Selective amygdalohippocampectomy: the trans-middle temporal gyrus approach

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The most common surgical procedure for the mesial temporal lobe is the standard anterior temporal resection or what is commonly called the anterior temporal lobectomy. There are, however, a number of other more selective procedures for removal of the mesial temporal lobe structures (amygdala, hippocampus, and parahippocampal gyrus) that spare much of the lateral temporal neocortex. Included in these procedures collectively referred to as selective amygdalohippocampectomy are the transsylvian, subtemporal, and transcortical (trans-middle temporal gyrus) selective amygdalohippocampectomy. In this manuscript the author reviews some of the surgical details of the trans-middle temporal gyrus approach to the mesial temporal structures. (DOI: 10.3171/FOC/2008/259/E4)

KEY WORDS • mesial temporal lobe epilepsy • middle temporal gyrus • selective amygdalohippocampectomy

Patients with mesial temporal lobe epilepsy may be candidates for surgical treatment of their epilepsy. There are 2 surgical options for these patients. The first option is a standard anterior temporal resection or “anterior temporal lobectomy.” The second option is a more selective removal of the mesial temporal structures, sparing much of the lateral temporal lobe. This procedure is called an SelAH. The SelAH has been available to the epilepsy surgeon for many years. However, not all centers with surgical epilepsy programs offer the SelAH as a surgical option. The procedure was first described by Niemeyer in 1958. There are a number of technical variations of the procedure called SelAH. Included in these variations are the transsylvian approach, popularized by Dr. Yaşargil et al. Other variations include the subtemporal approach, as well as the trans-MTG approach, or what is sometimes termed the transcortical approach. The transcortical approach may not be the best term to use, as both the subtemporal and transsylvian approaches breach the cortex either inferiorly (subtemporal approach) or medially (transsylvian approach) at the limen insula. As a result, it is probably best to refer to the transcortical approach as the trans-MTG approach. The trans-MTG approach is used by many surgical epilepsy centers, and was popularized by Dr. André Olivier at the Montreal Neurological Institute.

Patient Selection

Patient selection is important when deciding which patients may be better served by either a SelAH or an anterior temporal resection. Obviously the SelAH should be reserved for those with a mesial temporal origin of their seizures. Although this statement sounds obvious, in practical terms it may be difficult to prove preoperatively. The ideal patient is one with temporal lobe semiology, a temporal lobe electroencephalographic abnormality, a neuropsychological profile consistent with mesial temporal lobe epilepsy, and a mesial temporal lesion on imaging (usually mesial temporal sclerosis). Patients are rarely considered candidates for SelAH if the mesial temporal region looks normal on MR images. Anterior temporal resection may also be preferable when there are concerning lateral temporal features to their seizure history and investigation. In appropriately selected patients there does not appear to be a significant difference in seizure outcome between the 2 surgical approaches. There is, however, some evidence suggesting an improved neuropsychological outcome in selected patient populations after SelAH. Despite these studies identifying a difference, there are others that have been unable to identify any difference in neuropsychological outcome.

Although SelAH is still offered to selected pediatric patients, there is some evidence to suggest that the outcome in the pediatric population may be different from that expected in the adult population. Clusmann et al. compared the seizure-free outcome after anterior temporal lobectomy and SelAH in a pediatric cohort and found a better outcome after anterior temporal lobectomy (94% vs 74% Engel Classes I and II, respectively). Datta et al. compared the outcome after SelAH in an adult and pediatric cohort and found a better outcome in the adult patient population (100% vs 55%, Engel Classes I and II, respectively). This differential outcome may be due to the variation in pathological characteristics seen in the adult and pediatric populations.

Operative Technique

All SelAHs done at our center are done with the aid of neuronavigation (StealthStation, Medtronic). Although it is...
not absolutely imperative to use neuronavigation, the neuronavigation system is a useful adjunct. The neuronavigation system helps to identify the posterior extent of the neocortecotomy. It also allows a more direct trajectory toward the temporal horn of the lateral ventricle through the white matter stem of the temporal lobe. The neuronavigation system also helps in providing a second measure of the extent of the hippocampal resection as well as the parahippocampal resection. All patients undergo preoperative T1-weighted volumetric MR imaging, which allows operative registration of the patient’s face and intraoperative neuronavigation. Once the patient is brought to the operating room, the patient is positioned supine with a shoulder roll under the ipsilateral shoulder. This allows for rotation of the head in an attempt to place the head parallel to the floor in an almost lateral position. The head is also laterally flexed, allowing the frontal lobes to fall slightly and therefore minimizing the need for retraction. If the patient has a relatively restricted range of cervical rotation, it may be better to position the patient laterally as this permits lateral flexion without the need for superimposed rotation. For the SelAH, it is best not to have the patient’s head completely lateral (parallel to the floor), but rather ~10 or 15° short of full lateral. This provides a more posterior view of the hippocampus.

Approaching the MTG

There are 2 variations of the skin incision that may be used to approach the MTG. A standard curvilinear frontotemporal flap based at the root of the zygoma is the most often used incision at our center. The second type of incision is a linear incision made from the root of the zygoma superiorly, as described by Olivier. Localization of the corticectomy over the MTG is imperative. As a result, it is important to use the neuronavigation system for the linear incision because establishing landmarks is more difficult with the limited exposure offered by this approach. Using either incision, the exposure must be down to the root of the zygoma as this allows the most inferior exposure along the floor of the middle fossa. With an SelAH, the bone exposure down to the root of the zygoma along the floor of the middle fossa is not as imperative as it is with a standard anterior temporal resection. With an anterior temporal resection the neocorticectomy includes the inferior temporal gyrus as well as the occipitotemporal gyrus. With an SelAH the neocortical exposure only requires a view of the MTG.

Once the temporal lobe is exposed, the MTG must be identified. A decision must be made as to the extent or posterior limit of the neocorticectomy within the MTG. A number of possible techniques for limiting the posterior extent of this cortical incision have been developed. Some centers have reported using the central sulcus or the precentral sulcus as the posterior limit for the cortical incision. Others have reported using an arbitrary point 5 cm posterior to the temporal pole on the dominant side and 6 cm on the nondominant side. An alternative approach is to use the navigation system to identify the posterior extent of the neocorticectomy as a line extending from the MTG to the lateral mesencephalic sulcus at the junction between the tegmentum and tectum of the midbrain (Fig. 1). We have identified this point and measured the distance from this line to the temporal pole in epilepsy patients and healthy control individuals. In both control and epilepsy patients, this point is almost always 5 cm from the anterior temporal pole (5.02 ± 0.2 cm; 20 individuals). The length of the neocorticectomy extends ~2–3 cm anterior to this point over the MTG.

After coagulating and dividing the cortex, a CUSA ultrasonic aspirator (Radionics) is used to remove the neocortical contents. The CUSA ultrasonic aspirator is set at very low settings (aspiration 10%, irrigation 20 ml/minute, and amplitude 10%) to enable the most delicate removal of the neocortex without damaging any surrounding pial boundaries. The neocorticectomy is continued with the CUSA ultrasonic aspirator through the white matter of the MTG and temporal stem toward the ventricle. Occasionally, a large bridging vein will overlie the lateral temporal neocortex connecting the sylvian venous system with the inferior temporal venous system. These bridging veins often transect the line of the neocorticectomy. In transecting the neocortical incision they may obstruct the view and approach to the mesial temporal structures. One must be careful in deciding when to sacrifice or preserve these bridging veins. There is some risk associated with sacrificing any large bridging vein of Labbé, even on the nondominant side. The decision when to sacrifice or preserve these veins depends on a number of factors. The surgical risk increases when the vein or the dominant venous drainage of the sylvian system is large. In addition, the risk is increased if the vein is in the dominant hemisphere or is more posterior in the temporal lobe. If the decision is made to preserve this traversing vein, the degree of difficulty of the operation may increase, but this offers the best chance of avoiding a venous infarction perioperatively. These traversing veins, when preserved, can act as tethering elements, making it difficult to open the neocortical incision wide enough to access the mesial structures. In preserving a traversing vein, it is usually important to extend the neocorticectomy to optimize...
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the view of the deeper mesial structures and to lessen the
degree of retraction on the tethering vein.

While using the ultrasonic aspirator to dissect through
the MTG, it is advantageous to stay within the white mat-
ter and not to remove the gray matter from the superior and
inferior banks of the MTG. By leaving a small amount of
gray matter over the pial surface of both the superior and
inferior banks of the MTG, there is slightly less bleeding
than there would be from the otherwise exposed pial
boundaries. The white matter tract of the MTG is followed
down to the white matter of the temporal stem, guided by
the neuronavigation system. Deep to the white matter of the
temporal stem lies the ependymal lining of the temporal
horn of the lateral ventricle.

Intraventricular Portion

On approaching the ventricular lining, the first indica-
tions of a presumptive ependymal surface are the increased
vasculatony along the ependymal surface and the slightly
indurated feeling to the ependymal lining. Once most of the
white matter is removed, the exposed ependymal surface
appears very thin, gray, and translucent. The ventricle is
then entered by breaching the ependymal lining by using
bipolar cautery and a CUSA ultrasonic aspirator. Once the
ventricle is entered, it is important to identify the intraven-
tricular landmarks to aid in orientation. The first landmark
to identify is the choroid plexus, as this identifies the cho-
roidal fissure at the deep medial border of the ventricle. The
second point to identify is the lateral ventricular sulcus,
which is the demarcation between the hippocampus and the
collateral eminence (Fig. 2). The lateral ventricular sulcus
is the point of entry to the parahippocampal gyrus. With the
ventricle opened and the landmarks identified, the next step
is to extend the ventricular opening anteriorly to the end of
the ventricular system and posteriorly to the length of the
cortecctomy.

Retractors can be used to aid in exposing the mesial
structures. It is important to position the cottonoid and me-
dial retractor lateral to the choroid plexus. This helps in
exposing the fimbria for later resection. One should try to
minimize the degree of medial retraction as the brainstem
and vascular structures traversing the basal cisterns are
directly underneath the medial retractor blade. In addition,
it is helpful to position the medial retractor at the posterior
margin of the amygdala. This provides for a posterior limit
of the amygdaloid resection and allows the amygdala to
protrude out into the ventricular system. The lateral retrac-
tor should be positioned more superficially, allowing expo-
sure of the lateral ventricular sulcus and a component of the
collateral eminence. This provides a corridor for removal
of the parahippocampal gyrus. If the lateral retractor is
positioned too deeply, then the window between the lateral
ventricular sulcus and the retractor blade will be too small
to effectively empty the parahippocampal gyrus.

With the ventricle open and retractors in place, the
CUSA ultrasonic aspirator is advanced into the lateral ven-
tricular sulcus, and the parahippocampal gyrus is emptied
down to the pial border. The lateral border of the parahip-
ncampal gyrus is usually identified first, and then the
removal is continued along the floor to the edge of the ten-
torium, which can be visualized through the opaque pial
surface. Medially the subiculum is removed off the hip-

pocampal sulcus, exposing the remainder of the parahip-
ncampal gyrus, which should now be emptied. The em-
ptying of the parahippocampal gyrus can be continued an-
teriorly as it extends toward the anterior entorhinal area and
the ambient gyrus, and curves medially to the uncinate gyr-
uus. Posteriorly the parahippocampal gyrus is removed
back to the lateral mesencephalic sulcus. The posterior
limit of removal of the parahippocampal gyrus can be iden-
tified with either the neuronavigation system or with the aid
of anatomical landmarks.

The neuronavigation system can point directly to the lat-
eral mesencephalic sulcus underlying the pial boundary
mesially. This same point can be identified using anatomical
landmarks. The parahippocampal gyrus begins to dive
away from the operative field as it moves around the crus
cerebri toward the lateral mesencephalic sulcus. Identifying
this curve of the parahippocampal gyrus as it extends down
to the level of the tegmentum is a good anatomical bound-
ary for the posterior margin of the parahippocampal resec-
tion. In my opinion it is important to be complete with the
removal of the parahippocampal gyrus as there is evidence
to suggest that the extent of the parahippocampal gyrus
resection correlates with seizure outcome.1,20

With the parahippocampal gyrus removed, the hippo-
campus can then be folded down into the space previously
occupied by the parahippocampal gyrus. This allows a
longitudinal view of the hippocampus throughout its
length. At the medial border of the hippocampus, lateral
to the choroid plexus and choroidal fissure, a white matter
tract or band can be identified. This is the fimbria fornix
system, which covers the hippocampus (Fig. 3). The fim-
bria can be divided just lateral to the tela choroidea along
its length, back to the margin at which one must resect the
hippocampus. The fimbria is very thin and care must be
taken not to damage the vasculature underlying it. With the
fimbria removed from the head of the hippocampus to the
hippocampal posterior resection margin, the CUSA is then
brought perpendicularly across the hippocampus down to
the hippocampal sulcus. The same can be done at the ante-
rior border of the hippocampal resection. The hippocampus
is now only connected to the mesial structures by its adher-
cence to the hippocampal sulcus. By lightly grasping the
hippocampus on either side of the hippocampal sulcus, the
hippocampus can be teased off the hippocampal sulcus.

The CUSA ultrasonic aspirator can be used to remove
some of the adhesive tissue between the hippocampus and
hippocampal sulcus. The hippocampus can be teased off

FIG. 2. Intraventricular operative view of the hippocampus (H), lateral ventricular sulcus (LVS), amygdala (A), parahippocampal gyrus (PHG), and choroid plexus (CP).
the hippocampal sulcus with surprisingly little effort. One should try to resist the urge to coagulate all the vessels within the hippocampal sulcus. Occasionally the anterior choroidal artery lies within the hippocampal sulcus, and coagulation or damage to this vessel can lead to complications. In addition, coagulation of the hippocampal sulcus causes the sulcus to shrink, making it difficult to use it as a landmark for continued resection after the hippocampus is removed. Often a portion of the head of the hippocampus is left, as it extends more medially and curves from the body of the hippocampus down toward the pes of the hippocampus. This portion of the head of the hippocampus can be removed after the hippocampal body has been removed. If the posterior extent of the hippocampal resection is going to extend past the perpendicular cut made across the hippocampus, then it is important to leave a cottonoid in the temporal horn of the lateral ventricle marking the posterior continuation of the hippocampus. It can be difficult to identify the posterior margin of the hippocampus once the parahippocampal gyrus and anterior hippocampus have been removed. It is possible to follow the choroid fissure and choroid plexus back into the temporal horn of the lateral ventricle, or to use the hippocampal sulcus as a guide to the posterior portion of the hippocampus; however, it is easier to leave a cottonoid marking the posterior margin of the temporal horn of the lateral ventricle.

With the parahippocampal gyrus and the body of the hippocampus removed, attention can now be directed toward the amygdala, the uncus, and the head of the hippocampus. The medial retractor blade placed along the posterior margin of the amygdala allows a posterior demarcation of the amygdaloïd resection. There are no clear borders to identify the extent of the amygdaloïd resection. The intraventricular portion of the amygdala can be used to estimate the total size of the amygdala. We then usually resect ~ 50% of the estimated total size of the amygdala. In truth, we do not have any direct measure of the extent of the amygdaloïd resection until the postoperative MR images are obtained. Intraoperative MR imaging may be helpful in this setting, and it has been shown to be useful as an adjunct in cases of lesional epilepsy. In nonlesional epilepsy, intraoperative MR imaging has also been used to tailor the extent of resection. It may be especially useful in identifying the resection margins of the amygdala. Intraoperative MR imaging is less likely to be helpful in identifying the extent of the resection of the hippocampus, as the hippocampus can be easily identified within the ventricle. In addition there are good intraventricular landmarks for the hippocampal resection (hippocampal sulcus, choroid fissure, and fimbria). It should be kept in mind that, although there is evidence suggesting that the extent of the hippocampal resection is important, there is no clear evidence that the extent of the amygdaloïd resection impacts the seizure outcome.

Once the amygdaloïd resection is completed, attention can then be directed to both the head of the hippocampus, as well as the anterior entorhinal cortex. Extending from the previously emptied parahippocampal gyrus, one can identify and remove the uncus as it dips over the tentorial edge. It is important to be careful on the superior border of the uncus, as the entorhinal sulcus and its pial boundary extend more medially. Occasionally the anterior choroidal artery can dip into the area occupied by the entorhinal sulcus. Therefore, we usually empty the uncus and anterior amygdala until the entorhinal sulcus starts to wrap around medially and more superiorly, and stop at that juncture. At this point the parahippocampal gyrus, hippocampus, amygdala, and anterior entorhinal cortex should be resected. The hippocampal sulcus can be grasped with the forceps and reflected medially and laterally to ensure complete resection of the hippocampal remnants medially and the parahippocampal gyrus laterally. Once the resection is complete the retractors can be withdrawn and the dura is closed.
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Conclusions

The SelAH remains an important tool in the armamentarium of the epilepsy surgeon. In properly selected patient populations, the outcome is at least as good as and potentially better than the standard anterior temporal resection (Figs. 4 and 5). Technically, the operation is no more difficult than a standard anterior temporal resection and in some respects may be easier, because the exposure does not need to be as extensive inferiorly or anteriorly. Epilepsy centers are beginning to evaluate the different surgical approaches to selectively removing the amygdala and hippocampus. There is at least some evidence that the “transcortical” or trans-MTG approach may be preferable to the transsylvian approach.19 It must be kept in mind that the evidence to date does not show a clear benefit to one approach over the other.

Disclaimer

The author reports no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References


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