Neuropsychological outcomes of subtemporal selective amygdalohippocampectomy via a small craniotomy

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OBJECTIVE The objectives of this study were to describe a novel minimal-access subtemporal approach for selective resection of the amygdala and hippocampus in patients with medically refractory mesial temporal lobe epilepsy (MTLE) due to hippocampal sclerosis, and to analyze the related outcomes.

METHODS The authors analyzed data from all cases involving patients with unilateral MTLE due to hippocampal sclerosis who were treated with selective amygdalohippocampectomy via the posterior subtemporal approach through a relatively small craniotomy, without a neuronavigation system, at their institution during the period from September 2010 to September 2012. Data were obtained on baseline characteristics, preoperative evaluations of unilateral mesial temporal sclerosis, surgical complications, and Engel class seizure outcomes. All patients underwent memory testing, IQ testing, and language testing.

RESULTS The mean duration of follow-up was 33.6 months (range 24–48 months). There were no deaths and no cases of significant postoperative morbidity. One patient had a mild complication. At 2-year follow-up, 19 patients were seizure free (Engel Class I outcome). Verbal memory scores obtained at 3 months and at 2 years after surgery were significantly lower than preoperative scores for patients who underwent surgery on the left side of the brain (p < 0.05). Pictorial memory scores were higher following surgery compared with before surgery regardless of whether patients underwent left- or right-sided brain surgery. There was also improvement in performance IQ and total IQ following surgery in both groups. For patients who underwent right-sided brain surgery, verbal comprehension and semantic fluency testing scores were significantly higher at both 3 months and 2 years after surgery than before surgery. For patients who underwent left-sided brain surgery, scores on all language tests were significantly lower at 3 months after surgery than before surgery. Verbal comprehension testing scores returned to the preoperative level at 2 years after surgery.

CONCLUSIONS The posterior subtemporal approach through a relatively small craniotomy allows adequate exposure and safe resection of mesial temporal structures and effectively reduces medically intractable MTLE. It preserves IQ but may have a detrimental effect on verbal memory and language ability.

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KEY WORDS mesial temporal lobe epilepsy; hippocampal sclerosis; posterior subtemporal craniotomy; selective amygdalohippocampectomy; seizure outcome; functional neurosurgery

TEMPORAL lobectomy has been established as a definitive treatment for medically intractable temporal lobe epilepsy.19 When the seizures originate from the mesial part of the temporal lobe only, the lateral temporal neocortex should be preserved at all costs to minimize postoperative neuropsychological dysfunction.5,10,20 The type of operation that spares the lateral temporal neocortex is defined as selective amygdalohippocampectomy (SAH). Surgical approaches to the mesial temporal lobe can be broadly grouped into 3 categories: transsylvian,20,22 transtemporal,1,10,11,17,18 and subtemporal.4,9,12,13,21 Each approach has its advantages and potential pitfalls. Compared with the transsylvian and transtemporal approaches, the subtemporal approach is the most straightforward method to expose the mesiobasal part of the temporal lobe, including the fusiform gyrus and parahippocampal gyrus. This corridor preserves functional temporal lobe tissue in the superior, middle, and inferior temporal gyri. It avoids disruption of the frontotemporal white matter pathways in the temporal stem and the visual fibers near the roof of the
temporal horn that may be sacrificed in other techniques. However, subtemporal approaches afford little working space, risk injury to the vein of Labbé, and require vigorous brain retraction.\textsuperscript{4,5,7,21} To avoid such damage to the temporal lobe, Hori et al. modified the conventional subtemporal approach.\textsuperscript{3} By drilling away the retrolabyrinthine presigmoid petrosal bone, at least 1 cm of additional space below and 1 cm of additional space medially is obtained, in comparison to the space provided by the usual subtemporal approach, and temporal retraction pressure is diminished when approaching from below.\textsuperscript{4} In a subsequent report of 26 cases, Hori et al.\textsuperscript{7} presented encouraging neuropsychological and seizure outcomes, and no injuries to the vein of Labbé were reported. In 2009, Yang et al.\textsuperscript{21} reported similar outcomes using the so-called Hori approach with a large bone flap and a reversed U-shaped skin incision surrounding the auricle.

We refined the posterior subtemporal approach over the shaved roof of the external auditory meatus by using a relatively small craniotomy and selecting a short and direct precise route to the mesial temporal structures. The aims of this study were to describe our refined approach and evaluate the seizure and neuropsychological outcomes.

Methods

This study was a retrospective review of cases involving patients treated for epilepsy due to unilateral hippocampal sclerosis between September 2010 and September 2012 at our institution by means of a selective amygdalohippocampectomy (SAH) via the posterior subtemporal approach through a relatively small craniotomy, without a neuronavigation system. Patients who had undergone surgery for bilateral temporal lobe epilepsy or for the treatment of epilepsy due to other causes, such as tumors, were excluded from the study. All patients included in this study had been referred to the epilepsy center at the Fuzhou General Hospital for surgical evaluation. Patients selected for surgery had seizures that did not respond to medical management. Each patient underwent a standard presurgical evaluation that included: 1) history and physical examination with a description of the seizure semiology; 2) prolonged video-electroencephalography (EEG) for seizure localization; 3) MRI with T1- and T2-weighted sequences to assess hippocampal atrophy and increased T2 signal intensity; 4) interictal FDG-PET; and 5) detailed neuropsychological testing using the Wechsler Memory Scale (Chinese version), the Wechsler Adult Intelligence Scale or Wechsler Intelligence Scale for Children (Chinese version, including Verbal IQ, Performance IQ, and Full-Scale IQ scores), a verbal comprehension test, the Controlled Oral Word Association Test, trail making test, a semantic fluency test, a Chinese naming test (verbal confrontation naming test), and the Rey Auditory Verbal Learning Test (Chinese version). All findings were reviewed and, if appropriate, patients were recommended for posterior subtemporal selective amygdalohippocampectomy (PSSAH) using a relatively small craniotomy at a presurgical multidisciplinary conference. Consensus was not reached if the testing did not indicate laterality or suggested any lateral (neocortical) temporal or extratemporal involvement. Such patients were recommended to undergo multistage surgery involving invasive EEG monitoring. In accordance with the international standard protocol, invasive EEG monitoring is the last step of the seizure localization protocol. It is our policy to minimize the use of invasive intracranial recordings and Wada testing before epilepsy surgery for mesial temporal lobe epilepsy (MTLE) in a developing country. We chose strict selection criteria for a single-stage PSSAH, including patients with classic findings consistent with MTLE, such as complex partial seizures, epileptiform activity arising in the mesial basal temporal structures determined according to analysis of scalp EEG using BESA (Brain Electrical Source Analysis) software 5.2, unilateral hippocampal atrophy with or without T2 signal hyperintensity, and ipsilateral temporal hypometabolism and contralateral normal metabolism.

All patients were followed up in the epilepsy clinic at regular intervals after surgery, including at 6 weeks and 3, 12, and 24 months. A complete neurological examination was performed at every visit, including confrontational visual field testing by the attending neurologist and neurosurgeon. A follow-up MRI scan was performed at 6 weeks after surgery to assess the extent of resection.

All cases were prospectively entered into our epilepsy surgery registry. Clinical data recorded included patient age and sex, side of lesion, presence of mesial temporal sclerosis (MTS), surgical complications, and Engel class outcome. Our database was reviewed and all cases with at least 2 years of follow-up were queried. Twenty-three patients were identified who had undergone surgery between September 2010 and September 2012 and had a minimum of 2 years of follow-up. No patients were lost to follow-up. All patients (n = 23) were diagnosed with unilateral MTS based on radiographic criteria, including a small hippocampus, focus of abnormal signal intensity, and/or loss of anatomical configuration.

This study protocol was approved by the institutional review board of Fuzhou General Hospital of Nanjing Command, PLA.

Operative Technique

After induction of general anesthesia, the patient was placed supine, with the upper body slightly upward and the head rotated contralaterally to the side of trepanation. A generous shoulder roll was placed to limit neck rotation and compression of the jugular vein. After the head was fixed in the pinion, it was turned parallel to the floor, with the vertex inclined slightly downward to keep the deep mesial temporal structures situated caudally to the lateral part of the temporal lobe. This maneuver helped the temporal lobe fall away from the operative field and decrease the amount of retraction required. The surgeon was positioned at the caudal region of the patient’s head throughout the procedure.

A small C-shaped skin incision was made along the hairline around the auricle (Fig. 1A). After the temporal muscle fascia was incised, the scalp–thin muscle flap was retracted downward to the external auditory meatus, exposing the squamous bone to the supramastoid crest and the squamomastoid suture. The bur hole and craniotomy are shown in Fig. 1B. The bur hole was drilled just in front of the meeting point of the supramastoid crest, tempo-
ral squamous suture, and parietotemastoid suture. Care was taken not to drill the bur hole too posteriorly. We usually just exposed the anterosuperior edge of the junction of the sigmoid and transverse sinuses. After drilling the supramastoid crest and the suprameatal triangle and drilling the remaining bony structure at the roof of the external auditory meatus with a high-speed drill system, a C-shaped low temporal craniotomy approximately 2.5 cm in width and 2 cm in height was performed with a craniotomy mill.

Additional drilling of the mastoid near the external auditory meatus and the upper layer of the roof of the lateral portion of the external auditory meatus (to be made thinner, but left intact) (Fig. 1C) further facilitated the upward viewing angle. Open air cells were waxed temporarily and meticulously. The arcuate eminence should remain undrilled to protect auditory function.

During the opening, the brain was relaxed by means of mannitol administration and induction of modest hyperventilation to an end-tidal CO₂ of 30 mm Hg. Sometimes intravenous mannitol was not administered in patients who had obvious temporal lobe atrophy and moderate subarachnoid space and in whom it was easy to remove CSF at the beginning of the intradural procedure.

The temporal dura was incised in an arched fashion and reflected basally. The operating microscope was then introduced. The vein of Labbé usually did not appear in the operative field (it was more superior and posterior to the contour line of the small craniotomy in 20 of the 23 cases). The base of the temporal lobe was slightly elevated by a spatula. Temporobasal bridging veins may be encountered and should be preserved as far as possible. Dissecting the veins free from the cortical surface or from the dura of the middle fossa to the transverse sinus for several millimeters would allow further retraction of the temporal lobe without injury to the veins. At the beginning of the intradural procedure, the arachnoid covering of the inferior temporal sulcus and occipitotemporal sulcus should be dissected to aspirate the CSF slowly, and then the CSF may be aspirated from beneath the temporal lobe to increase brain relaxation. Usually it is not necessary to dissect the ambient cistern to remove CSF, and it is safer to leave the ambient cistern closed when performing this surgery.

The direction of the microscope was changed anteriorly to look into the fusiform gyrus. The fusiform gyrus lateral to the tentorial edge could be identified easily (Fig. 1D). Frameless navigation guidance or ultrasonography may be used to identify the temporal horn and collateral sulcus. Two cotton rolls were placed on the occipitotemporal sulcus to elevate the temporal lobe base minimally. A cortical incision was performed in the fusiform gyrus by means of microsuction and bipolar cutting, or by means of an ultrasonic aspirator, preserving the temporobasal bridging vein. The collateral sulcus was followed upward until the collateral isthmus was encountered. After aspirating the white matter of the collateral isthmus rostrocaudally, the ventricular wall was encountered. The temporal horn could be opened at its tip. When the ventricle was opened, egress of CSF provided additional brain relaxation. With the tip of the ventricle opened widely, the posterior inferior surface of the amygdala was identified just anterior and superior to the choroidal plexus that arises from the choroidal fissure and the head and body of the hippocampus, which forms the floor of the ventricle, were fully visualized. Because there is no longer a requirement for en bloc removal of the hippocampus for biochemical studies, we usually resect the anterior third of the hippocampus-parahippocampus (1.0–1.5 cm in length) en bloc for histological studies (using microscissors and bipolar cautery) and resect the remaining middle portion of the hippocampus-parahippocampus (1.5–2.0 cm) with microsuction and bipolar cautery. The vessels supplying the hippocampus were coagulated and cut as close to the hippocampus as possible, leaving intact the feeding vessels supplying important structures. The amygdala was resected with microdissectors, suction, and low-amplitude bipolar cautery until the pia and arachnoid membranes defining the undersurface of the Sylvian fissure were encountered. Using microdissectors, suction, and ultrasonic aspiration, the remaining tissue of the uncus/amygdala was removed.

If the hippocampus needs to be removed more posteriorly, this can be done easily when the surgeon stands at the rostral side of the patient’s auricle, allowing inspection of the posterior aspect of the temporal horn, and aspirating the tail of the hippocampus to a plane beyond the collicular plate. An adequate viewing angle and magnification of the operating microscope, as well as the use of refined instruments for each purpose, is important for precise manipulation in depth through the small craniotomy. These maneuvers can be performed with less invasion of the temporal lobe by presigmoid drilling than using the usual subtemporal approach. This approach to the left temporal

FIG. 1. Operative technique. A: Photograph showing site of C-shaped scalp incision. B: Volume rendering of CT images showing locations of bone hole and bone flap. The brown color indicates the skull defect at the lowest, posterior edge of the craniotomy, which was filled with bone fragments and dust at the end of the operation. C: Coronal CT (bone window) showing the external auditory meatus and the upper layer of the roof of the lateral potion of the external auditory meatus. D: Diagrammatic sketch of surgical anatomy in MRI style showing the location of the fusiform gyrus. The blue arrows indicate the fusiform gyrus (a) and minimal retraction after removal of CSF (b). Figure is available in color online only.
base is more straightforward than the usual subtemporal approach. The vein of Labbé appeared in the surgical field in only 3 of our cases; it could be preserved without difficulty, with minimal elevation of the temporal base.

It is important to repair the dural opening as completely as possible. The wax sealing the open air cells was removed, then the open air cells were covered by muscle fascia and fixed with glue, the small bone flap was secured with titanium plates, and the empty spaces were filled with bone fragments and dust. The temporal muscle fascia and skin were repositioned, with each layer sutured thoroughly.

**Statistical Analyses**

Data are presented as mean and standard deviation for continuous variables and as number and percentage for categorical variables. Scores of memory testing, IQ, and language testing are presented in box and whiskers plots. Friedman tests were used to compare scores from memory testing, IQ, and language testing before surgery and at 3 months and 2 years after surgery. Post hoc comparisons were performed by means of Wilcoxon signed-rank tests with Bonferroni methods used to adjust for Type I error when multiple comparisons were made. Figures for descriptive statistics were generated by GraphPad Prism 6. Statistical analyses regarding testing of statistical significance were carried out with IBM SPSS statistical software (version 22) (IBM Corp.). A 2-tailed p value < 0.05 was considered significant.

**Results**

The demographic and clinical characteristics of the patients are presented in Table 1. A total of 23 patients (13 male and 10 female) who had undergone PSSAH were included in the study. Their mean age was 29.6 years (SD 11.1 years). The follow-up duration ranged from 24 to 48 months (mean 33.6 months). Nineteen patients (82.6%) had Engel Class I outcomes and all these patients were seizure free 2 years after PSSAH. No patients needed reoperations for retained mesial structures. Only 1 patient had a wound infection (Table 1).

![Figure 2](image)

**FIG. 2.** Box and whisker plots for scores on verbal (upper) and pictorial (lower) memory testing before surgery, 3 months after PSSAH, and 2 years after PSSAH. The box indicates the interquartile range (IQR), the horizontal line indicates the median value, and the bars indicate minimum and maximum values. *p < 0.05.

The median score for Verbal IQ in patients with left-sided brain surgery decreased from 78.0 before surgery to 73.0 at 3 months after surgery (p < 0.05) and then returned to the preoperative level at 2 years after surgery (median 77.0 [IQR 74.0–82.0], p < 0.05) (Fig. 3A). Scores for Performance IQ were highest at 2 years after surgery on either side of the brain (median 85.0 [IQR 77.3–91.0] on the right side and median 87.0 [IQR 81.5–90.0] on the left side) (Fig. 3B). Similar results were also observed for Full-Scale IQ scores—that is, Full-Scale IQ scores were higher at 2 years after surgery (median 85.0 for right PSSAH and 80.0 for left PSSAH) than before surgery (median 79.5 for right PSSAH and 78.0 for left PSSAH) or 3 months after surgery.

### Table 1. Demographic and clinical characteristics*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in yrs (mean ± SD)</td>
<td>29.6 ± 11.1</td>
</tr>
<tr>
<td>Follow-up duration in mos (mean ± SD)</td>
<td>33.6 ± 8.1</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>13 (56.5%)</td>
</tr>
<tr>
<td>Female</td>
<td>10 (43.5%)</td>
</tr>
<tr>
<td>Wound Infection</td>
<td>1 (4.3%)</td>
</tr>
<tr>
<td>Mortality</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Engel Class</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>19 (82.6%)</td>
</tr>
<tr>
<td>II</td>
<td>2 (8.7%)</td>
</tr>
<tr>
<td>III</td>
<td>2 (8.7%)</td>
</tr>
<tr>
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<td>23 (100%)</td>
</tr>
<tr>
<td>Surgery Side</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>10 (43.5%)</td>
</tr>
<tr>
<td>Left</td>
<td>13 (56.5%)</td>
</tr>
<tr>
<td>Seizure-free status</td>
<td>19 (82.6%)</td>
</tr>
<tr>
<td>Reoperation</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

*AED = antiepileptic drug.
* Values represent number of patients (%) unless otherwise indicated.
surgery (median 81.0 for right PSSAH and 77.0 for left PSSAH; all p < 0.05), respectively (Fig. 3C).

In patients who underwent right-sided brain surgery, scores on the verbal comprehension test and the semantic fluency test were higher at 2 years after surgery than before surgery (p = 0.024 for verbal comprehension test and p = 0.045 for the semantic fluency test) and 3 months after surgery (p = 0.024 for the verbal comprehension test and p = 0.033 for the semantic fluency test) (Fig. 4A and D). In patients who had undergone PSSAH on the left side of the brain, scores on all language tests were lower at 3 months after surgery than before surgery (all p < 0.05) (Fig. 4). The verbal comprehension test score returned to the baseline level at 2 years after left-brain surgery (median 83.0, 79.0, and 81.0 for preoperation, 3 months, and 2 years after surgery, respectively).

Illustrative Case

This 23-year-old man was born with a pelvic presentation and suffered asphyxia. When he was 7 years old, he developed complex partial seizures, which were medically intractable. Intercritical scalp EEG analyzed using BESA software 5.2 revealed frequent intercritical spike activities in both temporal areas with left-sided predominance of more than 90%, and prolonged combinatorial video-EEG monitoring and BESA software analysis indicated that all 7 spontaneous seizures originated in the left mesiobasal temporal area. MRI-FLAIR images revealed hippocampal atrophy with increased signal intensity in the left hippocampus (Fig. 5A), and FDG-PET (Fig. 5B) showed left temporal hypometabolism. After comprehensive evaluation for intractable epilepsy, a consensus for surgical treatment was obtained at the multidisciplinary conference. A left subtemporal selective amygdalohippocampectomy was planned. After abundant CSF removal, the temporal lobe was slightly elevated from below and a 2.5-cm-long corticotomy was performed in the center of the fusiform gyrus, preserving the ventral vein riding on the occipitotemporal sulcus. Entering further into the gyrus revealed the wall of the inferior horn. After the temporal horn was opened, the hippocampus was traced from its tip to the point of attachment of the choroidal plexus, and the head of the hippocampus was removed en bloc. Next, the hippocampal body, the uncus, and the parahippocampal gyrus were removed piecemeal. Finally, the amygdaloid nucleus was removed. Other temporal structures, including the inferior temporal gyrus as well as the temporal tip, were preserved. In this case, the vein of Labbé was not disturbing the operative field and therefore it was preserved without difficulty. Postoperative MRI revealed the selective removal of the mesial temporal structures (Fig. 5C), and T2-weighted MR images obtained 6 weeks after the surgery detected no abnormal high-intensity signals caused by surgical damage. At the 2-year follow-up evaluation, the patient was completely free of seizures and showed no neurological deficit.

Discussion

We demonstrated that a durable surgical cure for medically intractable epilepsy using our relatively small craniotomy modified technique for posterior subtemporal SAH is possible in most patients with unilateral MTS based on video-EEG, MRI, and FDG-PET results. This type of pre-sigmoidal approach led to an Engel Class I outcome for almost 83% of patients at 2-year follow-up. Compared with before surgery, at 2-year follow-up patients had significant improvement in pictorial memory and IQ scores, but those patients who underwent surgery on the left side of the brain had a mild but statistically significant decrease in verbal memory. Patients who underwent right-sided brain surgery had significantly improved scores on verbal comprehension and semantic fluency tests at 3 months and 2 years following surgery compared with before surgery, whereas patients who underwent left-sided brain surgery had significantly lower scores on all language tests at 3 months after surgery compared with before surgery, although the verbal comprehension test score returned to baseline level at 2 years after surgery. Our study only included 23 patients, and larger studies would be needed to better assess the neuropsychological outcomes with our refined surgical procedure.

In 1993, Hori et al. first described a modification of the conventional subtemporal approach that was aimed at limiting temporal lobe retraction and thereby reducing the risk of damaging the temporal lobe. Unlike approaches via the anterior subtemporal area, their approach was via the posterior subtemporal area just anterior to the vein of Labbé as the corridor, with the rationale based on the anatomical characteristics of the temporal lobe. Anatomically, the deep medial temporal structure is situated higher.
than the lateral part of the temporal lobe, especially at its rostral portion. According to Talairach et al., at 8 mm anterior to the midcommissural point, the inclination of the mesial temporal lobe to the horizontal plane is about $50^\circ$, whereas at 13 mm posterior to the midcommissural point, the inclination is only $20^\circ$ (Fig. 1D). Thus, to reach the temporal horn and avoid excessive temporal lobe retraction, the surgeon should approach the deep mesial temporal structures upward from below the caudal side of the head to avoid the voluminous and steep anterior section of the temporal lobe. In the initial approach of Hori et al., a large U-shaped incision was made around the pinna. Lumbar drainage assisted with brain relaxation. After a low temporal craniotomy was fashioned, the temporal lobe was retracted and the tentorium was cut for additional working area. The operating microscope was positioned parallel to the inclination of the tentorium or temporal base. The fusiform gyrus was removed en bloc (or removed piecemeal subpially), and the temporal horn of the lateral ventricle was entered. Resection of the hippocampus proceeded to the level of the choroidal point. If the hippocampus needed to be removed more posteriorly, this was done easily with the surgeon standing at the rostral side of the patient’s auricle, allowing inspection of the posterior aspect of the temporal horn. The amygdala was removed as the final step. Subsequently, Hori et al. modified the approach. By drilling away the retrolabyrinthine presigmoid petrosal bone, at least 1 cm more space below and 1 cm more space medially was obtained than in the conventional subtentorial approach, and temporal retraction pressure was diminished. In a subsequent report of 26 cases, there were encouraging neuropsychological and seizure outcomes. There were no injuries to any bridging veins, including the vein of Labbé. In 2009, Yang et al. reported a similar outcome with the so-called Hori approach using a generous bone flap and incision. No injuries to the vein of Labbé and no visual field defects were reported. The more the cranial base technique becomes established, the more it can be refined and limited; excessively large craniotomies will no longer be justifiable for such operations.

If not specified, SAH refers to the surgical intervention of mesial temporal sclerosis (also called hippocampal sclerosis). Transcortical SAH is the most widely used method, but it may not assure the integrity of the lateral temporal neocortex, temporal stem, and fibers of the optic radiation. Transsylvian SAH is a classic selective resection that has been used in studies. However, surgical intervention involving the sylvian fissure and basal cisterns (which contain major vessels and nerves), which should be done in this procedure, is associated with a high risk for complications. Moreover, transsylvian SAH involves transection of the temporal stem/uncinate fasciculus, which contains fibers connecting frontal and temporal structures. Furthermore, this approach has a narrow view and presents difficulties for managing the tail of the hippocampus. The subtentorial approach can be classified into 2 types: 1) the tilt angle of the anterior temporal base is large and 2) the tilt angle of the posterior temporal base is relatively small. Thus, the subtentorial approach along the anterior temporal base.

**Fig. 4.** Box and whisker plots of language testing scores before surgery and at 3 months and 2 years after surgery: verbal comprehension test (A), Controlled Oral Word Association test (COWAT) (B), trail making test (C), semantic fluency test (D), Chinese naming test (E), and Rey Auditory Verbal Learning Test (F).
involves difficulties in exposing the medial temporal lobe. The subtemporal approach along the posterior temporal base is preferred because it has a wide view; however, it may cause wide damage. Our modified approach compared with other approaches (such as transsylvian or transcortical SAH) may ensure the integrity of the lateral temporal neocortex, temporal stem, and fibers of the optic radiation. Moreover, our modified approach is also convenient for the surgical intervention of lesions in the posterior portion of the temporal horn and temporal-occipital junction at the brain base. In addition to being used for the treatment of hippocampal sclerosis, it can also be used for the surgical treatment of other conditions, including ganglioglioma, cavernous hemangioma, and tentorial meningioma. After this study, we used this approach for such conditions and achieved favorable efficacy (data not shown).

In our study, patients who had surgery on the left side of the brain had significant loss of verbal memory. In contrast, Hori et al. reported no loss of verbal memory in their patients; there were no significant differences in verbal memory between patients who underwent surgery on the dominant hemisphere and those who underwent surgery on the nondominant hemisphere, and there was no significant loss of memory postoperatively compared with preoperatively. In addition, some other studies in which subtemporal SAH was performed also reported no loss of verbal memory. However, 2 reviews of the literature found that there have also been studies in which significant loss of verbal memory occurred following SAH. Spencer and Burchiel concluded that "the more selective approach does not obviate the need for careful preoperative cognitive assessment, particularly with respect to risk of verbal memory worsening following temporal lobe SAH." In recent studies it was found that approximately one-third of patients who underwent SAH on the left side of the brain had loss of memory, verbal intellect, and naming, whereas patients who had surgery on the right side of the brain mainly had loss of visual memory. Our results seem to confirm the findings of previous studies in which loss of verbal memory was reported after surgery on the dominant side of the brain; however, we cannot determine whether it is due to any disruption of unknown functional networks of mesial temporal lobe structures. Further studies are warranted to clarify these results. There are different concepts with regard to standard anterior temporal lobectomy. For example, in the Spencer type of anterior temporal lobectomy, the extent of lobectomy is smaller than previously reported, and thus the cognitive outcome seems similar.

Our study had several limitations. This case series was small, with only 23 patients included. The duration of follow-up averaged 33.6 months, which is not long enough to assess the long-term outcome of surgery. We only included patients with epilepsy due to unilateral hippocampal sclerosis; patients with bilateral temporal lobe epilepsy and patients with epilepsy from other causes, such as tumors, were excluded. Further studies are needed to address these limitations. Notably, our modified approach involves complexity with a presigmoid surgical approach and learning curve requirements must be taken into consideration. Dr. Yang (the first author) learned the surgical techniques directly from Professor Hori in Tokyo Women’s Medical University. Before he did the operations in the current study, the author had performed Hori-type subtemporal SAH in 80 cases. Step by step, the craniotomy scope was reduced to keep enough working space and minimize iatrogenic damage to temporalis muscle and skull. We applied lumbar drainage assisted with brain relaxation for the first 3 cases in the current case series. Step by step, the craniotomy scope was reduced to keep enough working space and minimize iatrogenic damage to temporalis muscle and skull. We applied lumbar drainage assisted with brain relaxation for the first 3 cases in the current case series. Starting with the fourth case of this series, we found that mannitol administration, induction of modest hyperventilation, and slow CSF release could make the brain slack without lumbar drainage. However, we cannot exclude the possibility that lumbar drainage may still be needed under special conditions.

**Fig. 5.** Illustrative case. In each set of images, the images labeled 1 and 2 show sections through the hippocampal head and the hippocampal body, respectively. **A:** Preoperative coronal FLAIR MR images showing left hippocampal sclerosis. **B:** Preoperative coronal PET images showing a significant reduction in the left mesial temporal cortex metabolism. **C:** Postoperative coronal FLAIR MR images obtained 6 weeks after selective resection of scleroid medial temporal lobe structures showing no abnormal high-intensity signals caused by surgical injury of the inferior temporal gyrus. Figure is available in color online only.
Conclusions

In this paper, we have described modifications to Hori’s subtemporal approach for SAH that involved using a relatively small craniotomy technique. Important aspects of the approach include a low temporal small craniotomy over the shaved roof of the external auditory meatus, minimal retraction by means of cotton rolls, incision in the fusiform gyrus, and subpial resection of the hippocampus and amygdala. The preliminary data presented here indicate that this approach offers effective seizure control, which is comparable with that achieved by other SAH techniques, with visual fiber preservation. There were no significant changes in IQ; however, patients who underwent left-sided posterior selective SAH with a relatively small craniotomy had a mild but statistically significant decrease in verbal memory. This loss of verbal memory confirms the findings of several studies; however, other studies of SAH found no loss of verbal memory. Patients who underwent right-sided brain surgery had statistically significant improvement in verbal comprehension and semantic fluency, whereas patients who underwent left-sided brain surgery had significant reduction in language testing scores. Further studies are needed to clarify the neuropsychological effects of this type of surgery for patients with medically intractable epilepsy.

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References


Disclosures

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

Author Contributions

Conception and design: Yang, Zhang, Pei, Lin, Zhong. Acquisition of data: Zhang, Mei, Chen, Jia, Zheng. Analysis and interpretation of data: Mei, Chen, Jia. Drafting the article: Yang, Lin, Jia. Reviewed submitted version of manuscript: all authors. Statistical analysis: Zhang, Jia. Study supervision: Yang.

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