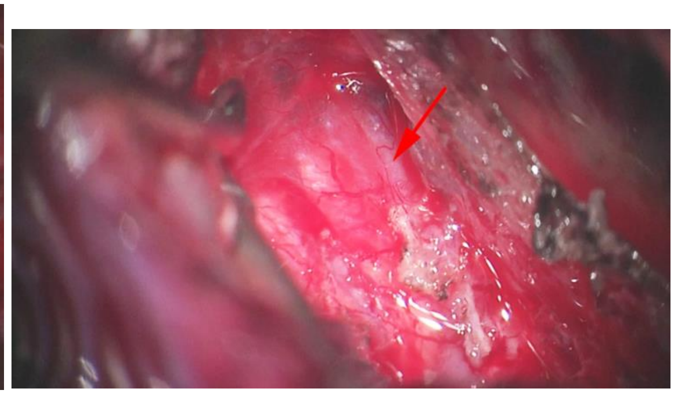
- after extraction of the pes, the posterior parahippocampal gyrus is mobilized away from the collateral sulcus until the posterior portion/tail of the hippocampus is seen to curve medially toward the calcar avis.
  - arteriolar branches of the posterior cerebral artery to the hippocampal body will be encountered during dissection of the collateral sulcus and anterior mobilization of the hippocampal body/tail. These small arteries are cauterized once they are well within the sulcus and severed sharply to avoid avulsion injury to the parent vessel and other vessels coursing near this space.
  - combined block of posterior parahippocampal gyrus and hippocampus are elevated and removed. Dissection over the hippocampal fissure and arachnoid bands over the brainstem and thalamus allows mobilization of the medial parahippocampal gyrus, hippocampus, and fimbria:



Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

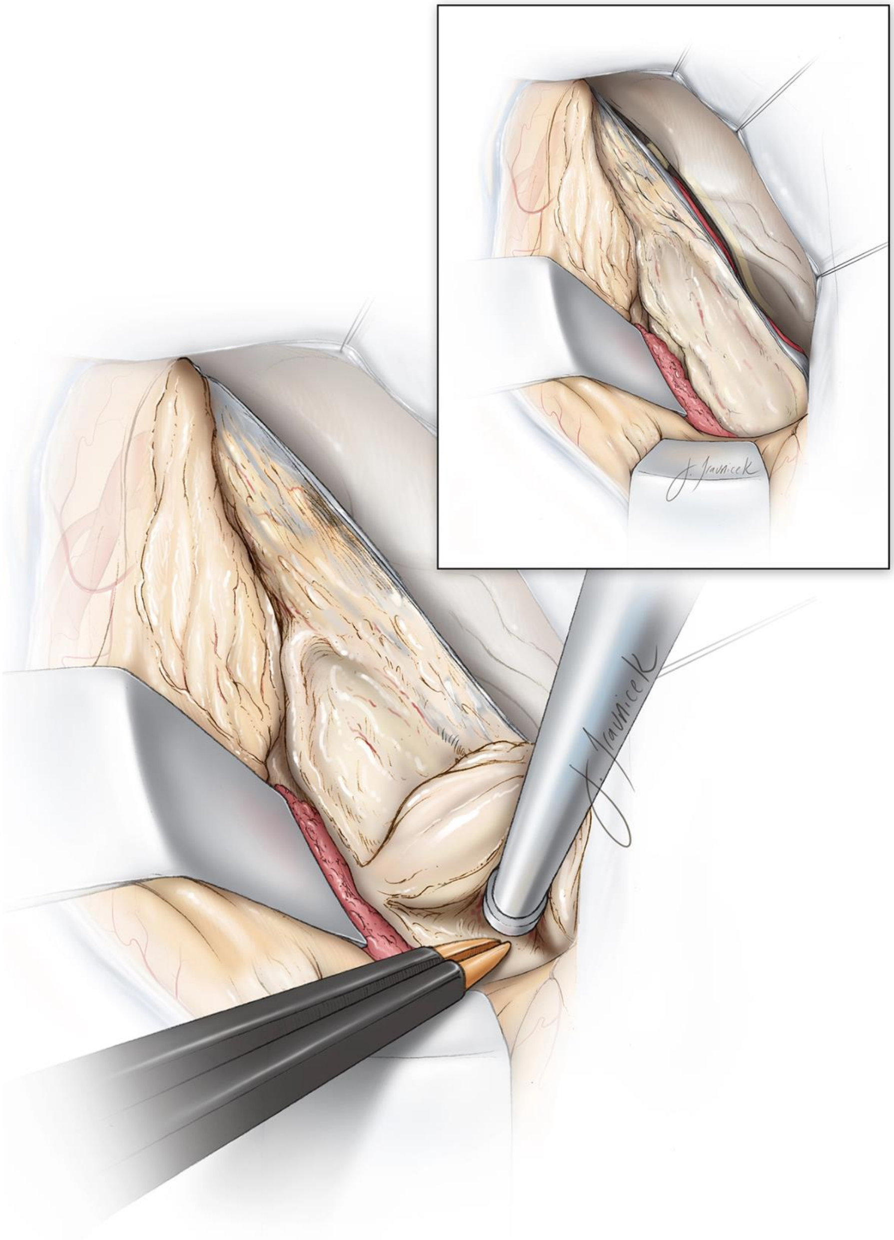
— left photo demonstrates PCA (*blue arrow*) and perforating arterioles to the posterior hippocampus (*yellow arrow*). Care must be taken to *maintain arachnoid layers over brainstem and perforating vessels to avoid postoperative neurologic deficit* (*bottom photo* - red arrow points at the top edge of PCA):





Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- remaining tail of the hippocampus before it turns medially within the ventricle is subpially evacuated via the use of the hand-held suction device or by transecting the hippocampus across its tail.
    - use the hand-held suction device to dynamically mobilize the posterior neocortex laterally and create access to the posterior portions of the hippocampus.
    - thin layer of adherent brain tissue may be left on the arachnoid layers covering the basal cisterns to minimize their risk of tear.
    - *aggressive coagulation along the edge of the tentorium* is avoided to minimize the risk of injuring trochlear nerve.



Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

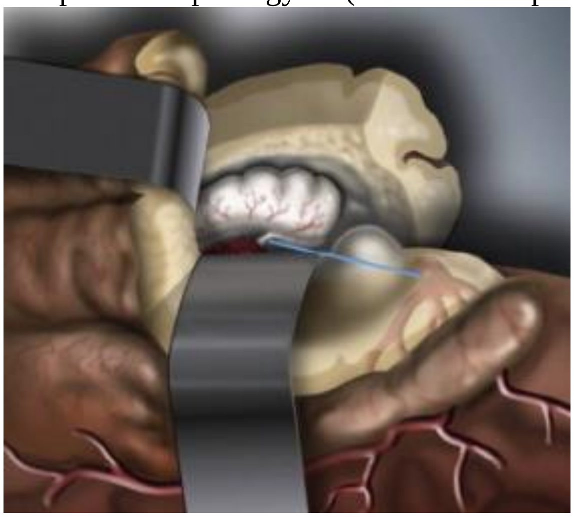
- hippocampectomy to the level of the quadrigeminal plate is advised.
- PCA can remain safe during hippocampus mobilization by carefully cauterizing and transecting the perforating vessels entering hippocampal sulcus once they are well within the fissure.

N.B. retained mesial structures is the most common cause of recurrent seizures.

N.B. transient neuropathies (CN3-4) can be avoided by meticulous protection of arachnoid planes and by avoiding bipolar cauterization near tentorial edge.

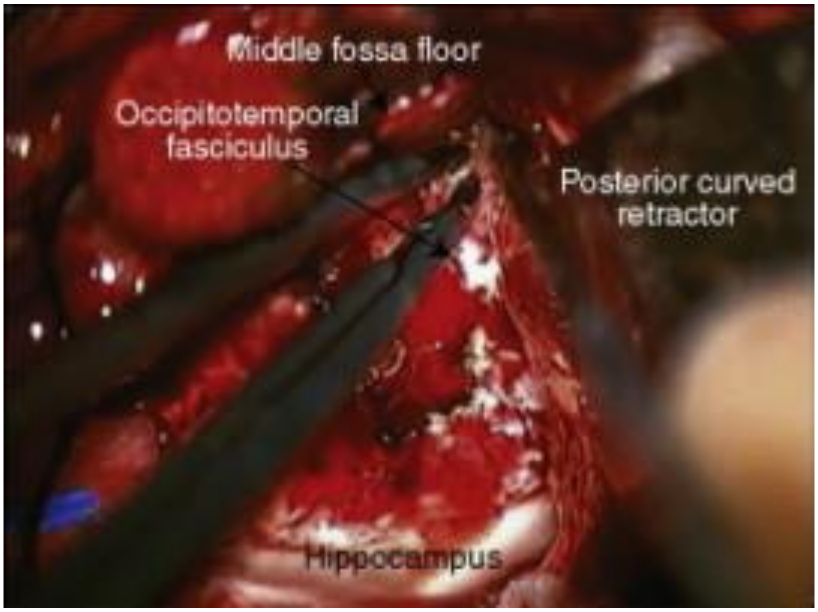
The most important anatomical landmark in the mesial structures resections is the choroidal fissure (**7,15**), which can be easily identified by following the choroidal plexus in the temporal lobe. All structures located laterally to the choroidal fissure can be removed, and all structures located medially to it should be preserved. The presence of the choroidal fissure marks the beginning of the body and more posteriorly the tail of the hippocampus, as the head of the hippocampus is located anteriorly to the inferior choroidal point (**8,9,16**). The resection of the mesial portion of the temporal lobe can be divided, didactically, in three steps: 1. anterior disconnection of the hippocampus and resection of the amygdala. 2. mesial disconnection with opening of the choroidal fissure and disruption blood supply to the hippocampus. 3. posterior disconnection of the hippocampus with resection of the fornix and the posterior aspect of the parahippocampus gyrus.

- 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):



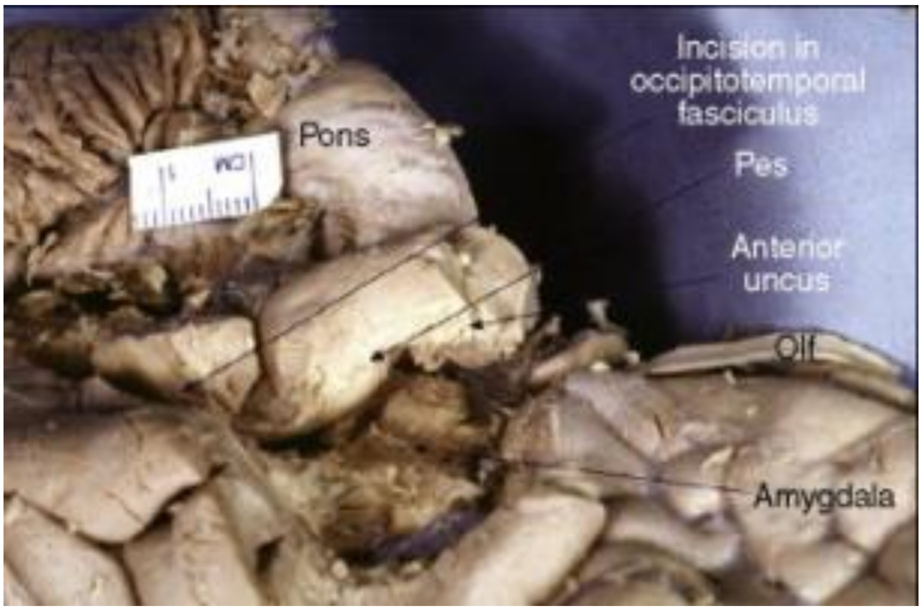
Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- 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).
  N.B. never retract above choroid plexus!
  "Choroid plexus is your friend – guides anatomy!"
- 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:



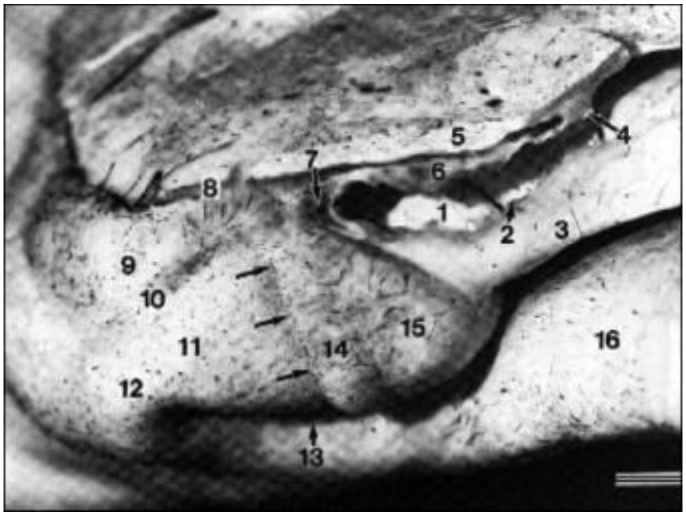
Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- cadaveric dissection:



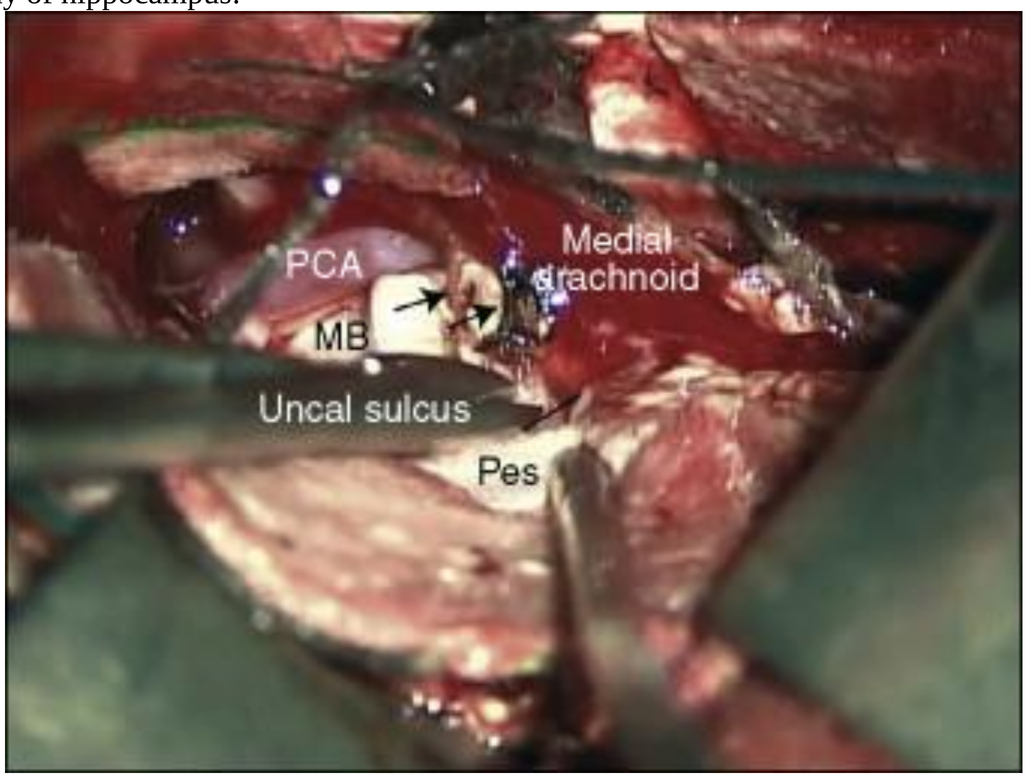
Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- hippocampus is lifted from pia using Penfield 4 (while patty in other hand 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:



Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- 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:



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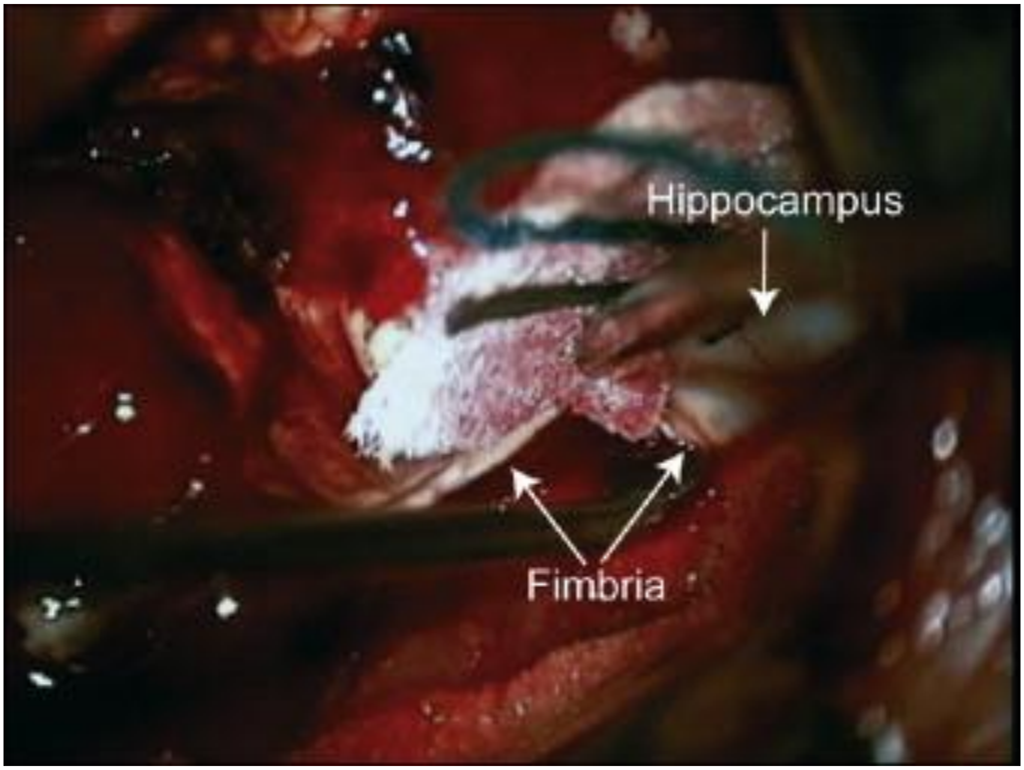
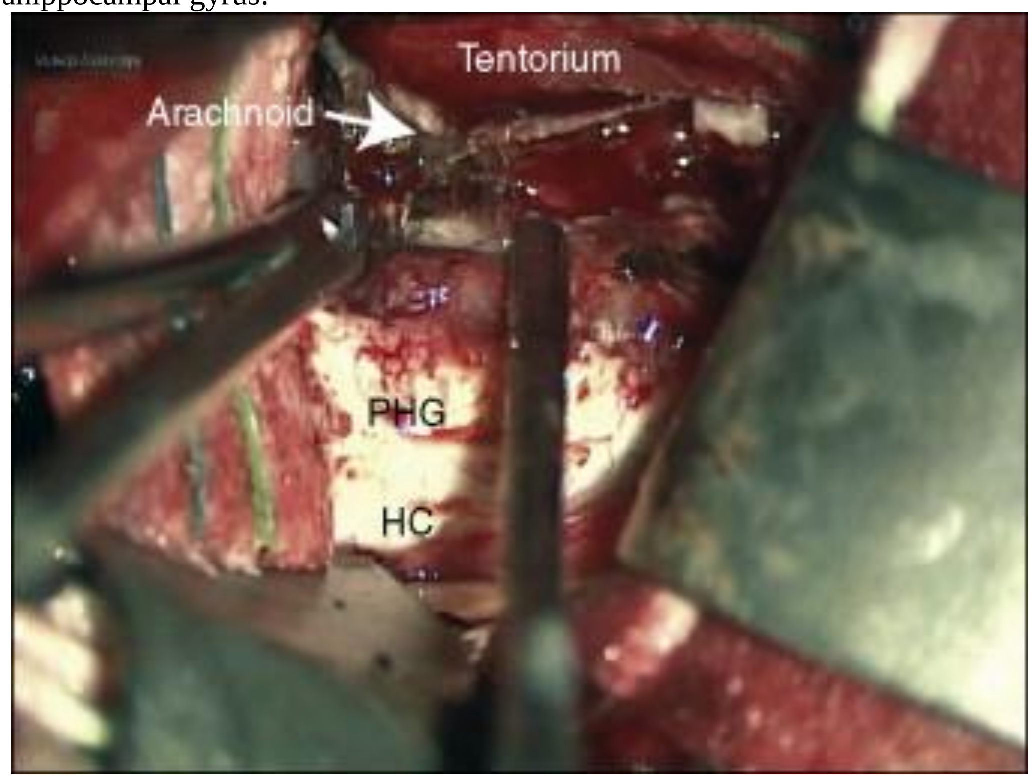
N.B. bipolar and cut hippocampal vessels only after being certain they are not choroidal fissure vessels, distal in the hippocampal arcade!

- 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:



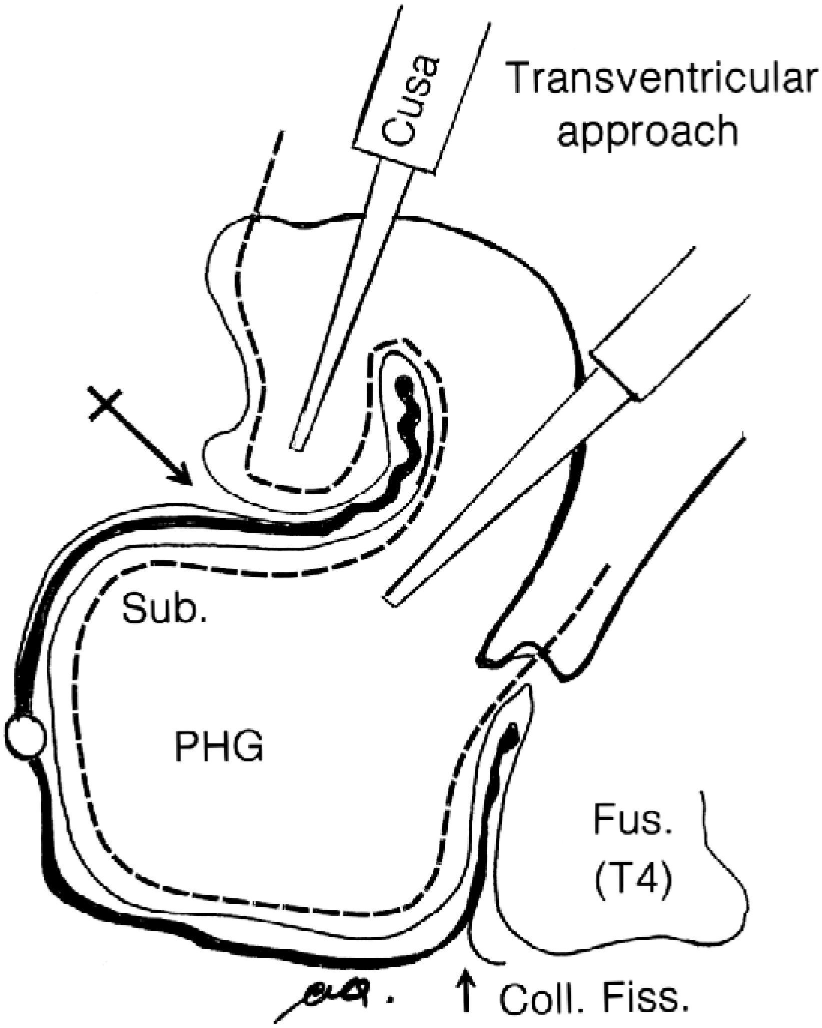
Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- 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:



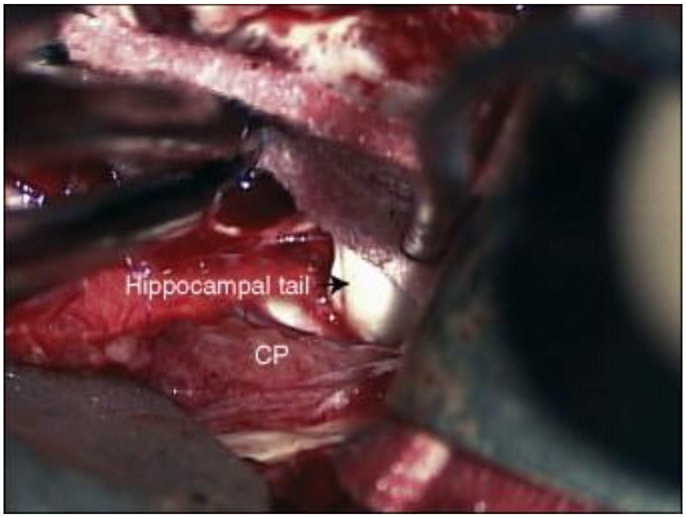
Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

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):



- 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 (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).



Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

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.

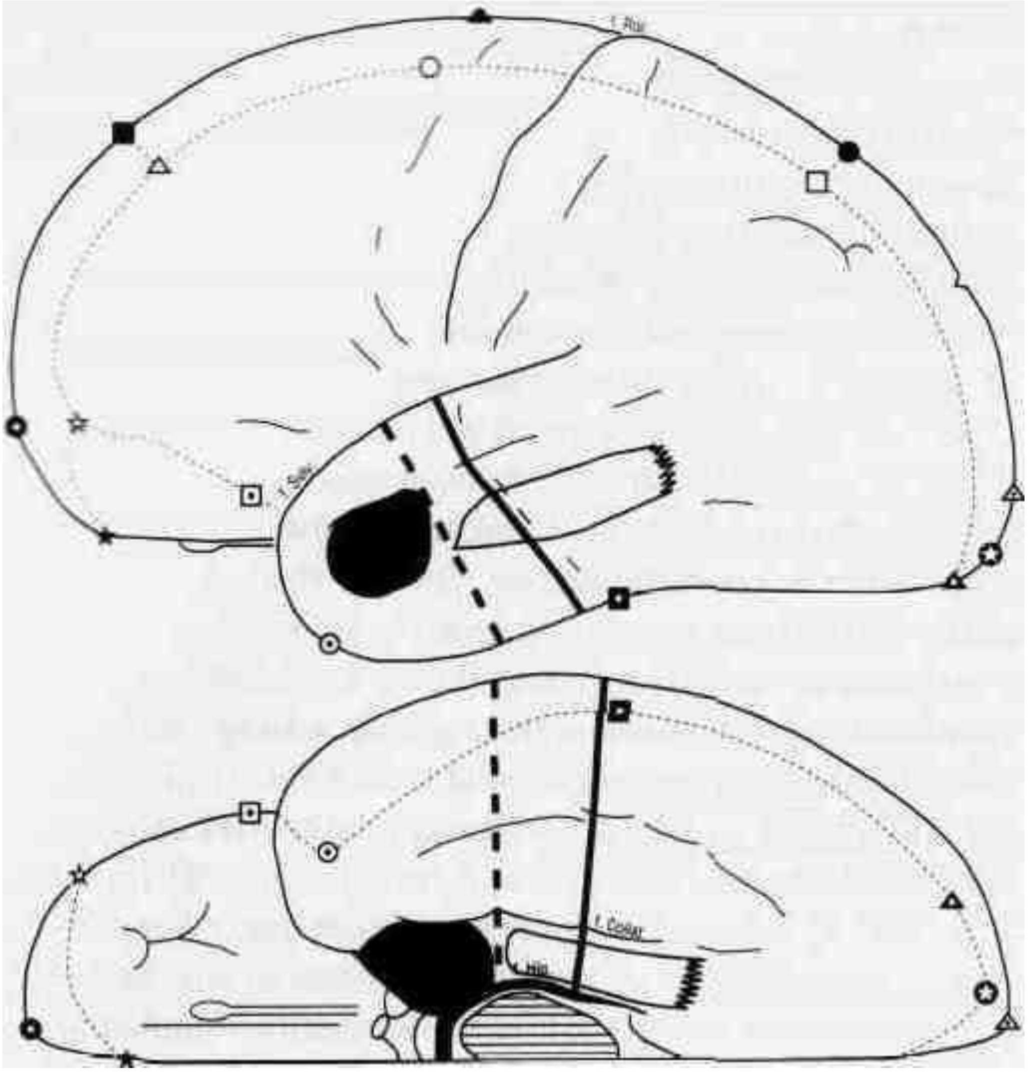
- with hippocampus removed, pial bank overlying tentorial incisura and cerebral peduncle should be intact; below this barrier should be cerebral peduncle, PCA, PComA, and CN3.
- pial bleeding is controlled carefully by bipolar cautery at low setting.
- demonstrable herniation of uncus mesially in incisura 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



Source of picture: Marshall B. Allen, Ross H. Miller "Essentials of Neurosurgery: a guide to clinical practice", 1995; McGraw-Hill, Inc.; ISBN-13: 978-0070011168 >>

<u>Cleveland course</u>

The mesial disconnection of the hippocampal formation is a critical point during the removal of the hippocampus. The most important landmark at this point is the choroidal fissure and the fimbria; The choroidal fissure can be easily identified by following the choroid plexus in the temporal horn of the lateral ventricle (**7,15)**. The choroidal fissure demarcates the beginning of the body portion of the hippocampus, as the head of the hippocampus is located anteriorly to the inferior choroidal point, which is the region where the anterior choroidal artery gains the ventricle and the choroidal plexus starts. With gently lateral retraction of the hippocampus, leaving the choroidal plexus medially, the taenia fimbriae (a layer of ependymal covering that attaches the choroid plexus with the fimbria of the hippocampus) is clearly exposed. In order retract the hippocampus laterally to expose better the choroidal fissure and its structures, the remaining parahippocampus gyrus is aspirated until its pia is completely exposed. This maneuver will create room for the lateral retraction of the hippocampal.

The taenia fimbriae penetrates into the hippocampal formation, continuing its trajectory into the hippocampus sulcus (or fimbrio-dentate sulcus) between the fimbria and the dentate gyrus of the hippocampal formation. It is in this thin layer of ependyma that the vessels responsible for the hyppocampal blood supply are located. The hippocampal formation is supplied by the hippocampal arteries, which can originate from the anterior choroidal artery, the main trunk of the posterior cerebral artery (Uchimura artery), and the inferior temporal, lateral posterior choroidal, and splenial branches of the posterior cerebral artery (**2,3,6)**. The basal vein of Rosenthal is the main venous structure that drains the mesial temporal region (**11)**. The inferior ventricular vein is responsible for the entire drainage of the veins located in the temporal horn. It exits the temporal horn trough the inferior choroidal point to drain into the second or perpendicular segment of the basal vein of Rosenthal, located in the ambient cistern.

The section of the taenia fimbriae together with the veins and arteries responsible for the hippocampus blood supply is performed as far as possible from the vascular and neural structures located in the ambient cistern. In fact, we believe that the opening of the choroidal fissure in order to perform the mesial disconnection brings additional unnecessary risks for the patient. In that way, we perform the opening of the hippocampal sulcus by coagulating and aspirating the fimbria of the hippocampus, exposing widely the taenia fimbriae, the hippocampal arteries, veins and the dentate gyrus located underneath the ependyma. This maneuver is performed extensively from the inferior choroidal point, where the hippocampal sulcus starts, to the end of the hippocampus. An important landmark that indicates the end of the tail of the hippocampus is where the tail of the hippocampus meets the calcar avis (the inferior prominence on the medial wall of the atrium of the lateral ventricle).

The veins and artery are separeted along the hippocampal sulcus, far from the choroidal fissure, from the choroidal point to the end of the tail of the hippocampus, and dissected with a microscissor, completing the mesial disconnection.

Posterior disconnection: This is the last stage of the hippocampal formation and parahippocampal removal. At this point, the only structure that connects the hyppocampal formation to the rest of the nervous system is the fornix. The microscope is redirected into a more posterior and mesial direction. In a gentle maneuver, the posterior aspect of the remaining temporal lobe and the lateral wall of the temporal horn of the lateral ventricle is retracted posteriorly exposing the calcar alvis at the median wall of the atrium of the lateral ventricle and the parahyppocampus gyrus at its junction with the cingulate gyrus. The remaining posterior aspect of the parahippocampus gyrus is coagulated and aspirated exposing the mesial pia. At the end of the tail of the hippocampus, the fornix is aspirated. At this point the complete disconnection is finished and the hippocampal formation can be removed safely from the skull cavity.

SELECTIVE AMYGDALO-HIPPOCAMPECTOMY (SAH)

Suggested reading:

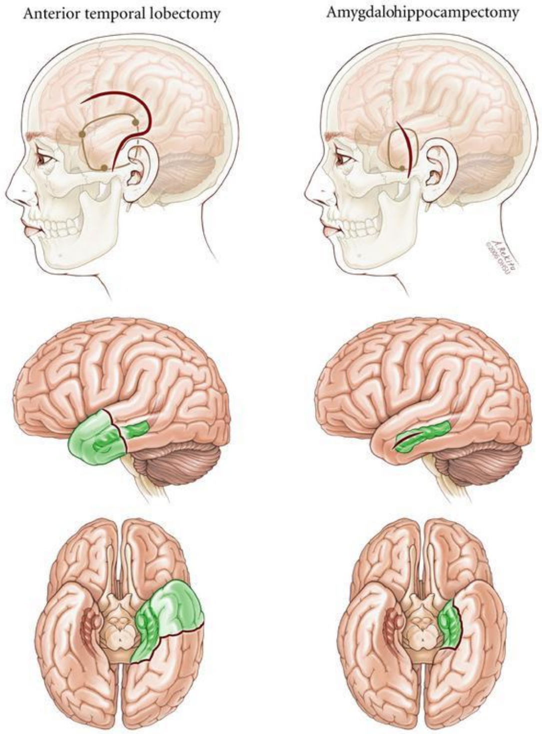
M.G. Yasargil, P.J. Teddy, P. Roth, L. Symon, et al. (Eds.), **Selective** amygdalo-hippocampectomy: operative anatomy and surgical technique, Advances and technical standards in neurosurgery, vol. 12, Springler-Wien, New York (1985)

T. Hori, S. Tabuchi, M. Kurosaki, S. Kondo, A. Takenobu, T. Watanabe. **Subtemporal** amygdalohippocampectomy for treating medically intractable temporal lobe epilepsy. Neurosurgery, 33 (1993), pp. 50-56

M.R. Schoenberg, W.E. Clifton, R.W. Sever, F.L. Vale. Neuropsychology outcomes following trephine epilepsy surgery: the **inferior temporal gyrus approach** for amygdalohippocampectomy in medically refractory mesial temporal lobe epilepsy. Neurosurgery (2017) [PMID: 28595352]

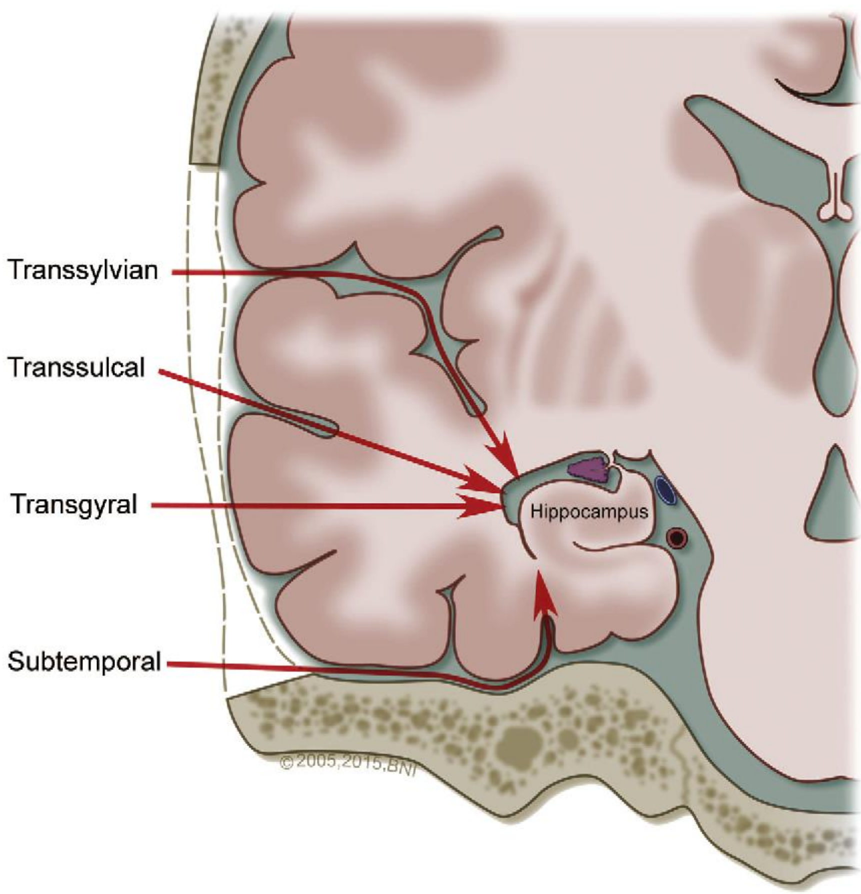
S.W. Hill, S.D. Gale, C. Pearson, K. Smith. Neuropsychological outcome following minimal access **subtemporal** selective amygdalohippocampectomy. Seizure, 21 (2012), pp. 353-360

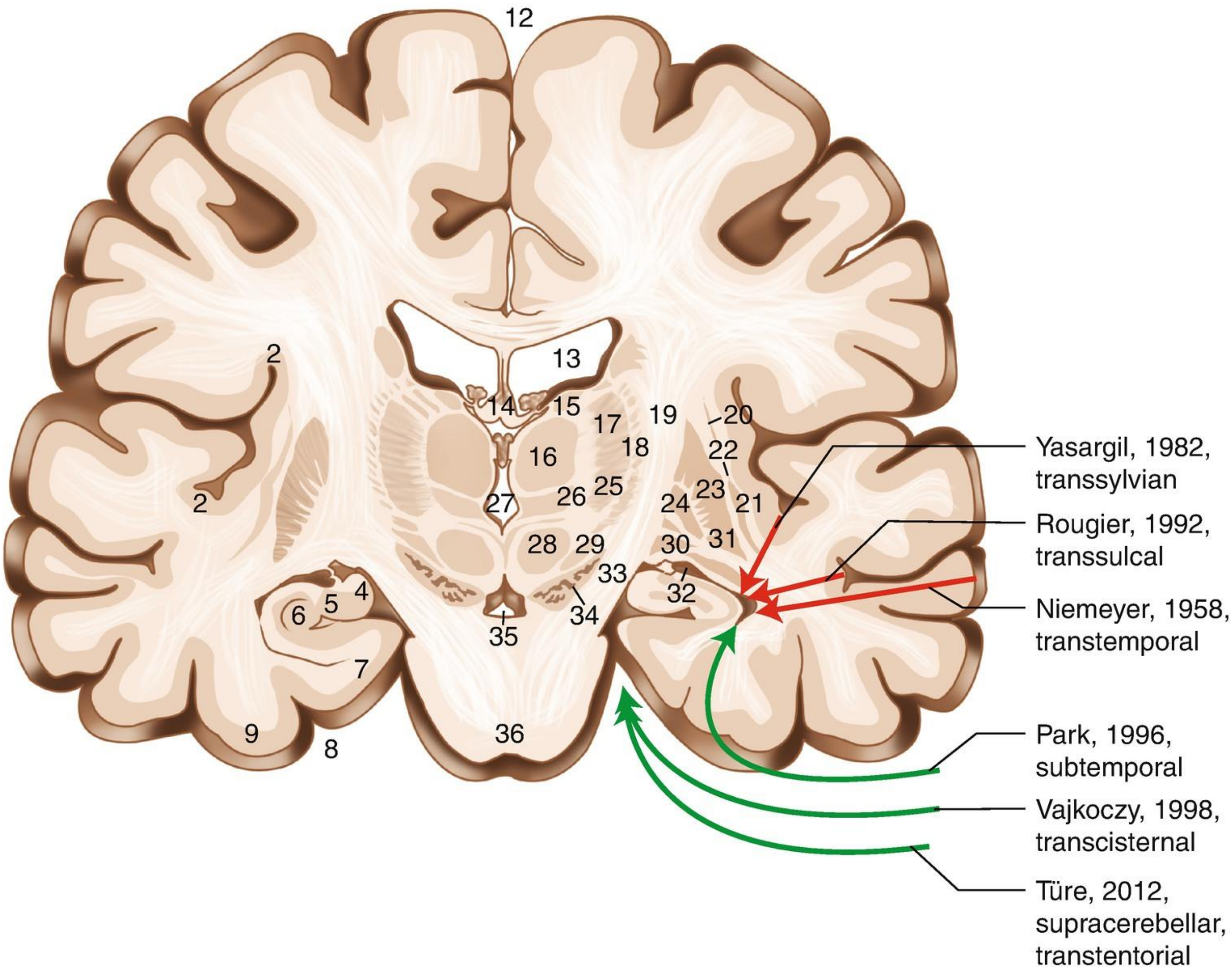
Morino M, Uda T, Naito K, Yoshimura M, Ishibashi K, Goto T: Comparison of **neuropsychological outcomes** after selective amygdalohippocampectomy versus anterior temporal lobectomy. Epilepsy Behav9:95–1002000



- amygdala lies in the roof of anterior temporal horn of lateral ventricle.

APPROACHES

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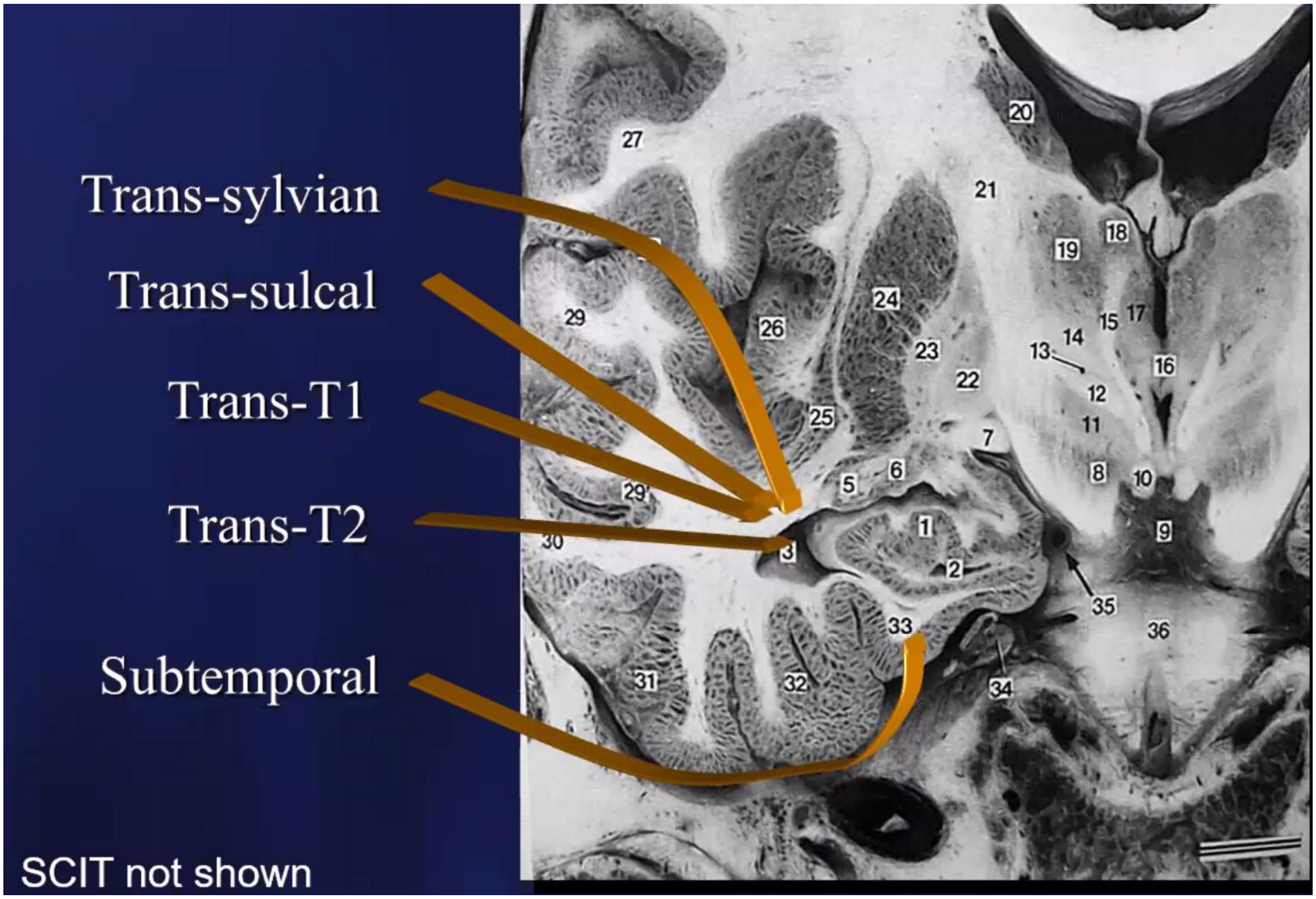
Yasargil, 1982, transsylvian
Rougier, 1992, transsulcal
Niemeyer, 1958, transtemporal
Park, 1996, subtemporal
Vajkoczy, 1998, transcisternal
Türe, 2012, supracerebellar, transtentorial



A. **Transcortical-Transventricular** approach - most direct and simplest approach. >>

B. **Subtemporal** approach - through paraphippocampal gyrus (entails significant retraction) >>
Hori T Yamane F Ochiai T. et al Selective subtemporal amygdalohippocampectomy for refractory temporal lobe epilepsy: operative and neuropsychological outcomes. J Neurosurg. 2007;106(1):134–141.

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-transtentorial paramedian** approach (Türe 2012) >>

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 (SRS)
C. Stereotactic radiofrequency ablation (RF)
D. MR-guided focused ultrasound (FUS) ablation

CRITERIA / ALGORITHM

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)

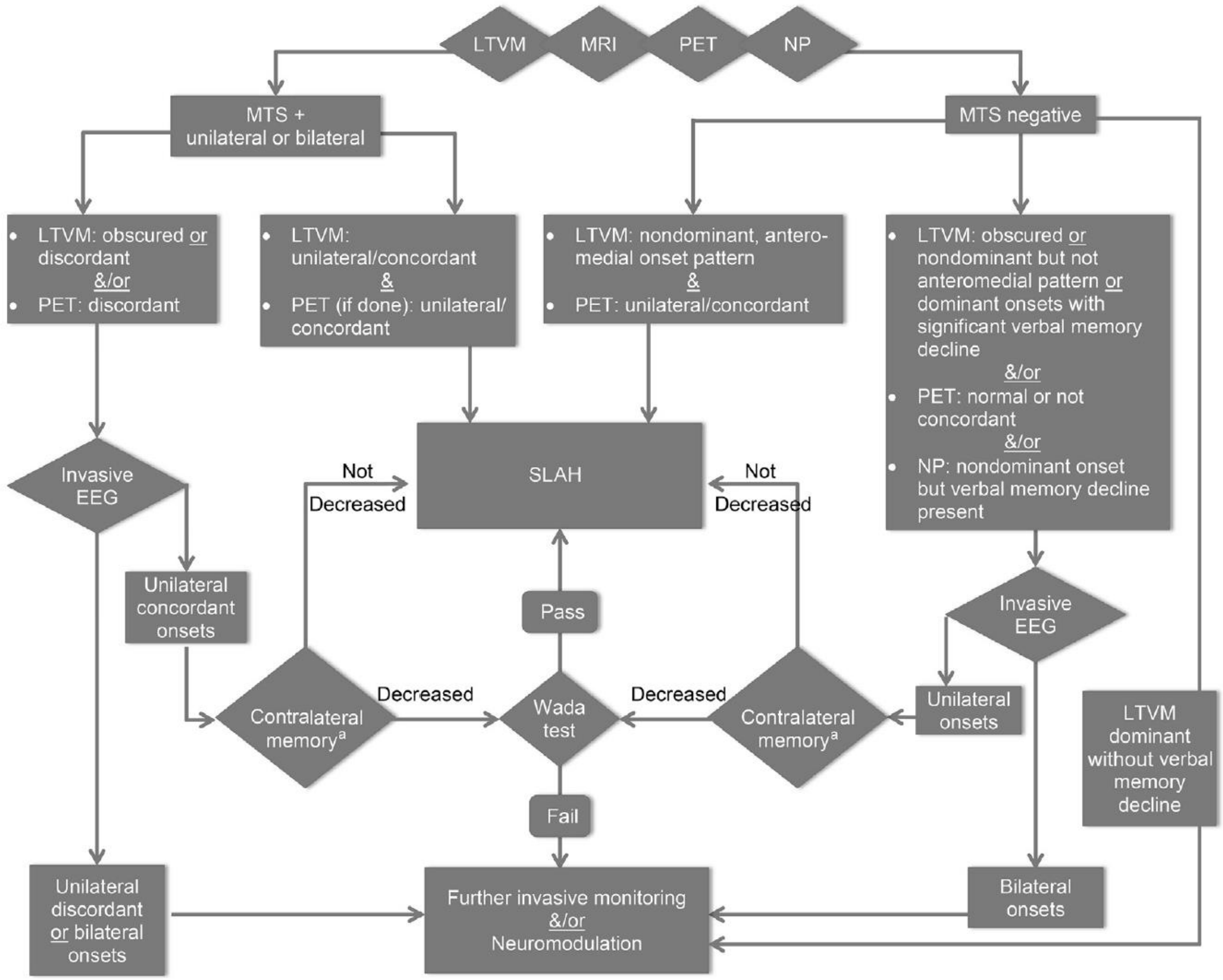
intact (visuospatial memory, MRI-) nondominant hippocampus is acceptable for ablation.
intact (verbal memory, MRI-) dominant hippocampus – do RNS (or VNS) instead of SAH.

N.B. electroclinically typical temporal lobe epilepsy but intact (verbal memory, MRI-) hippocampus – be careful it is not a mimicker (epilepsy and normal lobe function are hardly compatible) – consider SEEG!

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 icEEG, 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).

RNS does not preclude later LITT/SAH.



LTVM (long-term video monitoring) = video EEG

[a] Wada testing is almost always performed with bilateral carotid amobarbital injections, to also determine ipsilateral memory performance that may factor into decision making as well

Robert E. Gross, Jon T. Willie, Daniel L. Drane. The Role of Stereotactic Laser Amygdalohippocampotomy in Mesial Temporal Lobe Epilepsy. Neurosurg Clin N Am 27 (2016) 37–50

LITT (STEREOTACTIC LASER AMYGDALOHIPPOCAMPOTOMY)

Procedure details (general) – see p. Op345 >>

<u>Suggested resources</u>:

"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

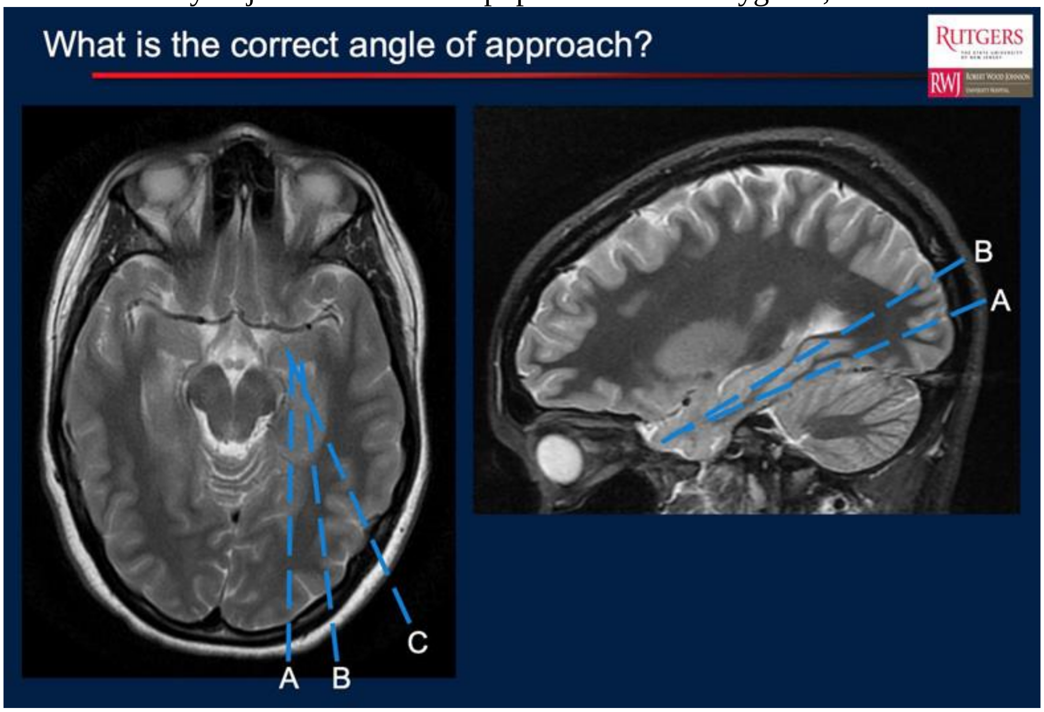
- in modern times, ***open surgery is reserved*** for patients with persistent seizures after one or more failed ablations, those who desire the highest chance of seizure freedom with a single procedure, or those with more lateral involvement in the EZ.

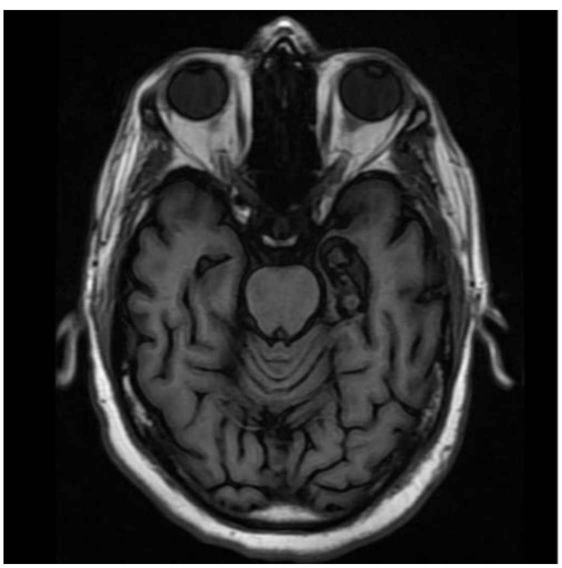
TRAJECTORY, TARGETING

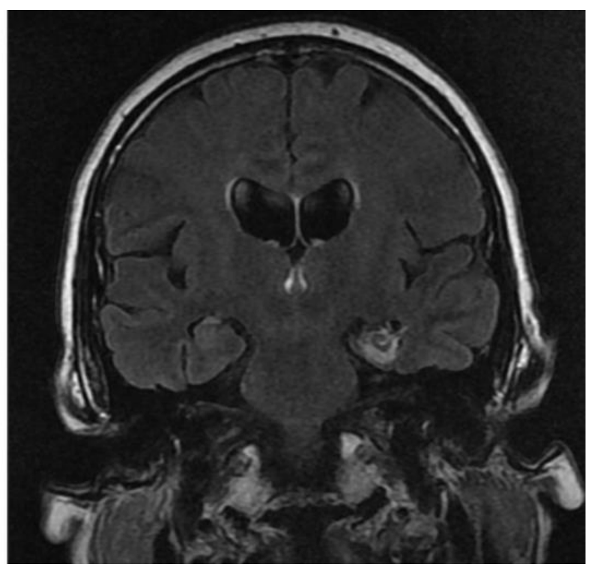
- longitudinal occipital trajectory.

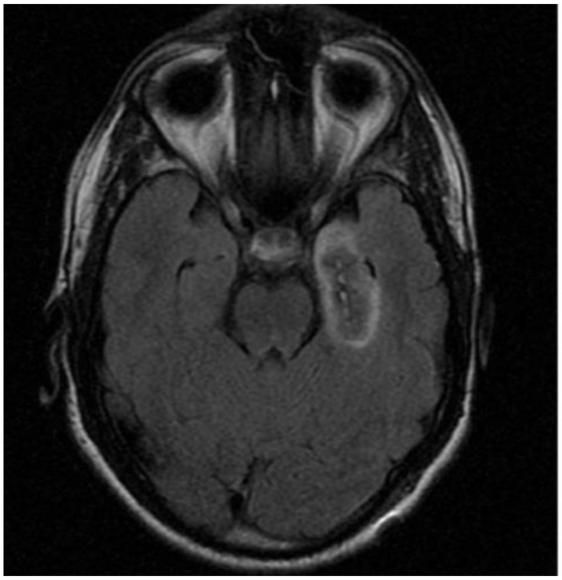
Wu et al study for selection of best trajectory – *see below >>*

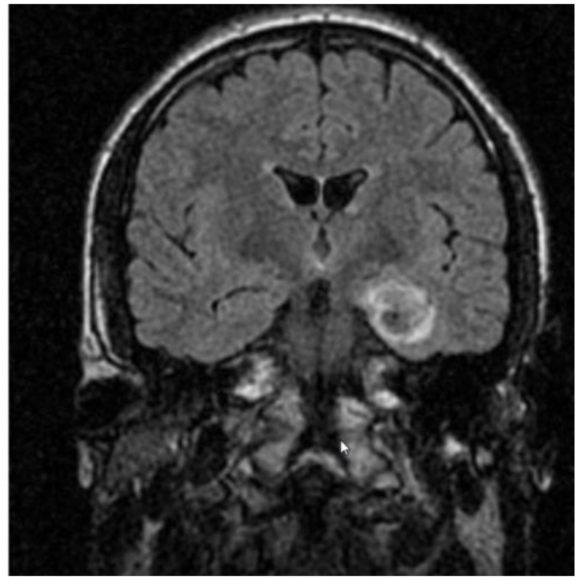
- lateral entry trajectories are more popular – ablate amygdala, less risk of visual complications



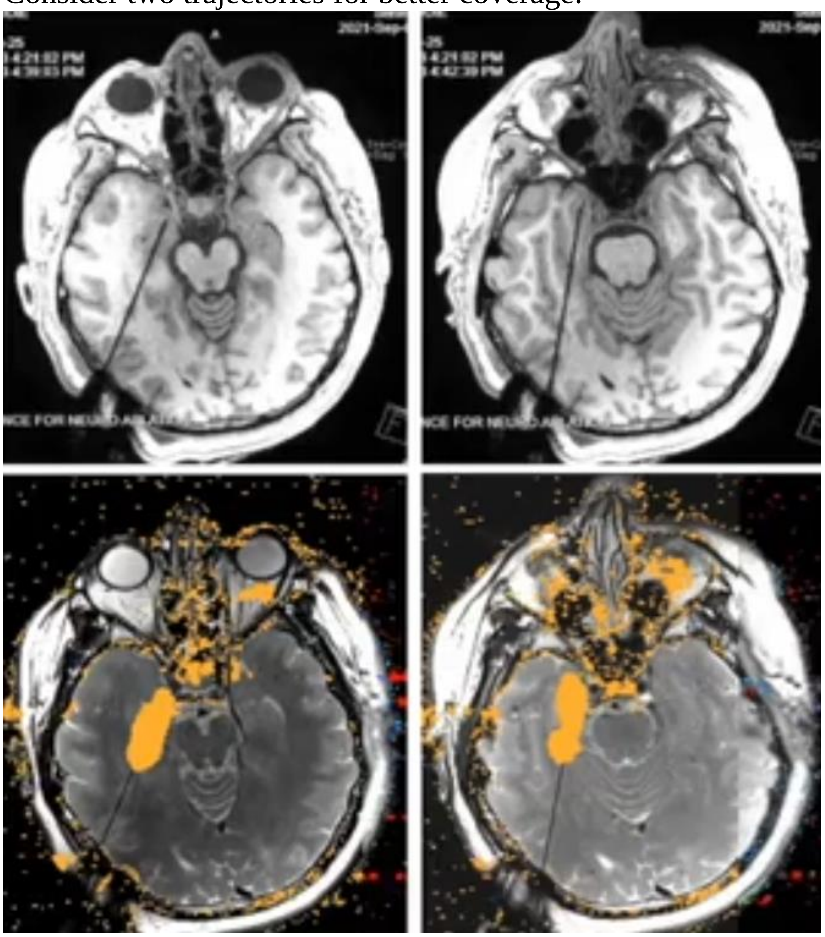


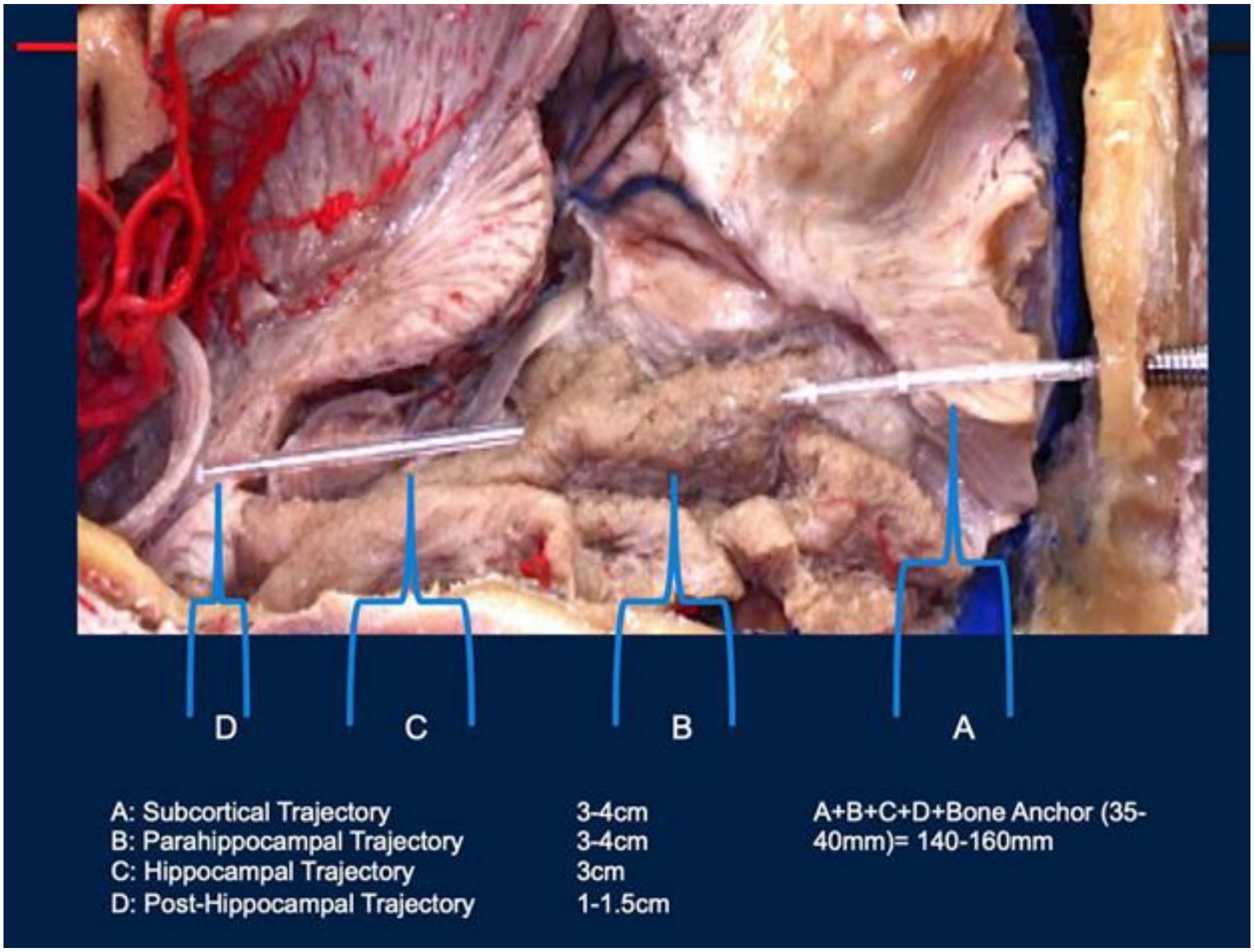






Consider two trajectories for better coverage:

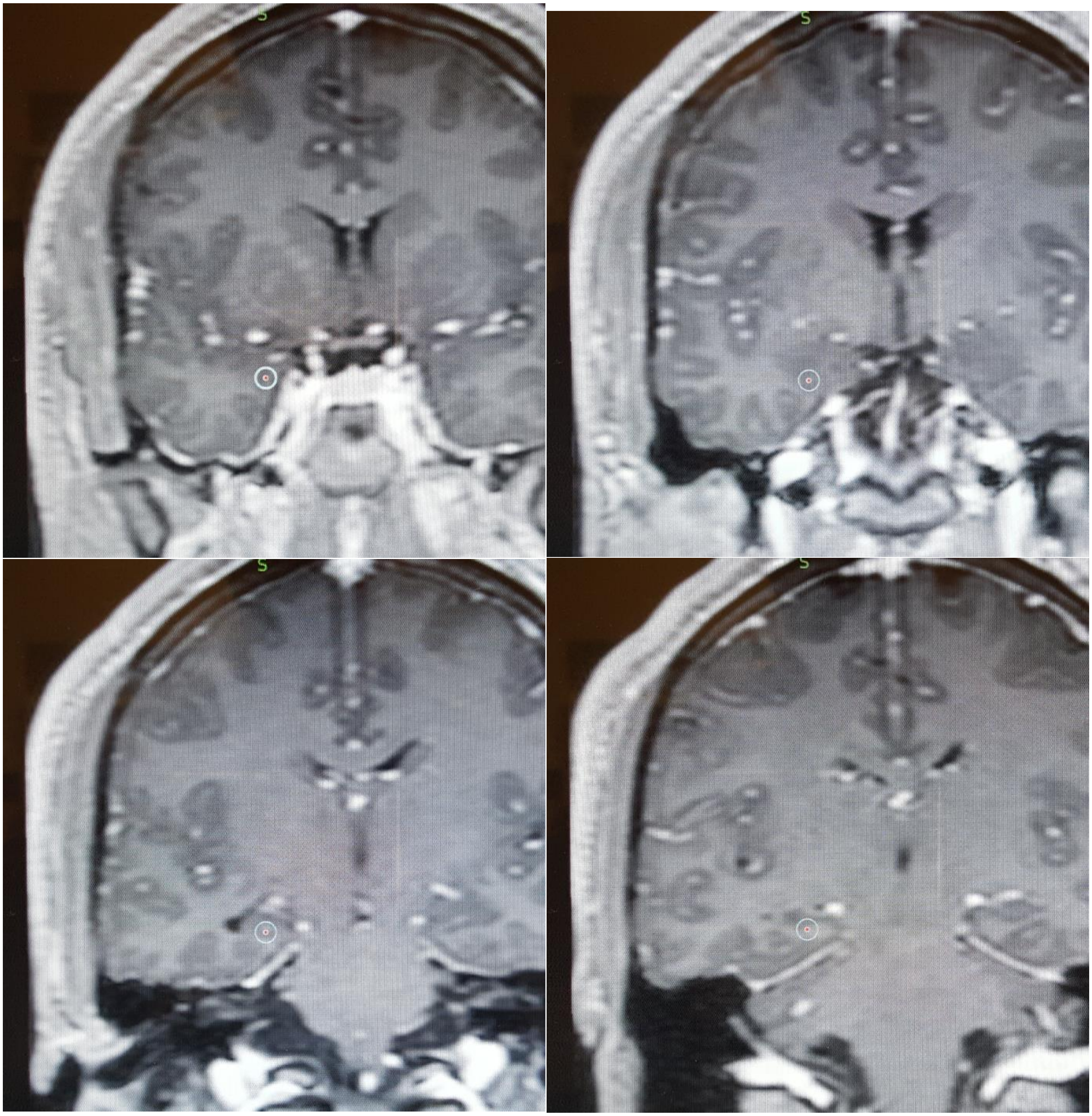




It is hard to avoid blood vessels (use T1 with gadolinium and/or CT with contrast*) but, if inserted carefully (very slowly and rotating the laser), vessels yield and hemorrhage is rare

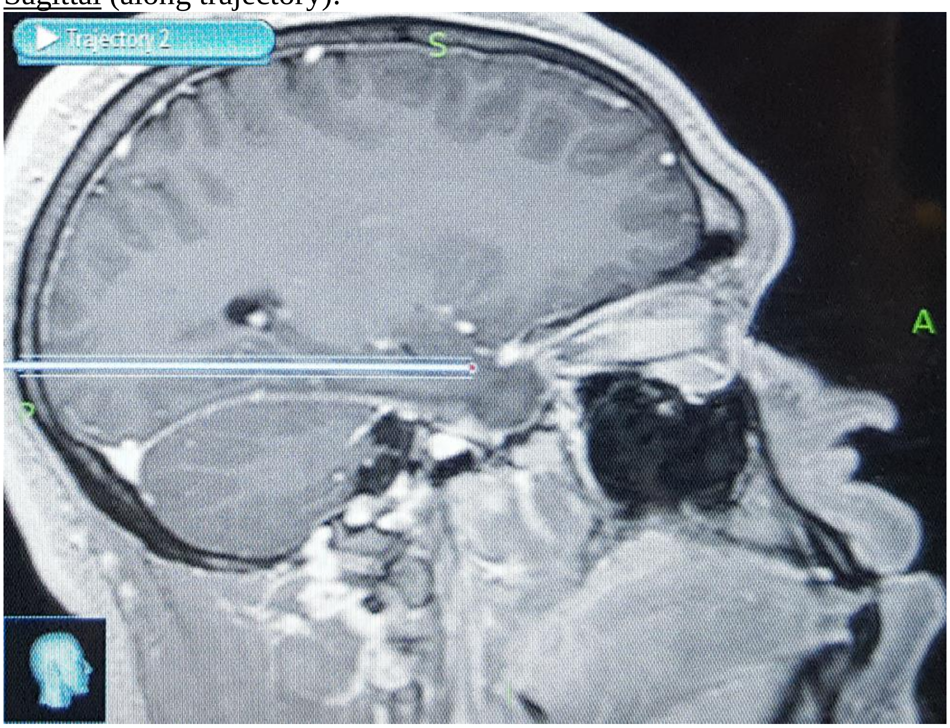
*CTA may miss cortical veins but overall CTS has better vessel definition

<u>Coronal</u> – probe's eye view (at target → moving towards entry):



Axial (along trajectory):

<u>Sagittal</u> (along trajectory):



<u>Drs. Gross and Sharan</u>

Chengyuan Wu, Michael J. LaRiviere, Nealen Laxpati, James J. Evans, Robert E. Gross, and Ashwini D. Sharan. Extraventricular Long-Axis Cannulation of the Hippocampus: Technical Considerations. Neurosurgery. 2014 Jun; 10(0 2): 325–333. doi: 10.1227/NEU.0000000000000320

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 (inion) and 5.5 cm lateral to midline** (range 4-6 cm).
  Dr. Wyllie – entry point within 1 cm of lambdoid suture
- aim to place **laser probe into amygdala**.
- posterior extent of hippocampal penetration extended at least to the level of the lateral mesencephalic sulcus.

STRUCTURES AT RISK AND COMPLICATIONS

1. Visual pathway (optic tract, optic radiation – Meyer's loop)
2. Basal ganglia
3. CN3, CN4, CN5 (runs between dural leaflets of cavernous sinus – next to uncus)
4. CN7
5. White matter tracts

Complications rates of 20-24% (neurologic deficits 15.0%) have been cited in meta-analyses:

1) hemi-paresis
2) gait abnormalities
3) expressive language dysfunction
4) hemorrhage (1.3% radiographic, 0.4% symptomatic)
5) infection
6) wound complications
7) transient increase in seizures during the first 2 wk

Complications of stereotactic laser amygdalohippocampotomy

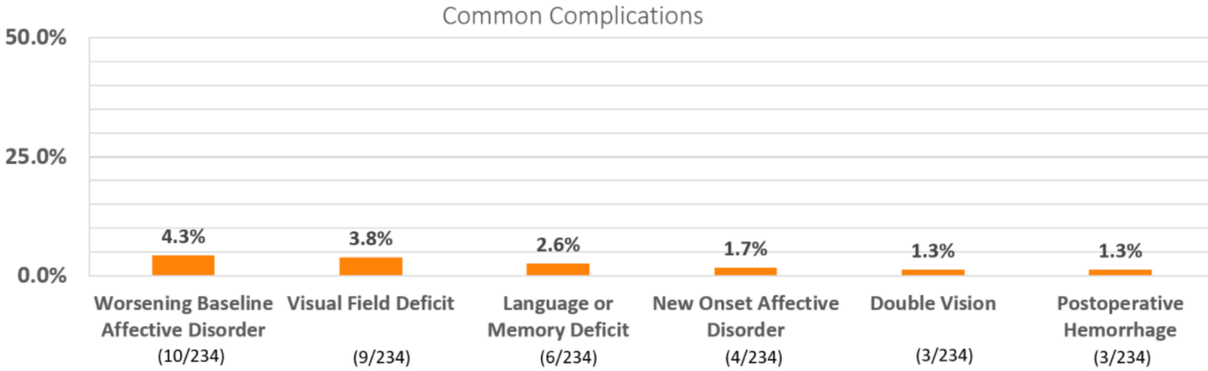
Complication	Incidence in 49 Procedures (6 Reoperations) (n) (%)
Hemorrhage	2 (4.1)
Visual field deficit (total)	4 (8.2)
Transient (superior quadrantanopia)	1 (2.0)
Persistent	3 (6.1)
Homonymous heminanopia	1 (2.0)
Superior quadrantanopia	2 (4.1)
Cranial nerve deficit (transient)	2 (4.1)
CN3	1 (2.0)
CN4	1 (2.0)

Robert E. Gross, Jon T. Willie, Daniel L. Drane. The Role of Stereotactic Laser Amygdalohippocampotomy in Mesial Temporal Lobe Epilepsy. Neurosurg Clin N Am 27 (2016) 37–50

COMPLICATIONS

Overall complication rate 15.0%

- A total of 42 complications reported in 35 patients; 8 transient, 34 persistent

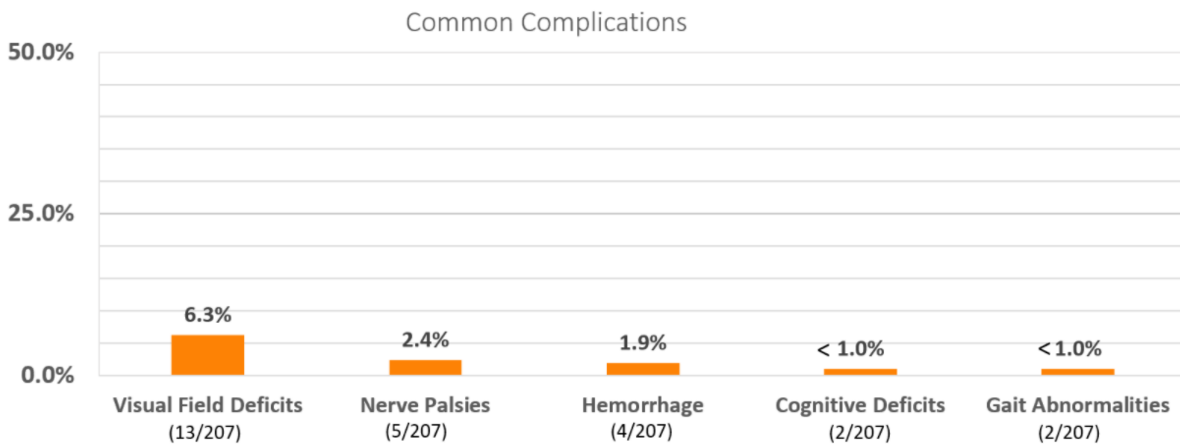


Note: One death attributed to SUDEP at 12mo post-op

Wu, C et al. Epilepsia. 2019; 60: 1171– 1183

COMPLICATIONS: Eight Studies / 207 Patients*

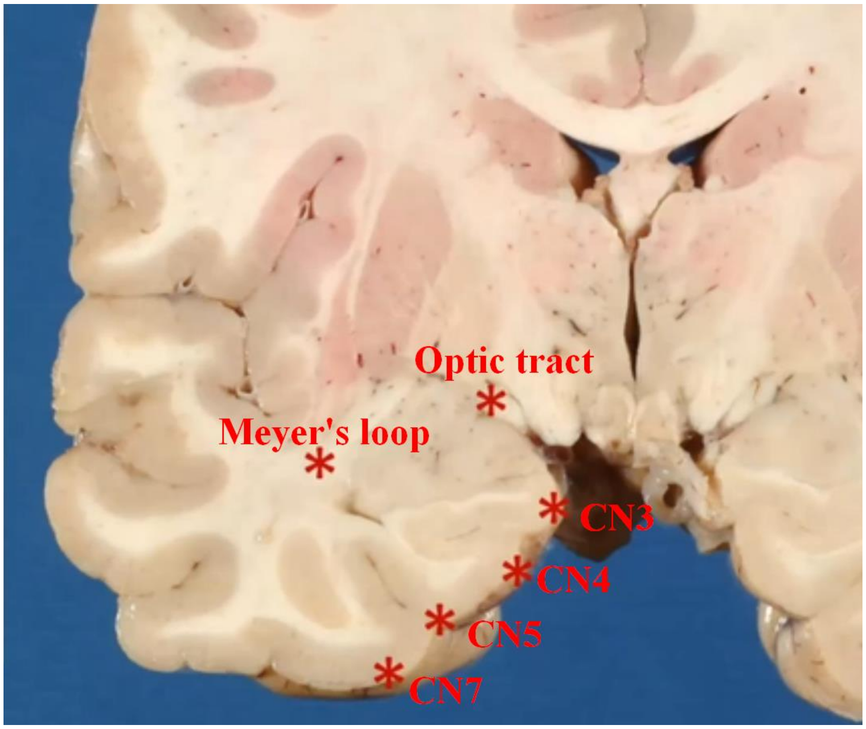
Overall Complication Rate 20% (95% CI, 14-26%)



*Donos et al. did not report complications

Grewal et al., World Neurosurg. 2019;122:e32-e47.

Place laser probe > 5-8 mm from structures at risk:



Hippocampal Trajectories:

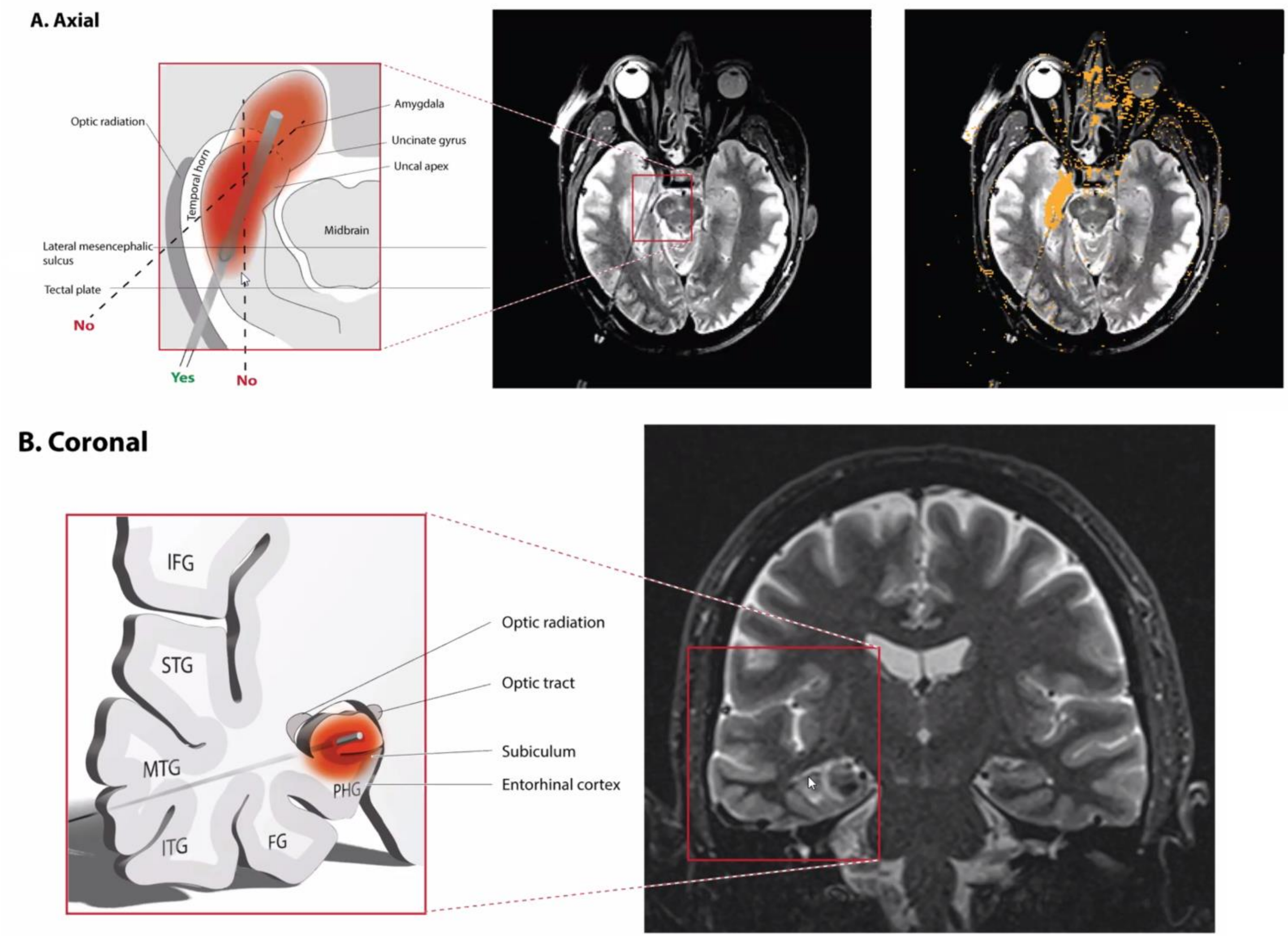
(Possible Risks of Extreme Eccentric Locations)[1]

a. Superior: optic tract, peduncle, internal capsule, lateral geniculate nucleus.

b. Medial: peduncle, CN3, CN4. Medial locations may require higher coagulation intensities to reach the lateral portion of the amygdala and hippocampus, and this elevated intensity combined with medial location may damage the above collateral structures.

c. Lateral: optic radiation, which may be injured posteriorly where the ventricle is very narrow and the optic radiation within the external sagittal stratum is closely situated to the hippocampus (e.g. beyond the LMS). Lateral locations anteriorly might encounter Meyer's loop if the fiber bundle proceeds anterior to the uncal recess of the lateral ventricle.

d. Inferior: entorhinal and perirhinal cortices, may not be able to ablate enough of the hippocampus, even with higher laser powers. Thus, the laser cannula should lie in the middle of the hippocampus where the hippocampal sulcus can be expected to be located. See remarks above about PCA branches inferiorly, as well.

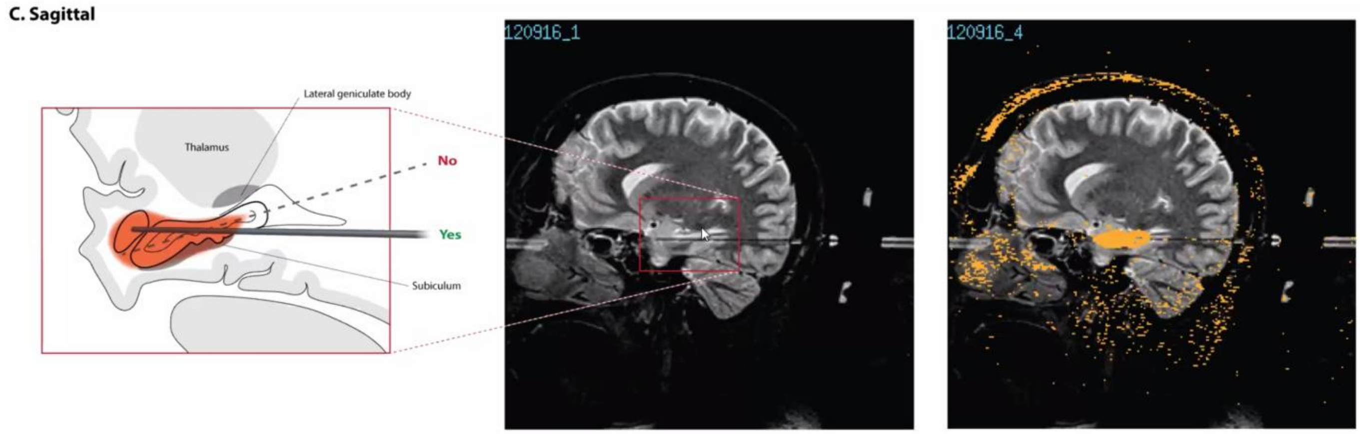


Visual pathways

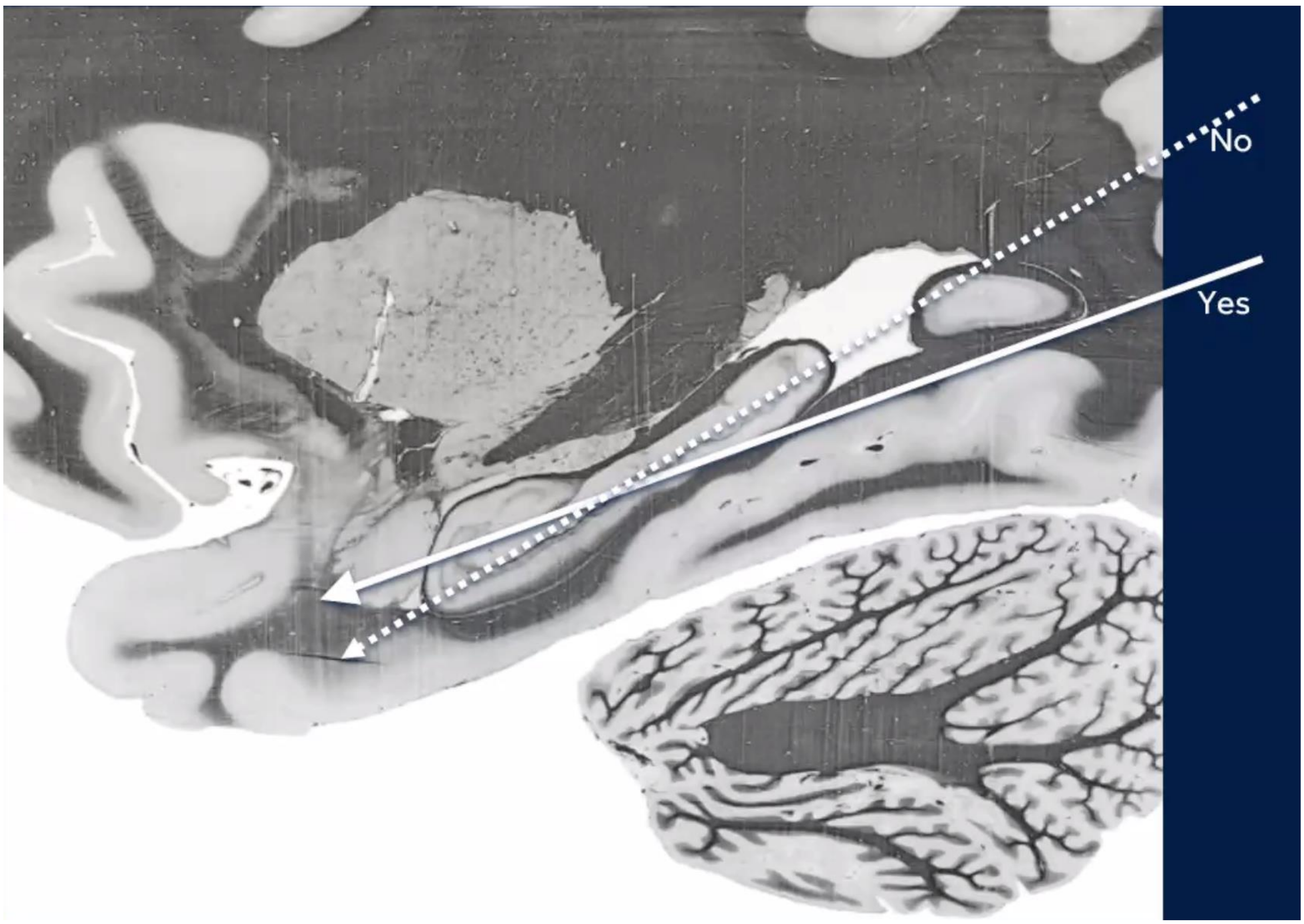
Visual field defects (VFD) - due to optic radiation damage (either at Meyer's loop by laser heating or occipitally by laser passing through optic fibers).

- in some parts of the world they can limit the patient's ability to drive even if seizure-free.
- prophylaxis - optic radiation mapping through DTI, avoid ablating hippocampus tail.
- incidence is much lower than after ATLs (37%* vs. 64%)

  *recommend preop DTI to minimize risk.
- probability is much higher after left (50%) vs right LITT (10%) (Fisher test, p = 0.05) - this laterality effect on VFDs is mirrored by ATL series; hypotheses:
  - left and right hippocampi have significantly distinct orientations in axial and coronal planes.
  - Nowell et al. have shown that left language dominant individuals have more anteriorly situated left Meyer loop.
- most consistent LITT-VFD occurred in the superior vertical octant (octananopsia).



(arrow points to lateral geniculate nucleus)



Spares temporal stem which is traversed by critical white matter tracts - uncinate fasciculus (UF) and the inferior fronto-occipital fasciculus (IFOF)

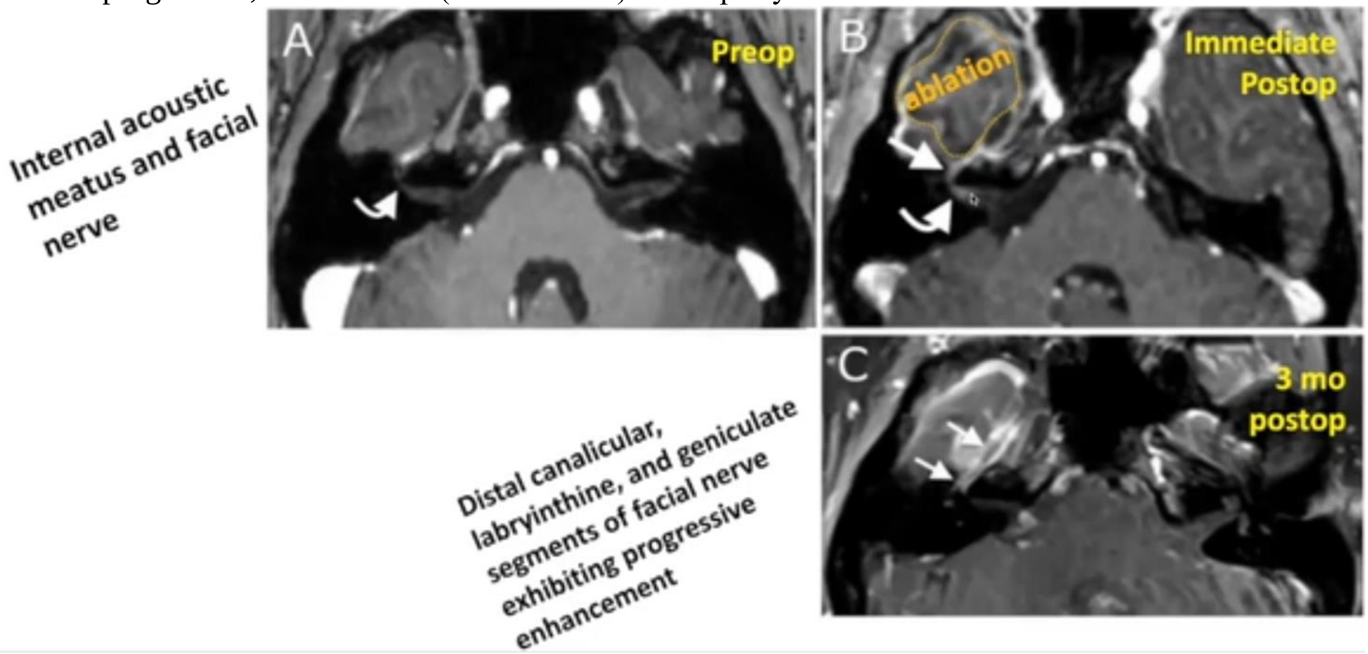
CN3-4-5

CN3-4-5 palsy – due to heat and/or inflammatory injury; tend to resolve in 12 mos

Temporal encephaloceles are epileptogenic but LITT may cause CN5 damage!

CN7

Case of progressive, self-resolved (in 12 months) Bell's palsy:



Neurocognitive risks

8) memory decline
9) neuropsychiatric symptoms, worsening of a preexisting affective disorder (4.3%).
10) language decline

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.
  D.L. Drane, J.G. Ojemann, V. Phatak, D.W. Loring, R.E. Gross, A.O. Hebb, et al. Famous face identification in temporal lobe epilepsy: support for multimodal integration model of semantic memory. Cortex, 49 (2013), pp. 1648–1667
- theoretically, LITT should circumvent this complication by limiting similar damage to the white matter of the temporal stem.
  - trend toward better preservation of naming with the SAH versus ATL in the dominant hemisphere.
  A. Mansouri et al. Neurocognitive and seizure outcomes of selective amygdalohippocampectomy versus anterior temporal lobectomy for mesial temporal lobe epilepsy. Epilepsy Res Treat, 2014 (2014), pp. 1–8
- 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).
  Robert E. Gross, Jon T. Willie, Daniel L. Drane. The Role of Stereotactic Laser Amygdalohippocampotomy in Mesial Temporal Lobe Epilepsy. Neurosurg Clin N Am 27 (2016) 37–50
- in several reports, LITT largely preserved naming and object recognition following language dominant ablations, functions that commonly decline following ATL or SAH.
  - verbal memory may decline following dominant side LITT; however, the risk appears to be lower than with open surgery.
  - Kang parsed out verbal memory changes and found a decline in noncontextual (word list) verbal memory, which is localized to the mesial structures, but preservation of contextual (narrative) verbal memory, which is supported by the temporal neocortex.
  Kang JY, Wu C, Tracy J et al. . Laser interstitial thermal therapy for medically intractable mesial temporal lobe epilepsy. Epilepsia. 2016;57(2):325-334

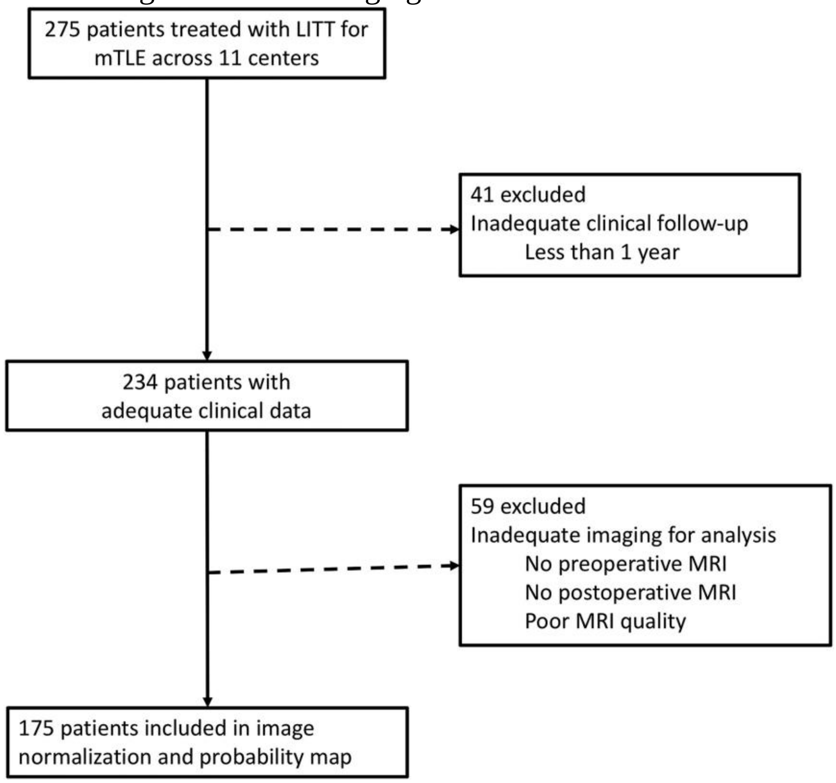
STUDIES

See also p. Op 345 >>

Effects of surgical targeting in laser interstitial thermal therapy for mesial temporal lobe epilepsy: A multicenter study of 234 patients

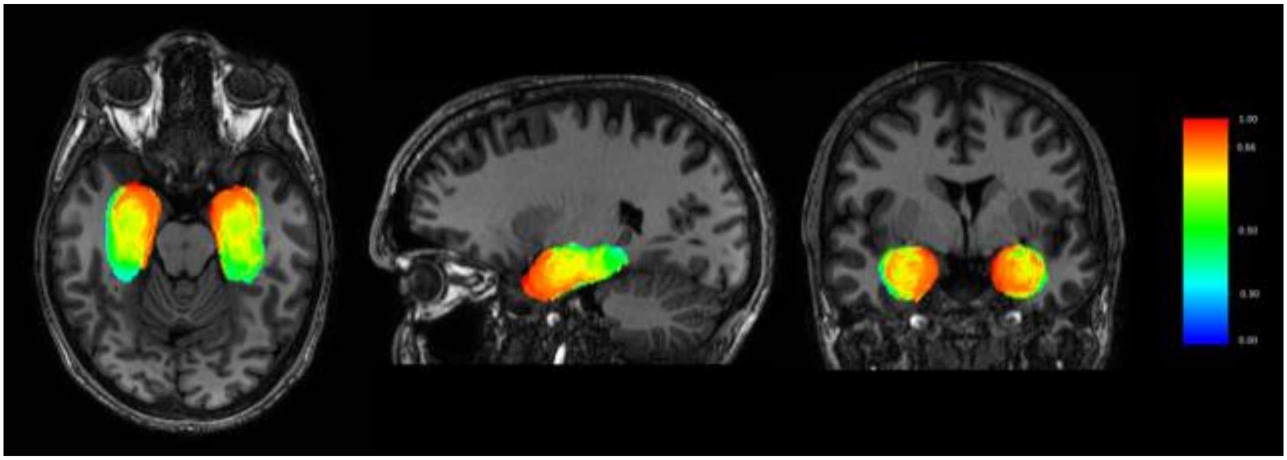
Wu C et al. Epilepsia, Volume 60, Issue 6, June 2019, Pages 1171-1183

- 275 patients operated at 11 comprehensive epilepsy centers; 234 patients with at least 1 year follow up; 175 analyzed due to others having insufficient imaging data:



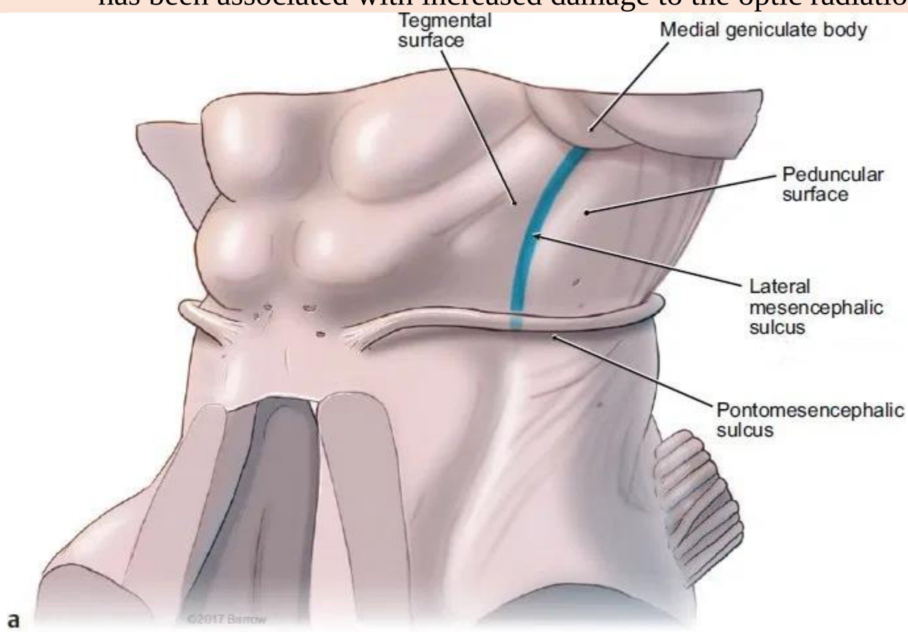
- de-identification, normalization (nonlinear registration to a common reference space derived from 7T MRI), and data comparison were accomplished with the CranialCloud platform (Neurotargeting LLC) and algorithms developed at Vanderbilt University.
- 58% of patients were Engel 1 at both one and two years post-procedure; 80% of patients were classified as Engel 1 or 2.
- history of bilateral tonic-clonic seizures decreased chances of Engel I outcome (patients are more likely to have lateral neocortical rather than mesial onset).
- *radiographic hippocampal sclerosis* was not associated with seizure outcome.
- ablations including more anterior, medial, inferior temporal lobe structures, which involved greater amygdala volume, were more likely to be associated with Engel class I outcomes.

Heat map of the likelihood of relevance of ablation for seizure control: colored zones were ablated; red zones show higher likelihood of ablation contributing to seizure control.



Ablations must prioritize the amygdala and also include the hippocampal head, parahippocampal gyrus, and rhinal (entorhinal, perirhinal) cortices to maximize chances of seizure freedom.

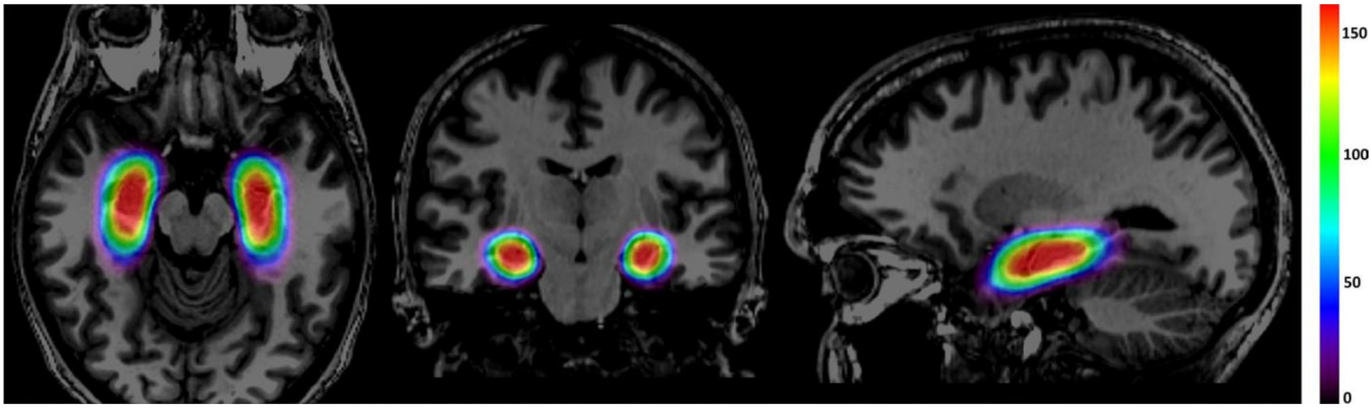
Ablations posterior to the lateral mesencephalic sulcus yields diminishing returns and has been associated with increased damage to the optic radiations



- more extensive amygdala ablation was associated with Engel I outcomes at 6, 12, and 18 months, and at last followup (OR = 1.60-1.77 per additional percent ablated, $P \leq 0.040$)
- increasing hippocampal ablation was associated with a decreased chance of Engel I outcomes at 6, 18, and 24 months (OR = 0.04 per additional percent ablated, $P \leq 0.040$).

N.B. focus on ablation location more so than ablation volumes alone!

Heat map of the ***distribution of ablations in 175 patients*** **-** all ablations (red) were centered around the long axis of the AHC and extended posteriorly to the level of the lateral mesencephalic sulcus; less frequently ablated regions (green and blue) extend from this central core: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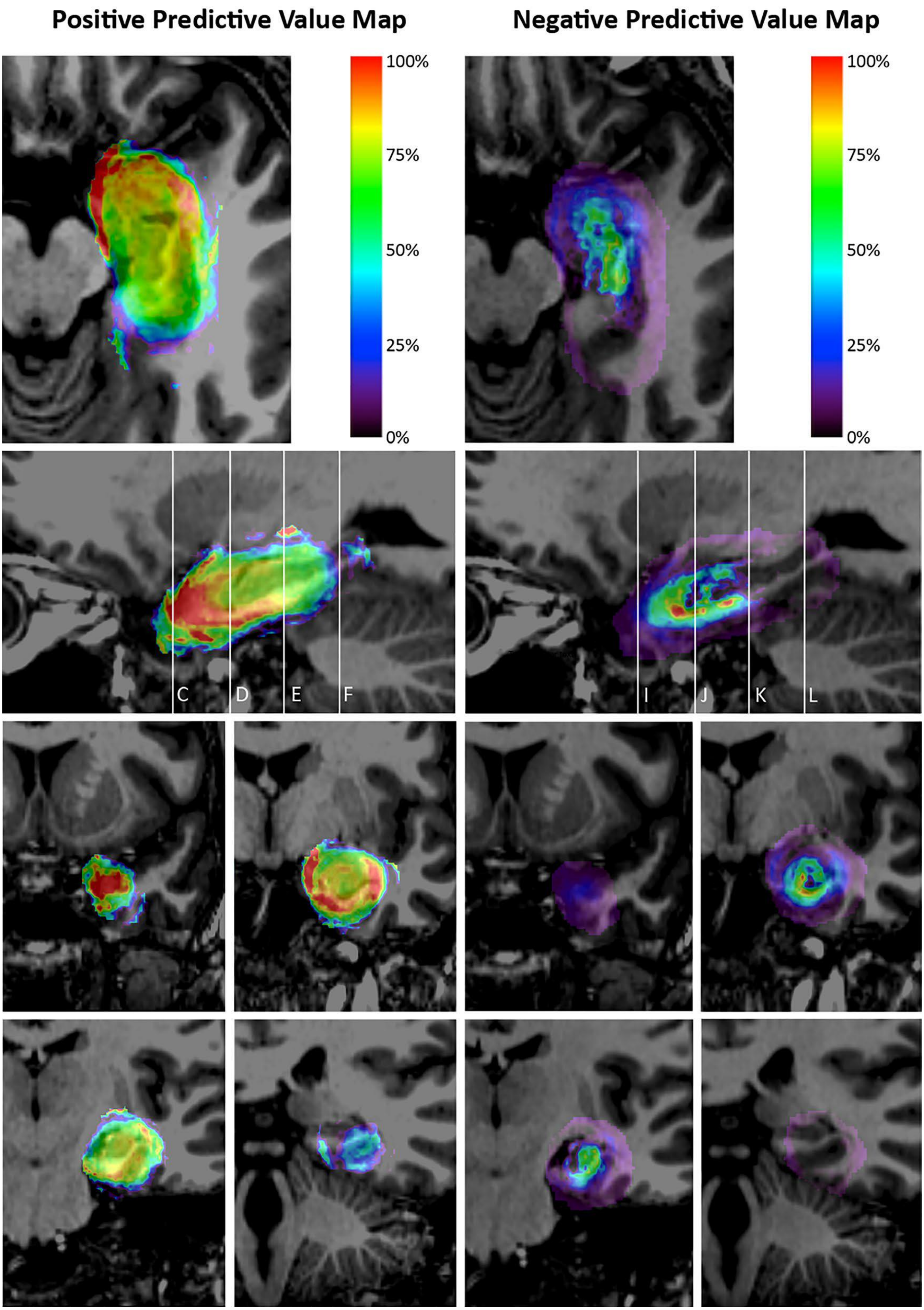
Positive Predictive Value Map
Negative Predictive Value Map
100%
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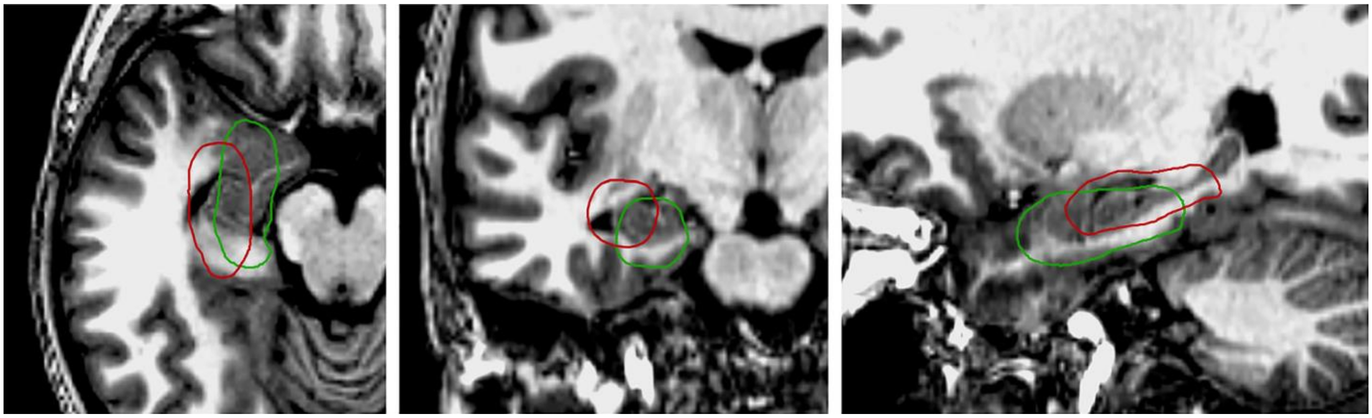
Theoretical ***favorable*** (green) and ***unfavorable*** (red) ***ablation locations*** based on the PPV and NPV maps. Both ablations are of roughly the same volume, but are located and oriented differently within the mesial temporal structures.

- favorable ablation is located more anteriorly, medially, and inferiorly to cover the high probability voxels for both the PPV and NPV maps - ablation covers the amygdala, hippocampus, parahippocampal gyrus, and rhinal cortices.
- suboptimal ablation is located more posteriorly, laterally, and superiorly to exclude the high probability voxels for both the PPV and NPV maps - ablation covers the posterolateral amygdala and hippocampus, but misses a large part of the amygdala, the mesial hippocampal head, parahippocampal gyrus, and rhinal cortices:

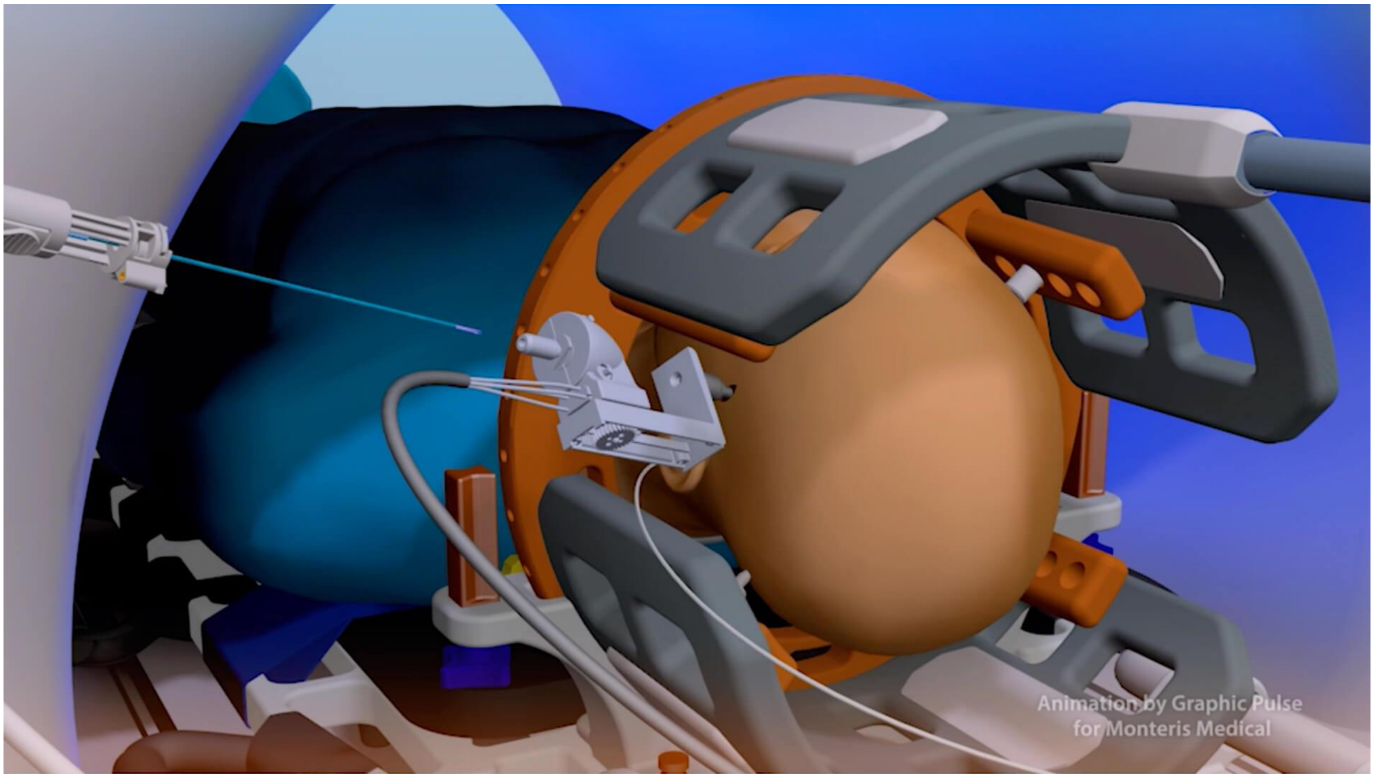


IN OR

see p. Op345 >>

IN MRI SUITE

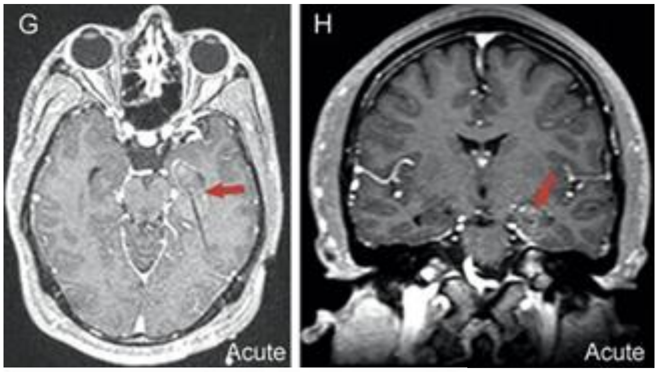
- patient is placed supine within the magnet with the head turned to situate the treatment side up to protect the laser assembly and anchor bolt:

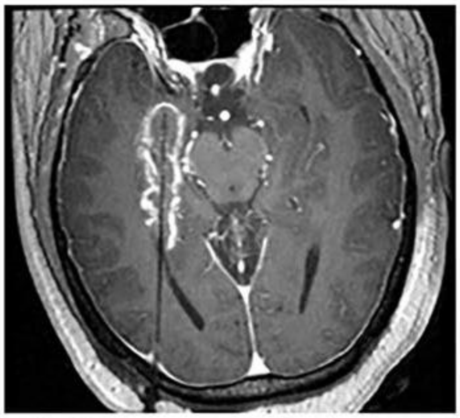


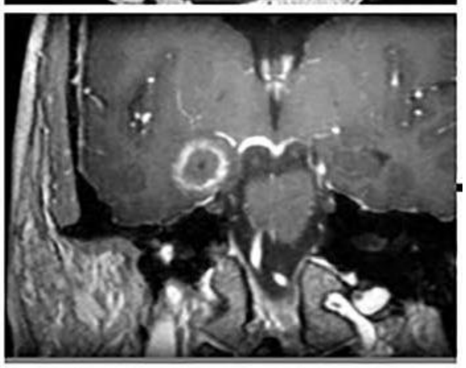
- laser probe needs to be placed precisely in center of hippocampus or will leave some unablated (H: ablate via suboptimally positioned probe then reposition and ablate again)
- laser energy diffusion allows nice ablation of curved hippocampus (as laser light is reflected from reached ependymal surface, plus, CSF in ventricle acts as heatsink).
- safety points (to automatically terminate laser delivery if these structures exceeded 45°C or even 43°C):
    1) lateral thalamus
    2) basal ganglia
    3) optic tract
    4) lateral mesencephalon (white square in anterior mesencephalon, and blue diamond in lateral mesencephalon):

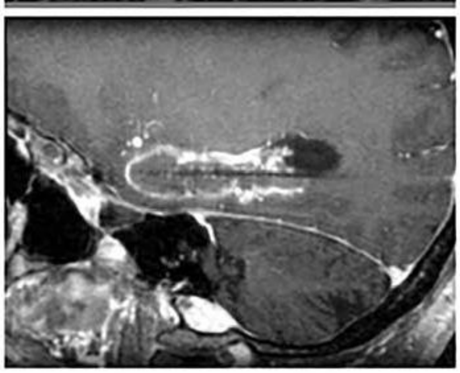
    

- amygdala and hippocampus are targeted moving the laser fiber from deep towards the entry point by 6-10 mm increments – follow blue line ("killing zone") encompassing intended treatment volume.
    - as many as 5 overlapping focal ablations are created, resulting in a confluent tubular ablation zone to at least the lateral mesencephalic sulcus.
- immediate postprocedure MRI including DWI, FLAIR, and T1 postgadolinium are acquired, verifying the final lesion location and volume.
    - T1 with contrast highlights the borders of the lesion:



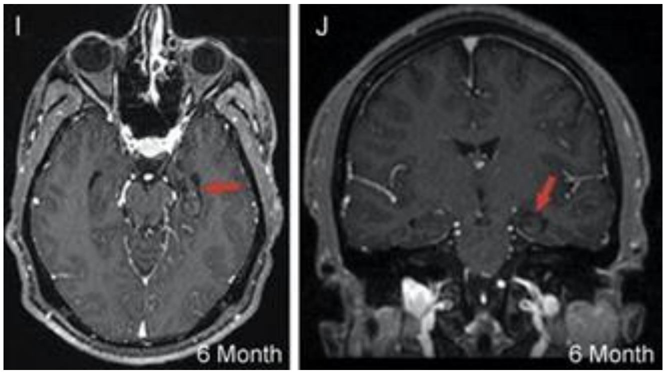




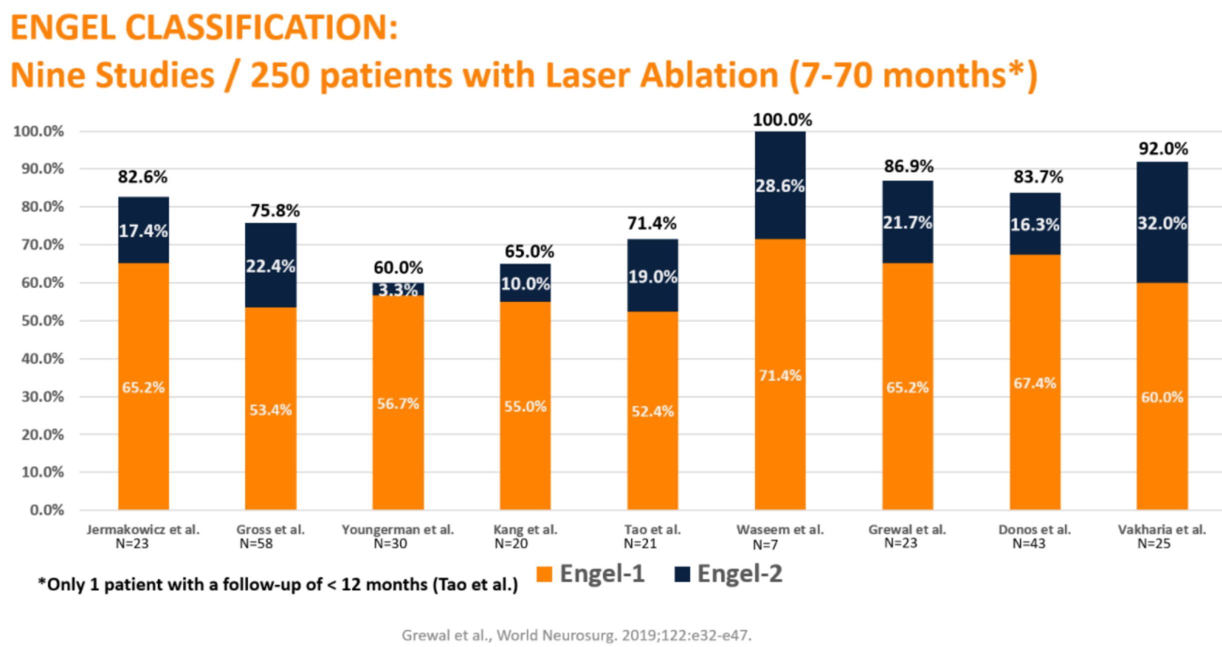


FOLLOW UP

- at 6 months, the amygdalohippocampal complex demonstrates well-circumscribed nonenhancing pseudocystic atrophy:



OUTCOMES



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

RNS

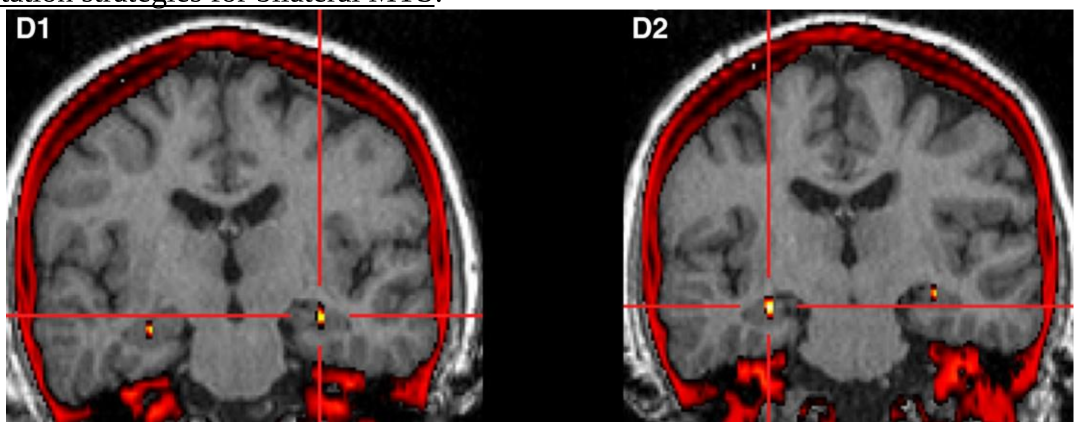
Temporal lobectomy is the most effective treatment for medically intractable mesial temporal lobe epilepsy (MTLE).

- 25–35% of patients who are treated with resective or ablative surgeries do not achieve sustained seizure freedom, and others are not candidates for surgery because the risks, particularly to memory or language, are too high - neuromodulation therapies are a treatment option for some of these patients!

<u>Implantation strategies for unilateral MTS</u>:

a) depth along hippo axis + anterior subtemporal strip
b) depth along hippo axis + depth in parahippocampal gyrus

<u>Implantation strategies for bilateral MTS</u>:



- some experts would also implant bilateral subtemporal strips and leave them not connected to RNS.

<u>Outcomes</u> – see p. E25 >>

- seizure reduction is not dependent on the location of depth leads relative to the hippocampus – it is enough to place electrode into network!
  - one study showed that decreases in epileptogenic activity were related to proximity of the active electrode(s) to the subiculum and not associated with the proximity of the active electrode(s) to the ictal focus.

    Bondallaz P et al. Electrode location and clinical outcome in hippocampal electrical stimulation for mesial temporal lobe epilepsy. Seizure 2013;22:390–395

TRANSCORTICAL- TRANSVENTRICULAR APPROACH

Image guidance is very helpful!

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

   Niemeyer P. The transventricular amygdala-hippocampectomy in temporal lobe epilepsy. In: Baldwin MBailey P, ed. The Temporal Lobe Epilepsy . Springfield, IL: Charles C Thomas; 1958:461–482

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

   Olivier A. Transcortical selective amygdalohippocampectomy in temporal lobe epilepsy. Can J Neurol Sci. 2000;27 (suppl 1):S68–S76; discussion S92-S96.

   Wheatley BM. Selective amygdalohippocampectomy: the trans-middle temporal gyrus approach. Neurosurg Focus. 2008;25(3):E4.

b) approach through anterior *superior temporal gyrus*.

Vajkoczy P, Krakow K, Stodieck S, Pholmann-Eden B, Schmiedek P: Modified approach for the selective treatment of temporal lobe epilepsy: transsylvian-transcisternal mesial en bloc resection:. *J Neurosurg*88:855–8621998

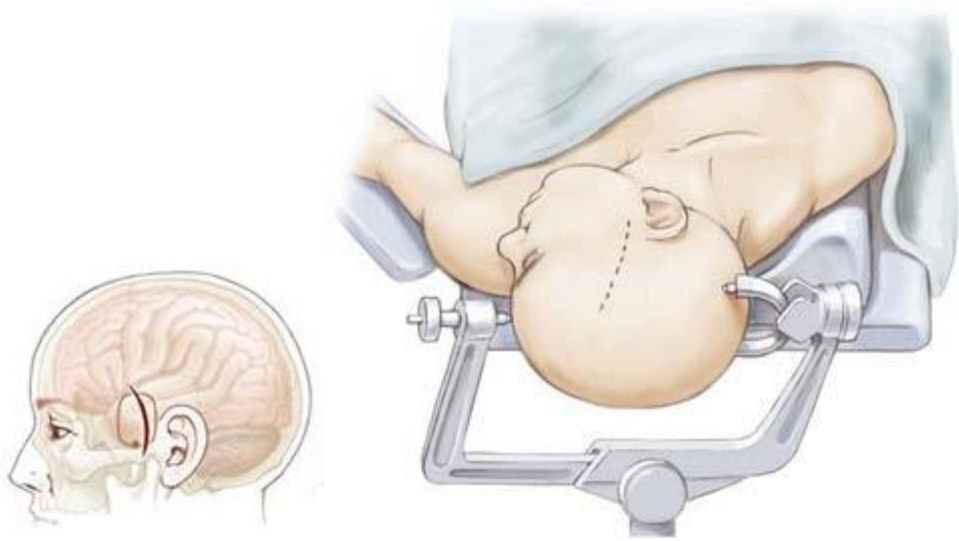
- disadvantages of this approach:
  1) unavoidably produces cortical injury
  2) necessity to dissect in close vicinity to optic radiation (Meyer's loop) which is located in the roof of the ventricle.

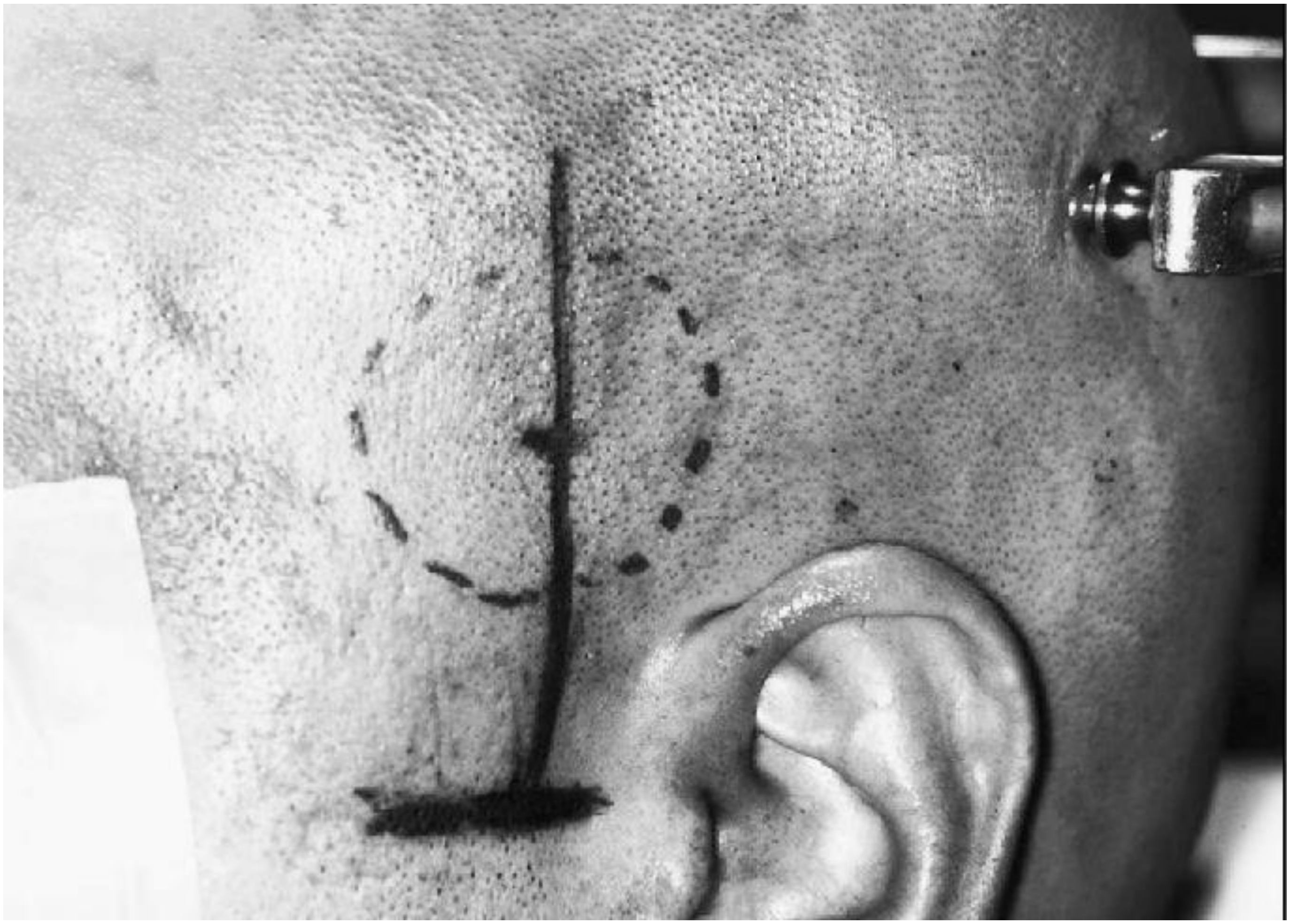
ANESTHESIA, POSITION

- 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





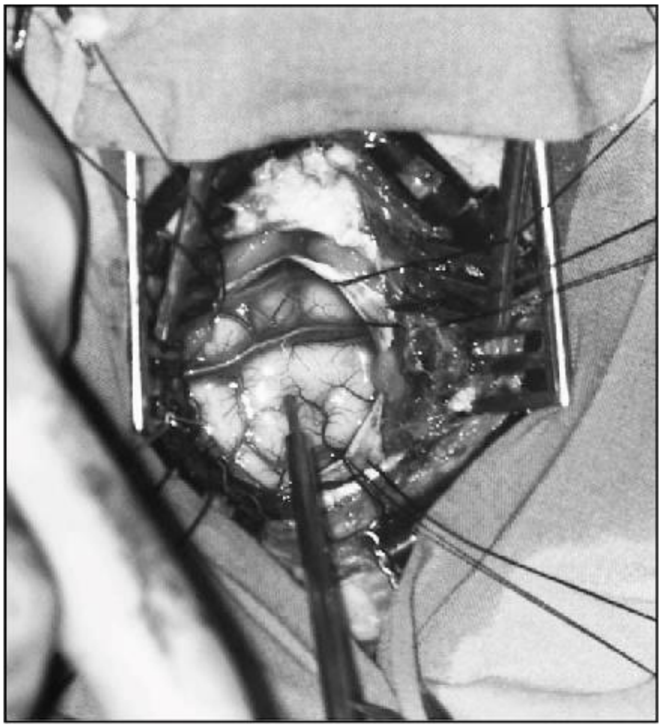
Source of picture: Olivier A. Transcortical selective amygdalohippocampectomy in temporal lobe epilepsy. Can J Neurol Sci. 2000;27 (suppl 1):S68–S76 >>

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.

TRAJECTORY / CORRIDOR

<u>Corticotomy</u>:

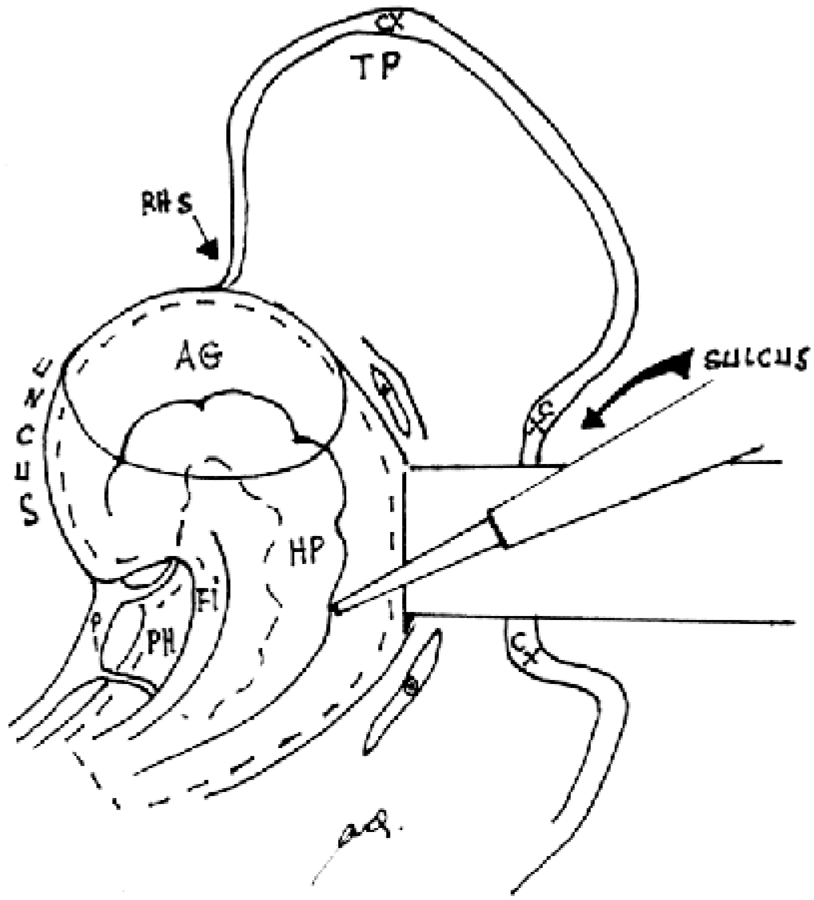
- either within the depth of the first temporal sulcus* (S1) or, preferably, along the upper border of the second temporal gyrus (T2) just below the superior temporal sulcus and in front of the central sulcus (on the dominant side, the incision should be placed in front of the posterior limit of the 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:



Source of picture: Olivier A. Transcortical selective amygdalohippocampectomy in temporal lobe epilepsy. Can J Neurol Sci. 2000;27 (suppl 1):S68–S76 >>

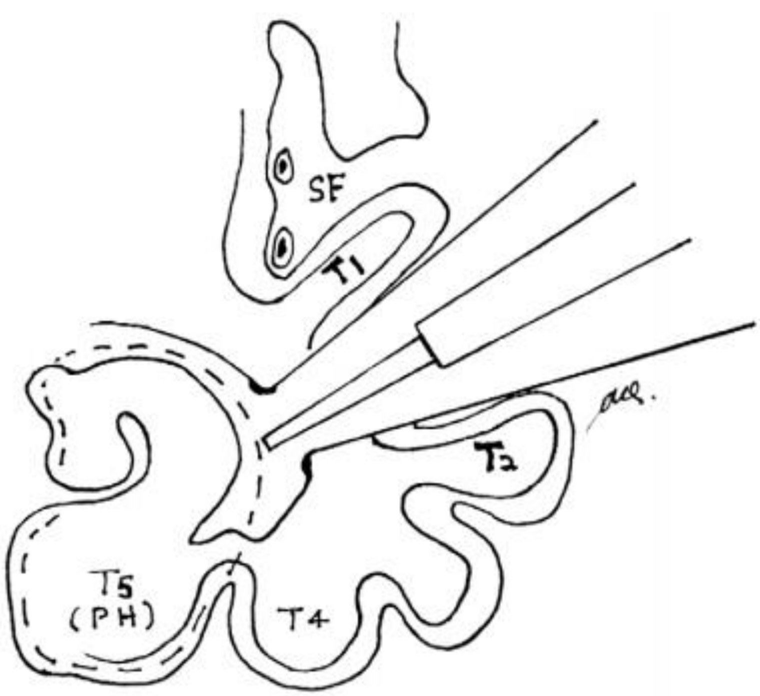
Corridor:

- 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):

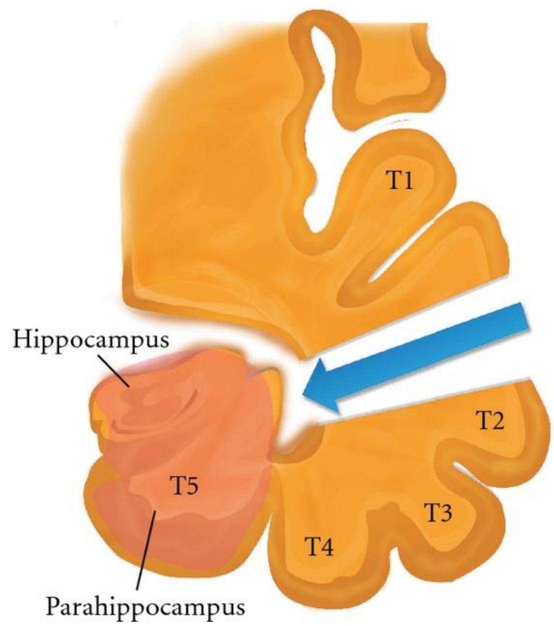


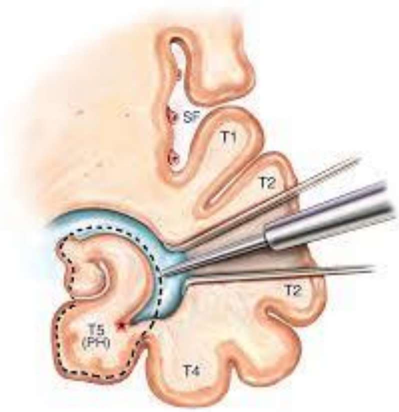
Source of picture: Olivier A. Transcortical selective amygdalohippocampectomy in temporal lobe epilepsy. Can J Neurol Sci. 2000;27 (suppl 1):S68–S76 >>

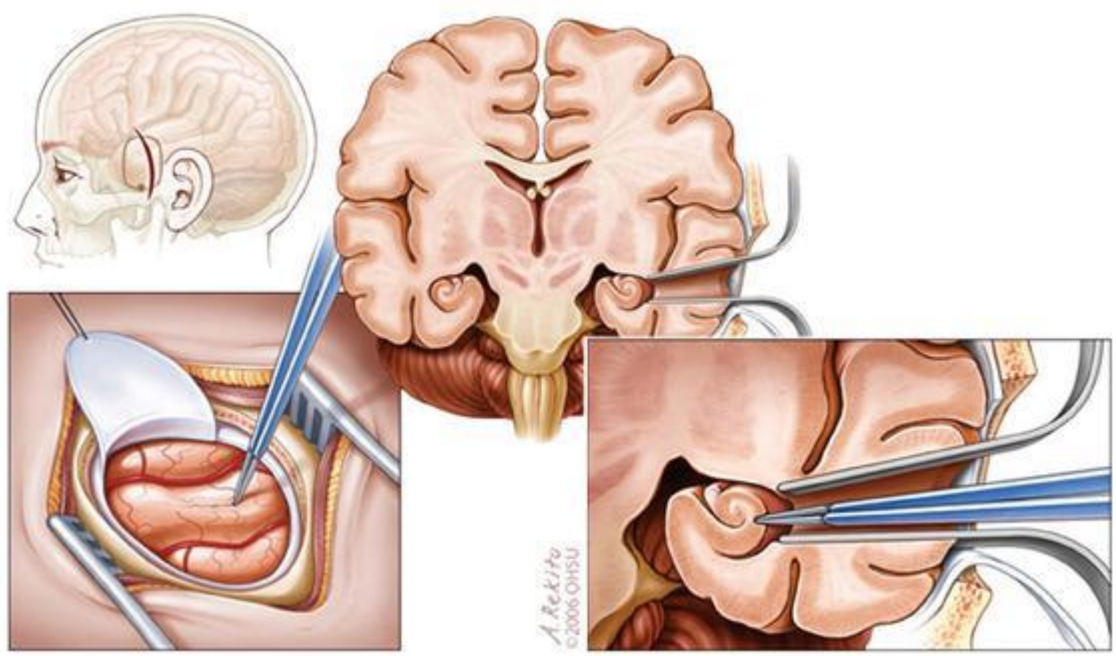
- self-retaining retractor has been installed - dotted line indicates the intended extent of resection. SF = Sylvian fissure, T1, T2, T4, T5 = temporal gyri. T5 corresponds to the parahippocampal gyrus (PH):



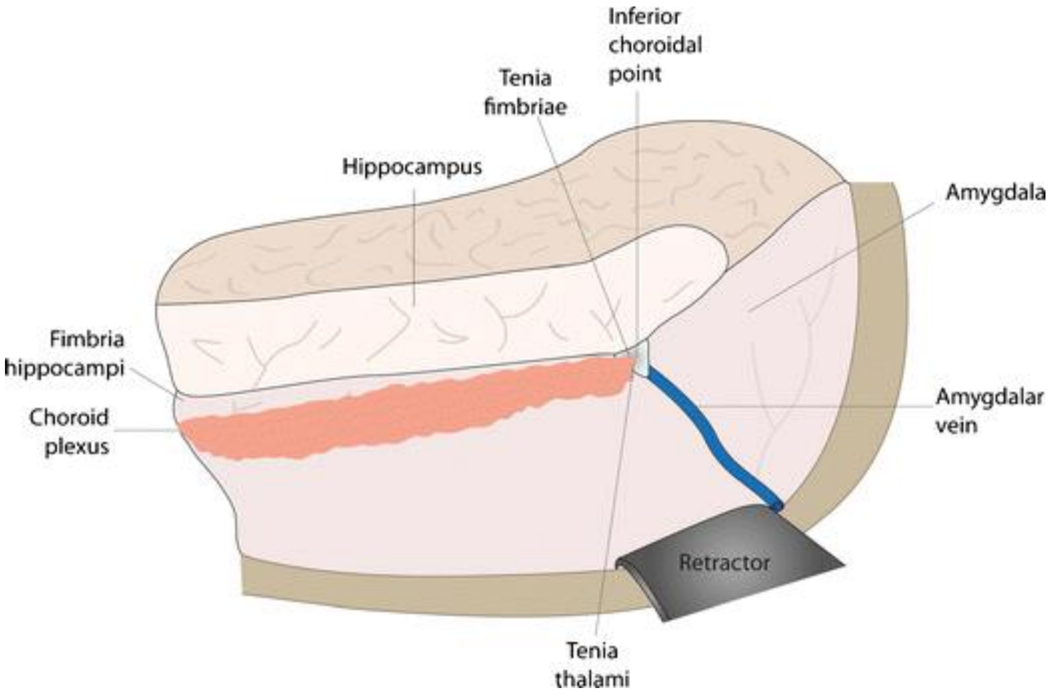
Source of picture: Olivier A. Transcortical selective amygdalohippocampectomy in temporal lobe epilepsy. Can J Neurol Sci. 2000;27 (suppl 1):S68–S76 >>





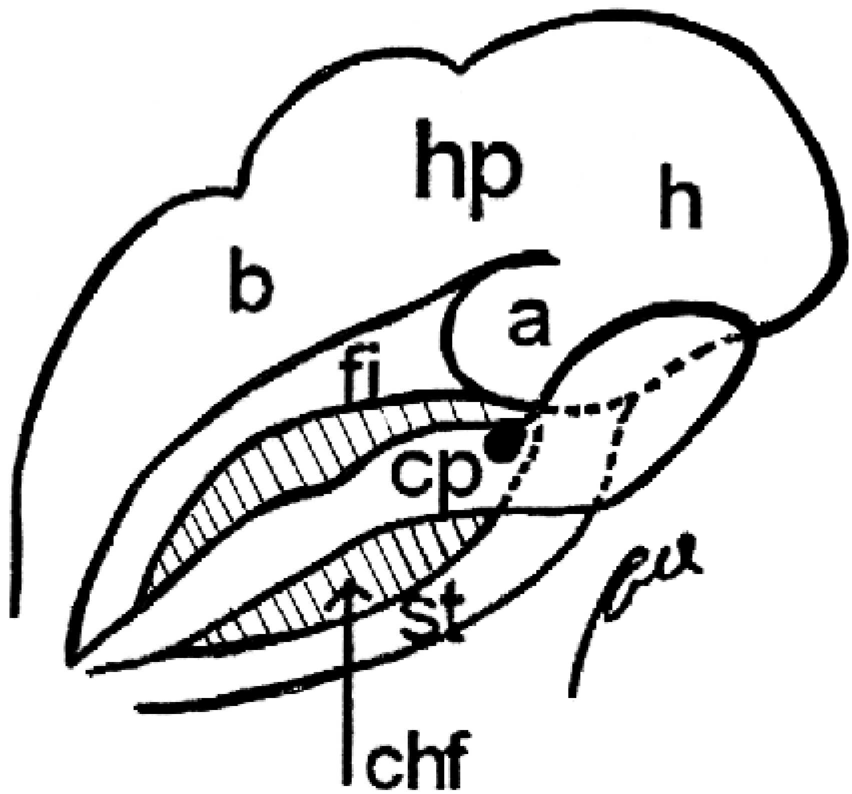


HIPPOCAMPAL RESECTION



- 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:



Source of picture: Olivier A. Transcortical selective amygdalohippocampectomy in temporal lobe epilepsy. Can J Neurol Sci. 2000;27 (suppl 1):S68–S76 >>

- 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

http://www.neurosurgicalatlas.com/volumes/epilepsy-surgery/temporal-lobe-surgery/transsylvian-selective-amygdalohippocampectomy

Badih Adada. Selective amygdalohippocampectomy via the transsylvian approach. Neurosurgical Focus Volume 25: Issue 3 (Sep 2008): Advances in the Management of Epilepsy.

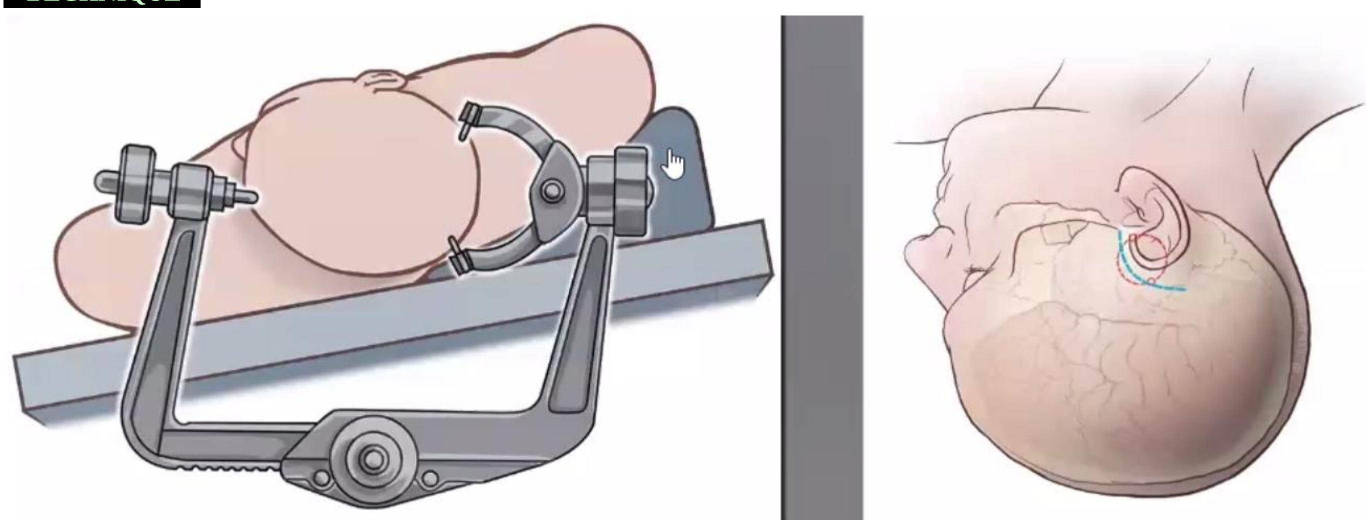
- more restrictive and necessity to dissect around the Sylvian vessels (risk of injury to M1 portion within sylvian fissure).

- 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.

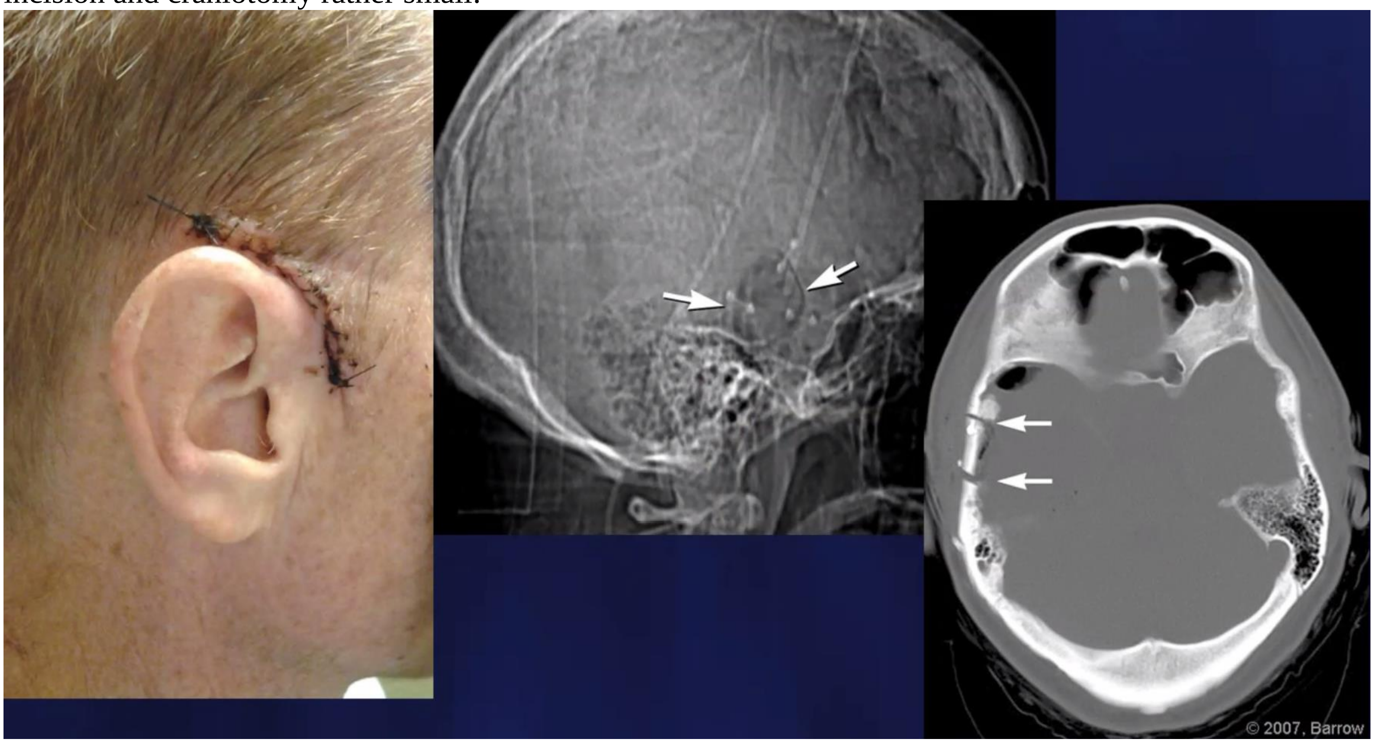
SUBTEMPORAL APPROACH

- 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;
     *rarely an obstacle but, if present, don't pull (to avulse it) rather enter temporal lobe cortex lateral to it.
  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.

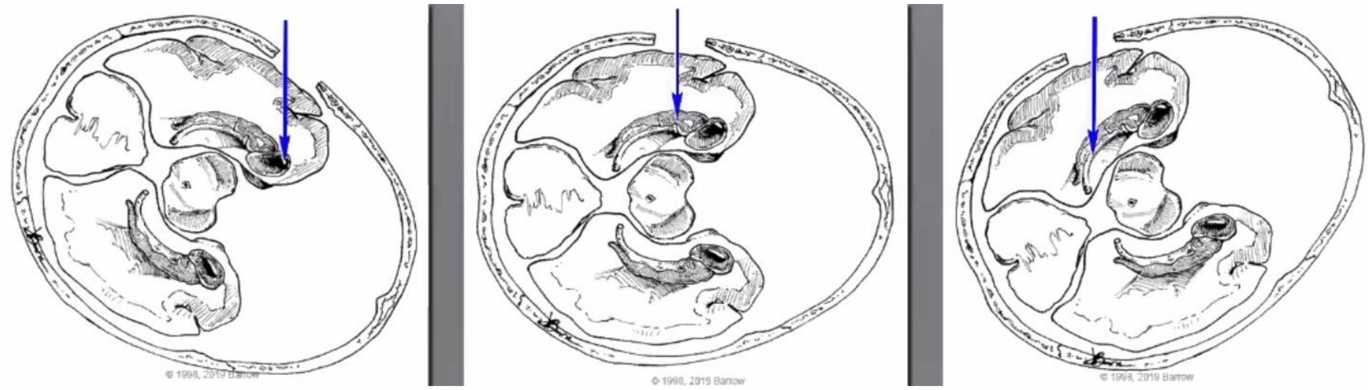
TECHNIQUE



- reverse Trendelenburg
- incision and craniotomy rather small:



- patience with CSF release
- start under amygdala and resect until temporal horn is opened for more relaxation and view of choroid plexus and fissure are clear.
- remove parahippocampal gyrus (subpial dissection) and then pull hippocampus down into this created space.
- use dynamic retraction (instead of Greenberg).



OUTCOMES

Modifications to the Subtemporal Selective Amygdalohippocampectomy Using a Minimal Access Technique: Seizure and Neuropsychological Outcomes

Andrew S. Little, MD, Kris A. Smith, MD, Kristin Kirlin, PhD*, Leslie C. Baxter, PhD*, Steve Chung, MD† Rama Maganti, MD†, David M. Treiman, MD†

MINIMALLY INVASIVE VIA TRANSPALPEBRAL ENDOSCOPIC-ASSISTED APPROACH

Mandel, Mauricio "Minimally Invasive Transpalpebral Endoscopic-Assisted Amygdalohippocampectomy." Operative Neurosurgery: December 11, 2015

SUBLABIAL ANTERIOR TRANSMAXILLARY APPROACH

Gardner, Paul A… Gonzalez-Martinez, Jorge A. Novel Sublabial Anterior Transmaxillary Approach for Medically Refractory Mesial Temporal Lobe Epilepsy: A Comparative Anatomic Study. Operative Neurosurgery: November 1, 2022 - Volume - Issue - 10.1227

SUPRACEREBELLAR-TRANSTENTORIAL PARAMEDIAN SAH

Sources (pending)

1. Neurosurgical Atlas >>
2. *Mehmet Volkan Harput et al. The Paramedian Supracerebellar- Transtentorial Selective Amygdalohippocampectomy for Mediobasal Temporal Epilepsy. Operative Neurosurgery: 23 December 2017*

- introduced in 2012 by Professor Türe.

  Ture U Harput MV Kaya AH. et al The paramedian supracerebellar-transtentorial approach to the entire length of the mediobasal temporal region: an anatomical and clinical study. Laboratory investigation. J Neurosurg. 2012;116 (4):773–791
- currently, mainly reserved for ***lesional cases*** – tumors, vascular, etc.

For details of supracerebellar approach – see p. Op300 >>

ADVANTAGES

- MTS is a disease of the hippocampal formation of the archipallium, which is separated from the neopallium by the collateral sulcus.
- ***neocortex-sparing*** surgical route - always remains on the medial side of the collateral sulcus - avoids iatrogenic damage to the neopallium and its vasculature.
- visual function outcome particularly benefits from this highly selective approach.

DISADVANTAGES

- difficult to reach anterior structures; H: addition of endoscope.

PREOP

- ***transthoracic echocardiography*** to detect any right-left shunt ← contraindication for the sitting position.

ANATOMY, TECHNIQUE

Main avoidance – CN4

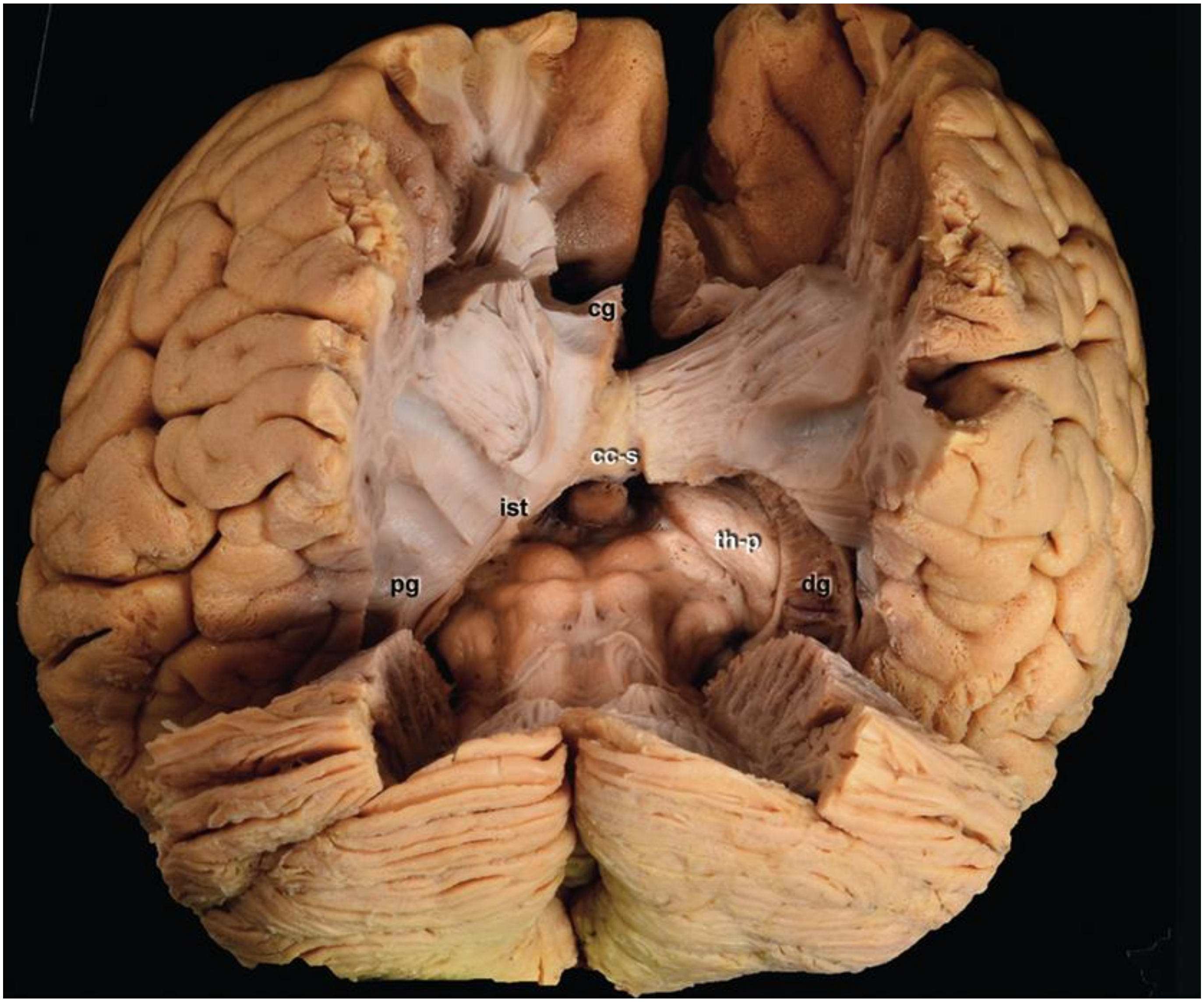
- no need to expose foramen magnum.
- expose from midline to sigmoid sinus.
- craniotomy extends superior to transverse sinus → open dura in U shape (reflect towards transverse sinus – this allows to displace transverse sinus superiorly thus widening corridor).
- it is OK to sacrifice **superior cerebellar bridging vein** (but often can spare it).
- tentorial opening – look for **tentorial sinus** (10-15%) – have Hemoclips ready (risk of venous infarction).

Stratigraphic depiction via brain specimen dissection of relevant anatomical structures involved in the PST.

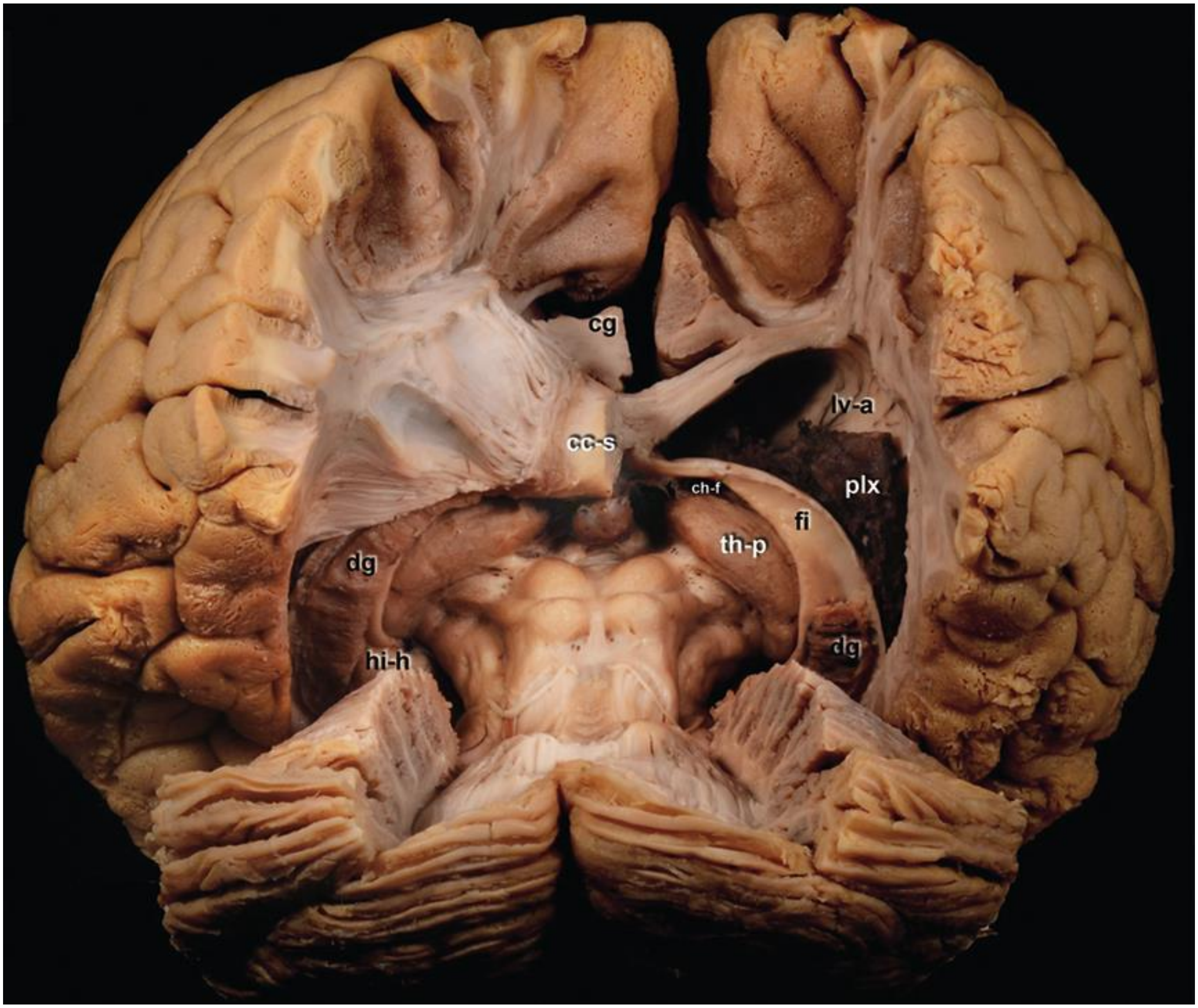
cc-s = splenium of corpus callosum; cg = cingulate gyrus; ch-f = choroidal fissure; cos = collateral sulcus; dg = dentate gyrus; fg = fusiform gyrus; fi = fimbria; hi-h = hippocampal head; ist = isthmus; lv-a = atrium of the lateral ventricle; pb = pineal body; pg = parahippocampal gyrus; plx = plexus choroideus; th-p = pulvinar thalami.

A: Supracerebellar view of the mediobasal temporal lobe after removal of the tentorium and vascular structures:

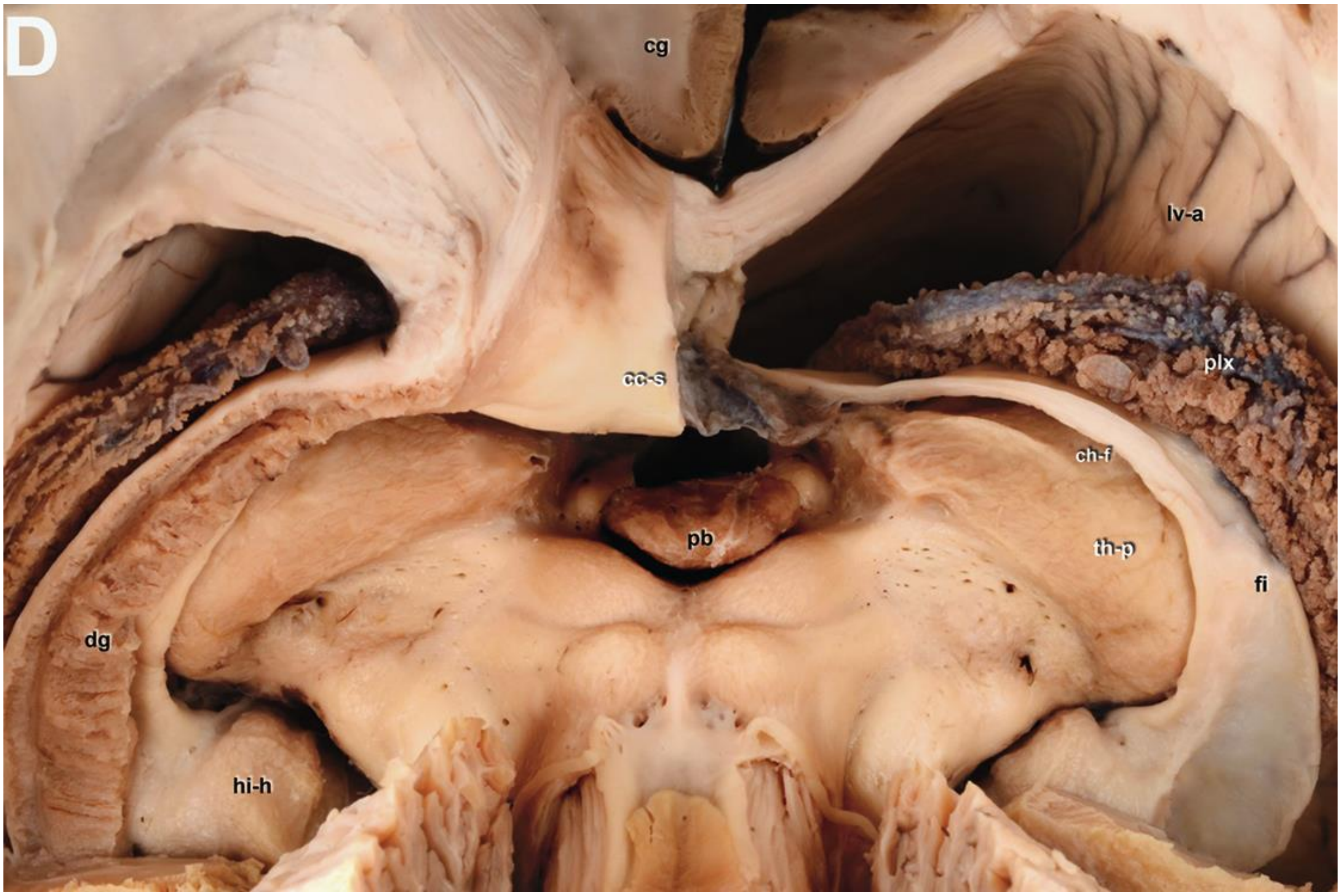
B: Removal of the superior parietal lobule, precuneus, cuneus, and lingual on both sides. Decortication of the cingulate gyrus and PHG on the left side to show the course of their longitudinally running fibers. On the right side both gyri have been removed to expose the retrocommissural portion of the hippocampal formation.



C: On the left side the dissection is brought forward as on the right side in panel B, whereas on the right side the splenial fibers have been removed to show the detailed course of the fimbria.



D: Supracerebellar close-up view of the mesencephalon and diencephalon. The whole hippocampus is now visible. On the right side the dentate gyrus has been removed.



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 TRANSINFERIOR 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

<u>After LITT</u>:

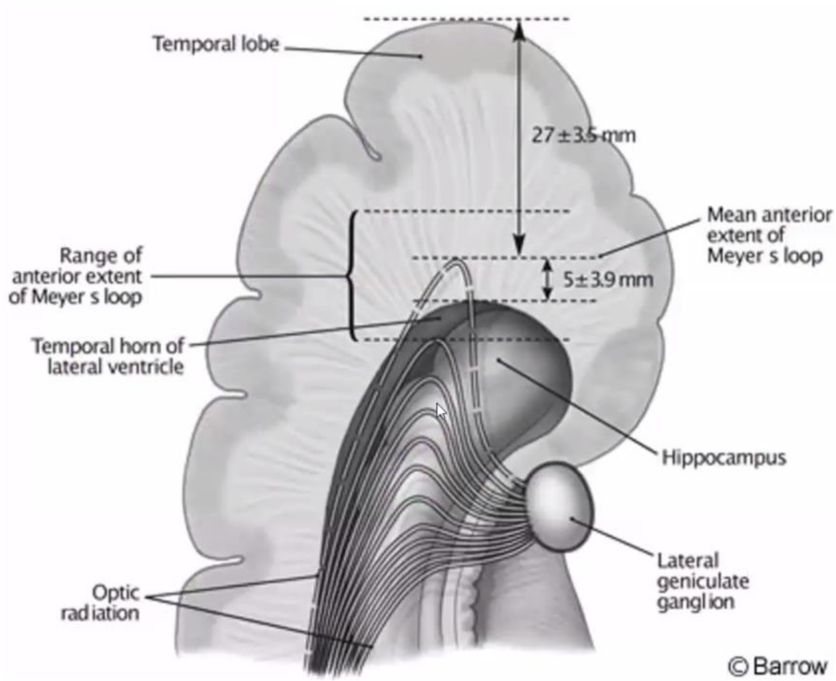
start on POD1: DEX 4 q 6 hours x 1 week → rapid taper

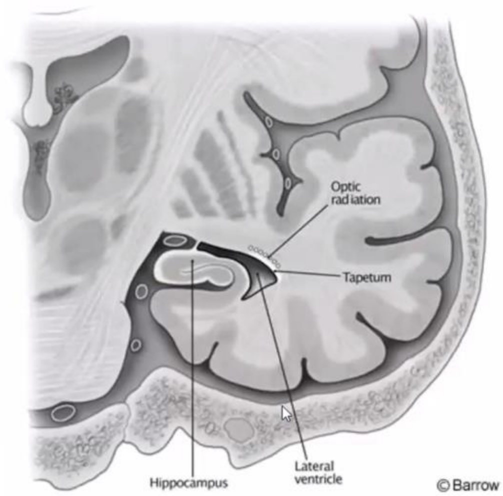
AED tapering – see below >>

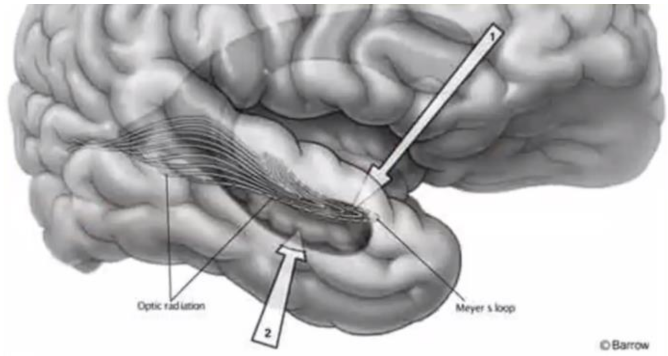
COMPLICATIONS

psychiatric effects of temporal lobectomy → see p. Psy5 >>
LITT complications – see above >>

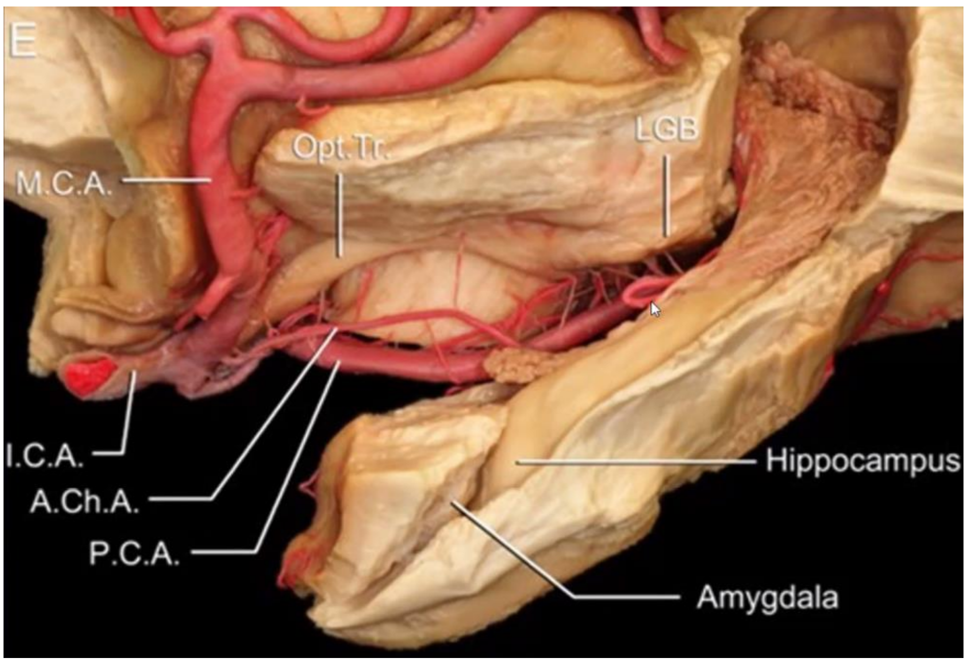
1. **Visual field deficits** - most common deficits!
   a) CONTRALATERAL SUPERIOR QUADRANTANOPSIA ("pie-in-the-sky" defect) - up to 55-78% patients, but usually minor and rarely noticed by patient - from damage to *Meyer loop*.
      — incidence can be minimized with minimal lateral cortical and maximal 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 HEMIANOPSIA - from *vascular damage to geniculate body or optic tract* by similar mechanism as hemiparesis; risk can be minimized with careful microsurgical technique.

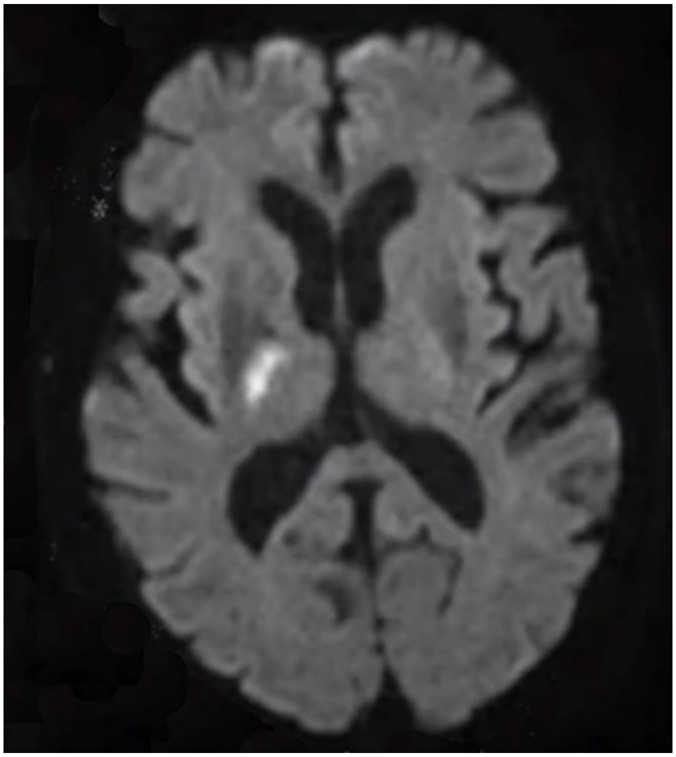






2. **Hemiparesis** (0.39-3.0%; incidence ≈ 5% in older literature) - due to damage (cauterization or tearing) of *small perforating vessels to peduncle or internal capsule* arising from PComA or anterior choroidal artery.
   - paralysis is present ***immediately*** and most usually is ***permanent***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

   Risk to verbal memory with left-sided* temporal resection - 44% (20% for right-sided surgery); risk for developing postoperative deficits is higher for patients with average or better memory and language function if undergoing a left temporal lobectomy (no such relationship has been found in patients who undergo right temporal lobectomy)

   *N.B. verbal memory is on the left side (regardless of hemispheric dominance for language)

   Dr. Spencer: "temporal lobectomy with hippocampal sparing has no neuropsychological benefit – already removed afferents"

   - **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.
- ***memory decline > 50-67% on WADA***.

Dr. Roper: "Don't take one hippocampus and leave the patient with bad hippocampus"

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).

OUTCOMES

Seizure freedom (at 1 year)
ATL – 75% (< 50% in long term)
SAH – 67%
LITT – 58% Engel I (77% Engel I or II)*
RF – 27% (orthogonal trajectories), 78% (along hippo axis)

*60-89% seizure freedom in patients with radiographic evidence of hippocampal sclerosis

If LITT has > 43% seizure freedom and < 40% morbidity risk, then it is equivalent to open resection.

M Attiah et al. Epilepsy Res 115:1, 2015

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

Wiebe S et al. Effectiveness and Efficiency of Surgery for Temporal Lobe Epilepsy Study Group. A randomized, controlled trial of surgery for temporal lobe epilepsy. N Engl J Med 2001 ; 345 : 311 – 318 .

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.

Outcome	Surgery group	Medical group	Statistical significance
Freedom from disabling seizures	58% free	8% free	$p < 0.001$
Freedom from all seizures	38% free	3% free	$p < 0.001$
Change in frequency of disabling seizures	100%	34%	$p < 0.001$
Mean severity of residual seizures (Scale = 10–48)	21.4	26.5	No significant difference
Mean quality of life from 3 to 12 months (Scale 0–100)	72	59	$p < 0.001$
Percentage employed or attending school at 1 year	56.4	38.5	No significant difference

– 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 ≥ 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 transsylvian SAH

Viola Lara Vogt et al. Neuropsychological outcome after subtemporal versus transsylvian approach for selective amygdalohippocampectomy in patients with mesial temporal lobe epilepsy: a randomised prospective clinical trial. Journal of Neurology, Neurosurgery, and Psychiatry 2017 December 22

- 47 patients randomised to subtemporal versus transsylvian 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 / RECURRENT SEIZURES / SURGERY FAILURE

Causes

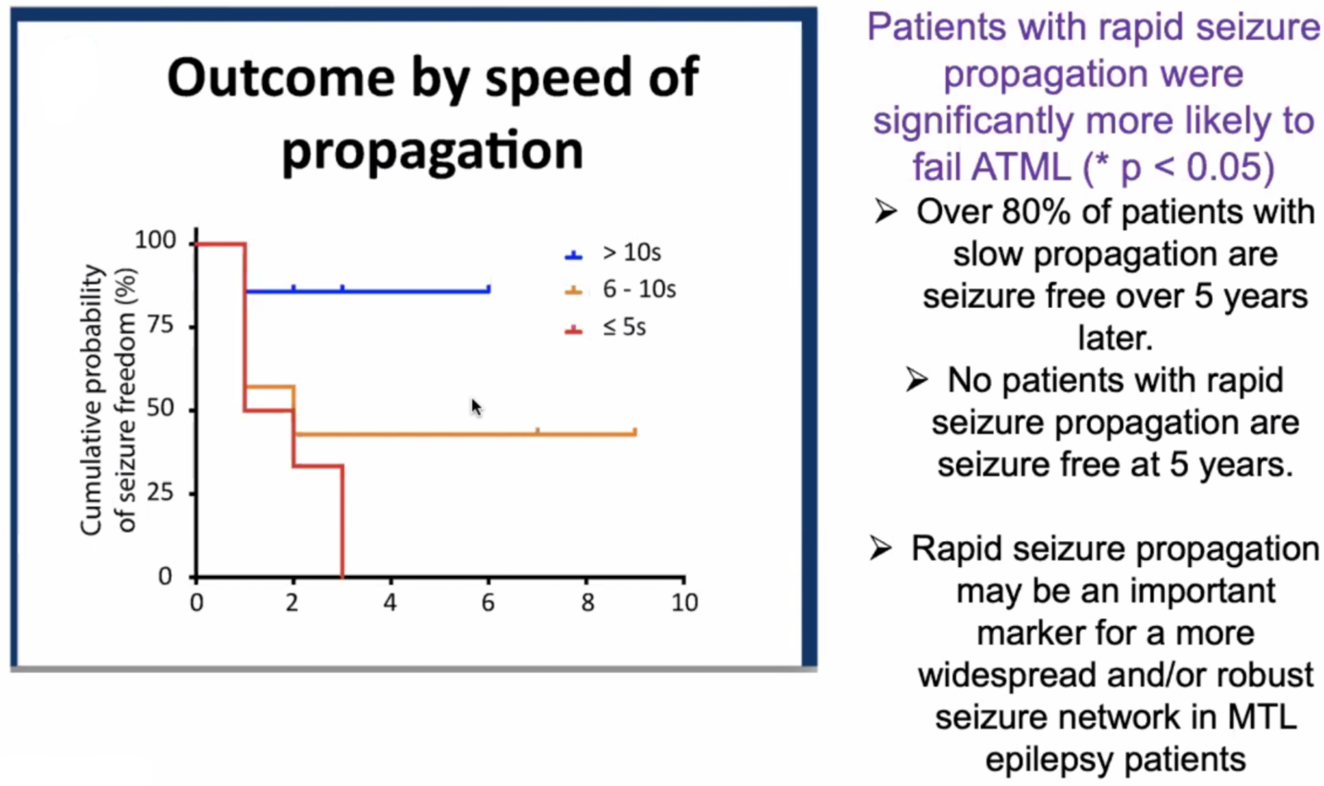
1. **Incomplete resection** of epileptogenic zone
2. **Incorrectly diagnosed** epileptogenic zone
3. **Dual pathology** – discrete lesions in same temporal lobe (e.g. MTS and FCD)
4. **Temporal +** epilepsy
5. **Bitemporal** epilepsy
6. **New** epileptogenesis

- 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

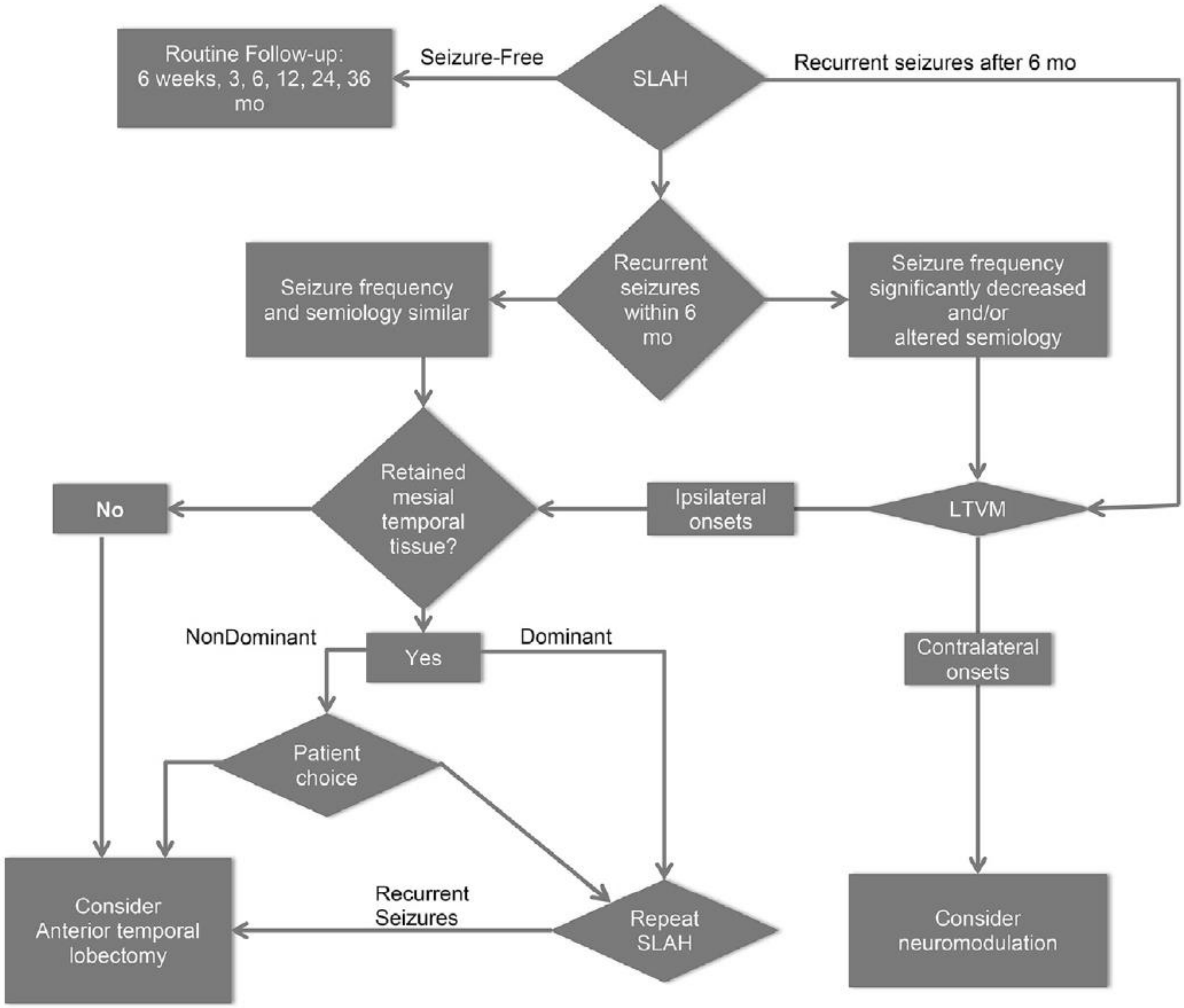
  Bonilha L "Presurgical connectome and postsurgical seizure control in temporal lobe epilepsy." Neurology. 2013; 81(19):1704-10 (ISSN: 1526-632X)

  – 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

- rapid seizure propagation out of temporal lobe is a good predictor of ATL failure:



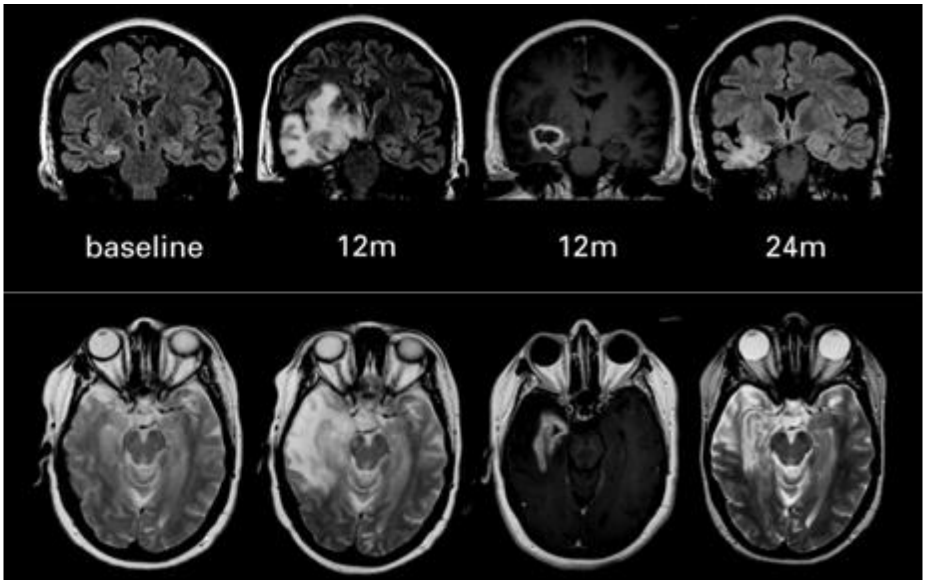
Decision tree for further surgical treatment in non–seizure-free patients after SLAH:



Robert E. Gross, Jon T. Willie, Daniel L. Drane. The Role of Stereotactic Laser Amygdalohippocampotomy in Mesial Temporal Lobe Epilepsy. Neurosurg Clin N Am 27 (2016) 37–50

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:
  - 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% non-inferiority margin = 0.82).
  - 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.
  - 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.

Regis J, Rey M, Bartolomei F, et al. Epilepsia 45:5-4-515, 2004.

- 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

     Bartolomei et al. Neurology (2008 May 6) 70(19):1658-63

- 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.

     Barbaro et al. Neurology (2008 May 6) 70(19):1658-63

BIBLIOGRAPHY for ch. "Epilepsy and Seizures" → follow this LINK
R. **Jandial** "Core Techniques in Operative Neurosurgery" (2011): Procedure 36 – Anteromedial Temporal Lobe Resection.