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Surgical Technique and Outcome of Extensive Frontal Lobectomy for Treatment of Intracable Non-lesional Frontal Lobe Epilepsy

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Abstract

Although extensive frontal lobectomy (eFL) is a common surgical procedure for intractable frontal lobe epilepsy (FLE), there have been very few reports regarding surgical techniques for eFL. This article provides step-by-step descriptions of our surgical technique for non-lesional FLE. Sixteen patients undergoing eFL were included in this study. The goals were to maximize gray matter removal, including the orbital gyrus and subcallosal area, and to spare the primary motor and premotor cortexes and anterior perforated substance. The eFL consists of three steps: (1) positioning, craniotomy, and exposure; (2) lateral frontal lobe resection; and (3), resection of the rectus gyrus and orbital gyrus. Resection ahead of bregma allows preservation of motor and premotor area function. To remove the orbital gyrus preserving anterior perforated substance, it is essential to visualize the olfactory trigone beneath the pia. It is important to observe the surface of the contralateral medial frontal lobe for complete removal of the subcallosal area of the frontal lobe. Thirteen patients (81.25%) became seizure-free and three patients (18.75%) continued to have seizures. None of the patients showed any complications. The eFL is a good surgical technique for the treatment of intractable non-lesional FLE. For treatment of epilepsy by eFL, it is important to resect the non-eloquent area of the frontal lobe as much as possible with preservation of the eloquent cortex.

Key words: intractable frontal lobe epilepsy, non-lesional frontal lobe epilepsy, extensive frontal lobectomy

Introduction

Frontal lobe epilepsy (FLE) accounts for 20–30% of partial epilepsies.[1,2] Approximately 30% of partial seizure patients suffer from drug-resistant seizures,[3] and patients with drug-resistant epilepsy may require surgery. FLE surgery accounts for approximately 10–20% of all epilepsy surgeries, and is the second most common type of operation after those for temporal lobe epilepsy (TLE).[2,4] However, it has been reported that the results of surgical treatment for FLE (45–60%) are generally unsatisfactory in comparison with those for TLE.[4–6] One reason for the poor surgical outcomes of FLE is the lack of a consistent target organ in FLE in contrast to targeting of the hippocampus in TLE. Neuroimaging techniques have been suggested to be useful for diagnosis of the seizure onset zone. Especially, magnetic resonance imaging (MRI) has become the standard modality for presurgical patients. Despite advances in MRI, MRI-negative FLE ("non-lesional FLE") accounts for about 30% of neocortical epilepsy cases.[6–8] Surgical resection of an epileptogenic lesion was shown to be associated with favorable postoperative outcome. In contrast, despite the advent of advanced imaging techniques, such as interictal and ictal electroencephalography (EEG), long-term video EEG, chronic intracranial EEG (iEEG), intraoperative electrocorticography (ECoG), and positron emission tomography (PET), surgical treatment of non-lesional FLE is one of the most challenging areas in epilepsy surgery.[5]

Frontal lobectomy is a commonly performed neurosurgical procedure, especially for treating brain tumors, such as poorly marginated low-grade glioma, cerebral hemorrhage and contusion. However, the main purpose of classical frontal lobectomy is to resect the lesion.[9]

A different concept is required in treatment of non-lesional FLE. This strategy requires resection of the

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non-eloquent frontal lobe area as much as possible but should not damage to eloquent area. The most important goal is to properly resect part of the anterior cingulate gyrus, orbital gyrus, and subcallosal area. However, the importance of resecting these parts has not attracted sufficient attention outside of the treatment of epilepsy. We call the frontal lobectomy that includes not only the classical resection area but also part of the anterior cingulate gyrus, orbital gyrus, and subcallosal area "extensive frontal lobectomy" (eFL). There have been a few reports regarding the surgical anatomy and technique of eFL. This paper will present the surgical anatomy and techniques of eFL and show the postoperative seizure outcomes in patients undergoing this operation.

Materials and Methods

Surgical strategy

All patients underwent MRI, single-photon emission computed tomography (SPECT), sleep activation EEG, and long-term video EEG as preoperative examinations. It was necessary for diagnosis of non-lesional FLE to confirm the typical frontal lobe seizures by long-term video EEG and the epileptiform discharges beginning from the area of the prefrontal lobe or frontal lobe on sleep activation EEG. Patients with lesions detected on MRI or SPECT underwent limited frontal lobectomy. Patients without any lesions on MRI and SPECT were diagnosed as non-lesional FLE. Focal resection is performed in non-lesional FLE patients if long-term video EEG and ECoG reveal a matched epileptogenic zone.

The iEEG is adopted for FLE patients whose laterality is difficult to identify, who are suspected to have another additional epileptogenic zone or localized epileptogenic zone in a frontal lobe, such as the temporal lobe.

The eFL is adopted in our department for non-lesional patients without localized findings on long-term video EEG and ECoG.

Patients

Operations for FLE were performed in 35 patients at the Department of Neurosurgery, Osaka City University Hospital, Osaka, Japan, between April 2000 and March 2010, in 33 patients at the Department of Neurosurgery, Tokyo Metropolitan Hospital, Tokyo, Japan, between April 2010 and March 2017, and in 11 patients at the Department of Neurosurgery, Kumagaya General Hospital, Saitama, Japan, between April 2017 and August 2018 (all operations performed by M.M.).

Lesions such as brain tumors or cortical dysplasia localized in the frontal lobe were detected in 44 of the total of 79 patients (56%) on MRI or SPECT. Thirty-five patients were diagnosed with non-lesional FLE; nine patients were followed up for <1 year (eFL was performed in three patients); eight patients underwent localized frontal lobectomy because of the focal epileptogenic zone [one in the supplementary motor area (SMA), six in the orbital gyrus, and one in the motor area; multiple subpial transection was performed in this latter case]; two patients were suspected to have multifocal epilepsy and underwent frontal lobectomy with an additional procedure (corpus callosotomy, temporal lobectomy). The iEEG was performed in seven patients, two of whom had ictal epileptic discharge at the orbital gyri and underwent localized frontal lobectomy. Sixteen patients (nine males, seven females) who underwent eFL were included in this study. Data collected included age at seizure onset and surgery, gender, side of surgery, preoperative MRI, preoperative total intelligence quotient (TIQ) score, and seizure outcome (according to the Engel classification) at least 1 year after the operation.[10] Five and 11 patients had surgery on the left and right hemispheres, respectively. The dominant hemisphere was left in all of these cases.

The mean age of patients who underwent epilepsy surgery was 27.25 years (range 11–45 years, SD 9.42), mean age at epilepsy onset was 6.88 years (range 3–19 years, SD 5.14), and preoperative mean TIQ score was 92.08 (range 70–103, SD 13.01). There were no statistically significant differences in characteristics between the patients according to the side of surgery (Table 1).

The study protocol was reviewed and approved by the Institutional Review Boards of the participating institutions.

Surgical anatomy and function

The frontal lobe is the largest area of the brain, and includes about one-third of the whole hemispheric

Table 1 Demographic characteristics and clinical data of the patients

	Right FLE (n = 11)	Left FLE (n = 5)	P-value
Gender			
Male (%)	54.55	60	0.844
Age at surgery (yr)	29.64 (3.01)	22 (3.33)	0.151
Age at onset of epilepsy (yr)	7.75 (2.95)	6 (0.41)	0.229
Preoperative TIQ	93.13 (4.36)	90.4 (6.90)	0.656
Seizure free (%)	73	100	0.242

Data are expressed as mean (standard error) unless otherwise indicated. Student's t-test, Wilcoxon rank sum test and Welch's test were used where appropriate. FLE: frontal lobe epilepsy, TIQ: total intelligence quotient, yr: years.

surface. The lateral surface of the frontal lobe is bounded by the central sulcus (rear), by the superior hemispheric border (above), and by the sylvian veins (below).

The lateral surface is divided by three sulci into four gyri (precentral gyrus, superior, middle, and inferior gyri). The precentral gyrus is bounded in front by the precentral sulcus and to the rear by the central sulcus. The superior, middle, and inferior gyri are located in front of the precentral gyrus, and are divided by the superior and inferior frontal sulci.

The inferior frontal gyrus includes the pars orbitalis, pars triangularis, and pars opercularis.

The medial surface of the frontal lobe consists mainly of the superior frontal gyrus (outside) and the cingulate gyrus (inside). The medial area under the rostrum of the corpus callosum is called the subcallosal area, which includes the paraolfactory gyrus and the paraterminal gyrus, which are connected to the superior frontal gyrus and the cingulate gyrus.

The basal surface of the frontal lobe is divided by the olfactory sulcus into the rectal gyrus and the orbital gyrus. The H-shaped orbital sulcus divides the orbital gyrus into the anterior, posterior, lateral, and medial areas. The posterior orbital gyrus and the anterior perforated substance are bounded by the medial and lateral olfactory striae. The anterior perforated substance is situated just behind these olfactory striae. The olfactory trigone is a small triangular area located among these olfactory striae. The anterior perforating arteries are a group of arteries that pass through the anterior perforated substance to the deep brain, and include the branch of the internal carotid artery, the perforator of the middle cerebral artery, such as the lateral striae arteries, the perforator of the anterior cerebral artery (ACA), such as the recurrent artery of Heubner, and the anterior choroidal artery. The anterior perforating arteries supply blood to many important structures in the deep brain (e.g., the caudate nucleus, putamen, internal capsule, pallidus, and thalamus). The primary motor cortex lies along the precentral gyrus, and the premotor area lies in front of the precentral gyrus. The SMA lies in the midline surface of the hemisphere anterior to the precentral gyrus. The speech area, so-called Broca's area, is a region in the posterior-inferior frontal gyrus of the dominant hemisphere, i.e., the pars opercularis and the pars triangularis. Damage to the primary motor cortex may result in motor deficits in corresponding body parts. The roles of the premotor cortex include decision making, movement selection, and planning, and damage to this area results in inability to perform such tasks.[11] The SMA is related to the selection, preparation, initiation, and execution of voluntary movements. It was reported previously that 33.3% of all patients with SMA resection had permanent deficits that interfere with activities of normal living, such as hemiparesis, motor aphasia, and SMA syndrome.[12] Damage to the pars opercularis and the pars triangularis can cause motor aphasia.

Furthermore, it is important to understand the anatomy and function of the white matter as well as that of the gray matter. The associated fibers between frontal and other lobes include the superior longitudinal fasciculus (SLF), the arcuate fasciculus (AF), the inferior frontooccipital fasciculus (IFOF), the uncinate fasciculus (UF), the cingulum, and the frontal aslant tract (FAT) (Figs. 1A–1C).

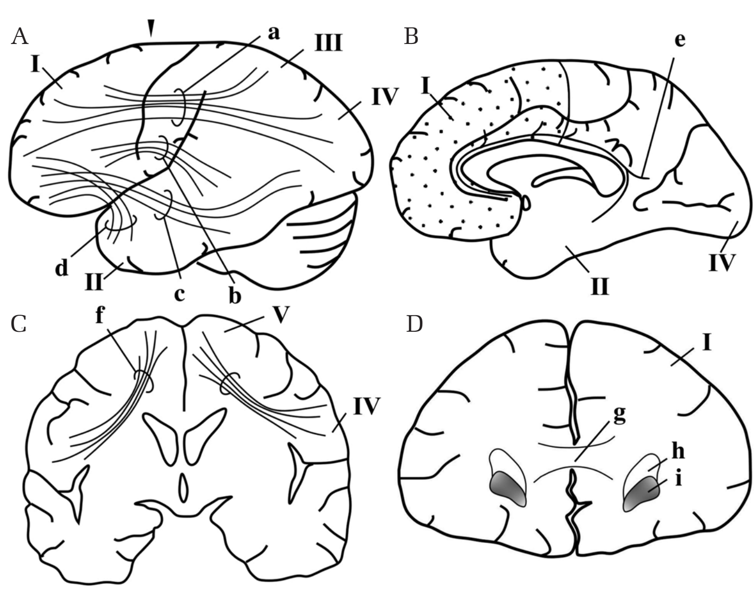

Fig. 1 Schematic diagram of white matter tracts connecting with the frontal lobe (A–C). The *dotted area* shows the area of resection in extensive frontal lobectomy (eFL) (B). Schematic of the coronal cross-section at the point of the *black arrowhead* in A (C). Schematic showing the coronal cross-section of the frontal lobe as for eFL (D). (a) Superior longitudinal fasciculus (SLF), (b) arcuate fasciculus (AF), (c) inferior frontooccipital fasciculus (IFOF), (d) uncinate fasciculus (UF), (e) cingulum, (f) frontal aslant tract (FAT), (g) corpus callosum, (h) section of IFOF, (i) section of UF. (I) Frontal lobe, (II) temporal lobe, (III) parietal lobe, (IV) occipital lobe, (V) supplementary motor area (SMA) and pre-SMA, (VI) pars opercularis of inferior frontal gyrus.

The SLF is the largest interlobar connection between frontal, temporal, and occipital lobes. The SLF has three distinct branches, i.e., SLF-I, II, and III.[13] SLF-I connects the superior parietal lobule and precuneus to the superior frontal and some anterior cingulate areas.[14] SLF-II connects the anterior intraparietal sulcus and the angular gyrus to the posterior regions of the superior and middle frontal gyrus.[14] SLF-III originates in the intraparietal sulcus and inferior parietal lobule, and terminates in the inferior frontal gyrus.[14] The major role of the SLF is in the visuospatial attention network.[15] The right hemisphere is known to be dominant for attention. Moreover, as hemi-inattention is most commonly caused by right parietal lesions, it is possible that the left hemisphere attends to contralateral stimuli, whereas the right attends to both contralateral and ipsilateral stimuli.[16] In particular, damage to SLF-II was shown to be the best predictor of left spatial neglect.[17]

The AF connects the posterior regions of the frontal lobe to the temporal lobe,[18] and constitutes the dorsal route of the auditory-language pathway connecting Wernicke's area with Broca's area.[19] The dorsal pathway from Wernicke's area to Broca's area includes the arcuate fasciculus and shows connectivity to Brodmann area 40, the lateral superior temporal gyrus, and the lateral middle temporal gyrus. A ventral route has been demonstrated to connect via the external capsule/uncinate fasciculus and the medial superior temporal gyrus.[19] The pathways are stronger in the dominant hemisphere, and their damage causes conduction aphasia.[20]

The IFOF is a large white matter tract, which originates in the occipital and parietal lobes and terminates in the inferior frontal lobe.[21] After leaving the occipital lobe, the IFOF passes through the temporal stem and then finally enters the frontal lobe. The fibers spread to form a thin sheet and terminate in the inferior frontal gyrus, the medial frontoorbital region, the frontal pole, and the superior frontal gyrus.[14,18] The IFOF primarily functions in sematic language processing with the middle longitudinal fasciculus and inferior longitudinal fasciculus.[21] Indeed, direct electrostimulation of the left IFOF during awake surgery induces sematic disorder.[22]

The UF connects the anterior part of the temporal lobe with the orbital and polar frontal cortex.[14] The UF originates from the temporal pole, uncus, parahippocampal gyrus, and amygdala. The fiber runs through the external capsule before terminating in the lateral orbitofrontal cortex, cingulate gyrus, and the frontal pole. The UF is associated not only with higher language function but also emotion because it is part of the limbic system.[23]

The cingulum contains fibers of various lengths. The long fibers connect the anterior temporal gyrus to the orbitofrontal lobe.[24] Shorter fibers connect to adjacent areas of the cingulate cortex, such as the frontal, parietal, temporal, and occipital lobes.[24,25] The major role of the cingulum is in executive and cognitive functions.[15]

The FAT is a direct pathway connecting Broca's region with the SMA and pre-SMA.[26] This tract is left lateralized in right-handed subjects, suggesting a possible role in language.[27] Indeed, damage to the FAT is correlated with reduced verbal fluency performance.[27]

However, the relationship between damage to the white matter and higher brain dysfunction has not been clarified in detail.

Surgical technique

Positioning, craniotomy, and exposure: The patient is placed in the supine position with the back and lower legs elevated at approximately 10°. The head is placed in a neutral position with the chin slightly tucked ensuring separation of at least two finger widths between the chin and sternum. This position allows sufficient observation and complete resection of the posterior orbital gyrus and subcallosal area. Both a smoothly curved bilateral frontal skin incision and extended question mark skin incision in the frontotemporoparietal area are useful. It is necessary for the posterior margin of the skin incision to be made approximately 10 mm posterior to bregma.

Burr holes are made at approximately 10 mm posterior to bregma, approximately 60 mm ahead of bregma, approximately 10 mm lateral to the midline at the midpoint of these two burr holes just below the highest point of the frontozygomatic suture, and at the intersection of the coronal suture and the linear temporalis. Frontal sinus violation often occurs in patients who have developed frontal sinus. In this surgery, however, it is not necessary to perform craniotomy just above the supraorbital border because it is possible to observe the orbital gyrus after resection of the lateral cortex of the frontal lobe. Therefore, we always attempt to avoid opening the frontal sinus. When the frontal sinus is opened, it is necessary to remove the mucosa, and it must be packed with abdominal fat to prevent cerebrospinal fluid (CSF) leakage.

The dura mater is opened in a radial manner to achieve wide exposure of the frontal lobe with its medial base facing the middle to protect the superior sagittal sinus (SSS) and draining veins.

Lateral frontal lobe resection: After the dura mater is folded and tacked up, it becomes possible to visualize almost all of the superior/middle frontal gyrus and the upper part of the inferior frontal gyri. For regular eFL, the posterior limit of resection is just above bregma. It has been reported that central and precentral sulci are located 47.8 ± 5.9 and 26.8 ± 7.2 cm behind bregma.[28] Therefore, this resection line ahead of bregma preserves the function of the motor and premotor areas. It is also important to preserve the bridging vein from the motor area. The next step involves dissection of the interhemispheric fissure to expose the surface of the corpus callosum, which is a landmark for the depth limit of resection. If it is difficult to dissect the interhemispheric fissure, it is advisable to resect the lateral frontal surface in advance to prevent damage to the interhemispheric surface.

The medial margin of resection is established 10 mm mesial to the medial surface. At this stage, it should be noted that the arterial branches entering the motor and premotor areas of the medial surface are preserved. If the medial surface of the superior frontal gyrus is resected deeply in the first stage, there is a risk of the callosomarginal artery and the pericallosal artery being damaged accidentally. After this stage, removal of tissue inside the hemisphere should be performed by subpial aspiration to protect contralateral structures. In the first step of lateral frontal lobe resection, only the superior and middle frontal gyri should be removed, without removing the inferior frontal gyrus and the orbital gyrus. In cases of surgery for the dominant side, the inferior frontal gyrus must be preserved. However, in cases of surgery on the non-dominant side, the inferior frontal gyrus is also removed completely, after which the sylvian veins can be observed on the other side of the pia mater. At this stage, the anterior limit of lateral frontal lobe resection is established just behind the orbital gyri. Finally, approximately a 50 × 50 mm lateral part of the frontal lobe is isolated.

Resection of the rectal and orbital gyrus: Following resection of the lateral surface of the frontal lobe, we remove the rectal and orbital gyrus. The lateral limit of resection is established just in front of the lesser wing of the sphenoid. The olfactory trigone is used as a landmark for the posterior limit of frontobasal removal (Fig. 2). Therefore, it is necessary to remove the basal surface of the frontal lobe completely until just anterior to the olfactory trigone by subpial aspiration.

After observing the olfactory trigone, however, we do not continue to aspirate posteriorly because of the anterior perforated substance supplying blood to important deep brain structures. Care should be taken at this stage not to damage the olfactory bulb and tract.

To protect the olfactory nerve, it is recommended to check the olfactory bulb before resection.

Following removal of the lateral parts of the rectal and orbital gyri toward the olfactory bulb, the medial parts are removed by gentle subpial aspiration. It is important to aspirate inside of the rectal and cingulate gyrus while observing the contralateral rectal and cingulate gyrus through the pia mater. The ACA(A2) is also a landmark for this aspiration stage. At the final part of this stage, the optic nerve and optic chiasm can be seen through the pia mater (Fig. 3). The last stage involves complete removal of the subcallosal area of the frontal lobe by aspiration while observing the opposite side of the medial frontal lobe surface (Fig. 4).

Figure 5 shows the results of postoperative MRI.

Results

Surgical outcome

Thirteen patients (81.25%; right 73%, left 100%) became seizure-free (Engel class I), while the remaining three patients (18.75%) continued to have seizures (Engel class II–III).

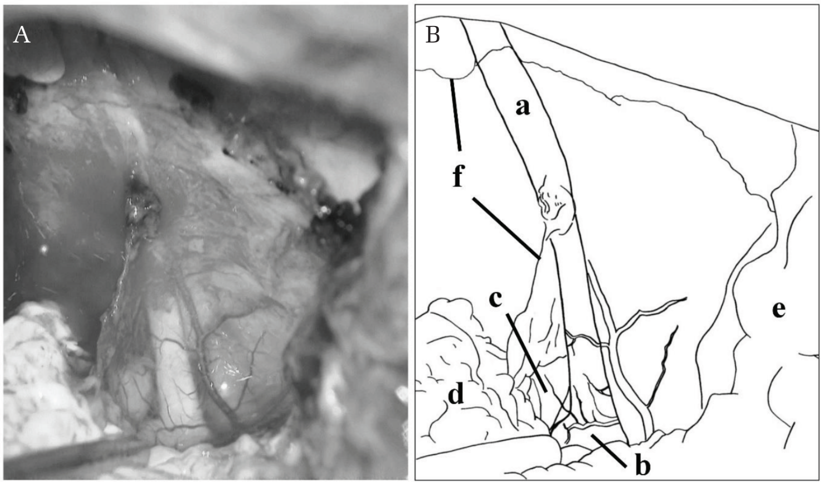

Fig. 2 Intraoperative view (A) and schema (B). The olfactory nerve is visible under the intact pia. The medial and lateral olfactory tract run posteriorly and end in the olfactory trigone. (a) Olfactory tract, (b) olfactory trigone, (c) right optic nerve, (d) rectal gyrus, (e) inferior frontal sulci, (f) pia mater.

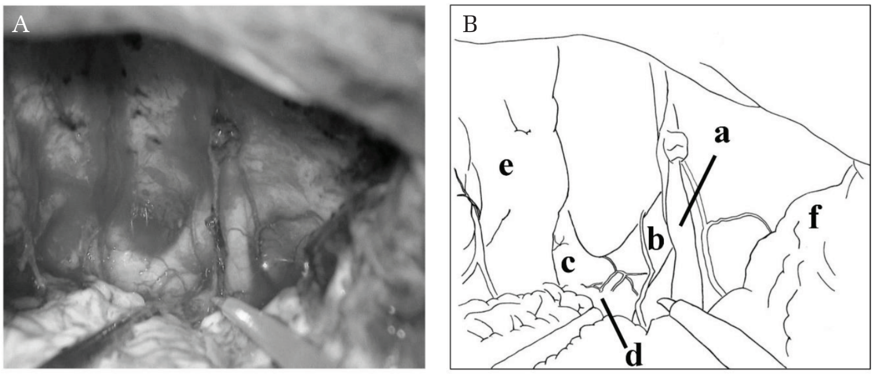

Fig. 3 Intraoperative view (A) and schema (B). The optic chiasma and contralateral medial surface of the frontal lobe are observed inside the olfactory nerve. (a) Olfactory tract, (b) right optic nerve, (c) left optic nerve, (d) optic chiasm, (e) left medial surface of the frontal lobe, (f) inferior frontal gyrus.

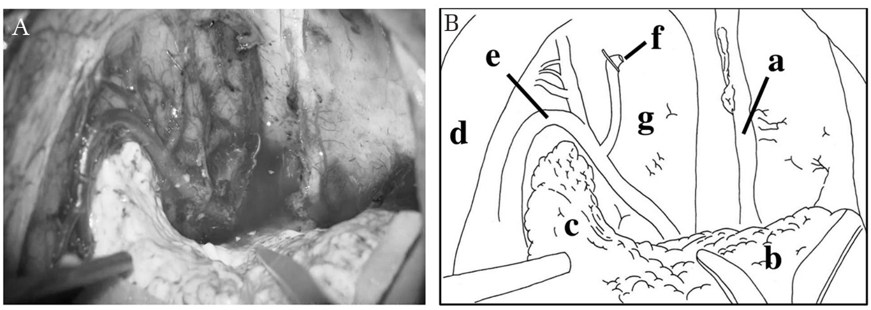

Fig. 4 Intraoperative view (A) and schema (B). The right subcallosal area is emptied subpially. The genu of the corpus callosum and subcallosal space can be seen. (a) Olfactory tract, (b) frontal lobe, (c) genu of the corpus callosum, (d) falx, (e) genu of the pericallosal artery, (f) orbitofrontal artery, (g) left medial surface of the frontal lobe.

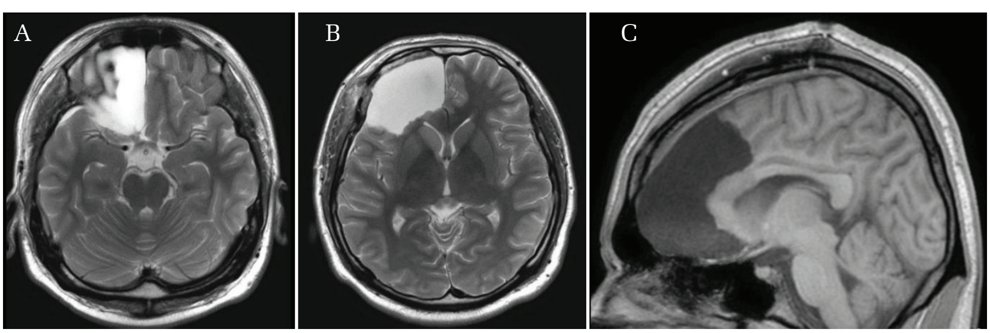

Fig. 5 (A) Postoperative T2-weighted magnetic resonance imaging (MRI) scans in the axial plane through the level of the frontal skull base. (B) Postoperative T2-weighted MRI scans in the axial plane through the level of the frontal horn of lateral ventricles and the basal ganglia. (C) Postoperative T1-weighted MRI scans in the sagittal plane through the midline. Frontal lobe decortication, including the orbital gyrus and subcallosal area, had been performed.

There were no significant differences in seizure-free rates between groups with operations on the right side compared with those with surgery on the left side. All patients continued to take antiepileptic drugs regardless of whether they did or did not show recurrence of epilepsy. Pathological data were available for 11 patients, and indicated one case each of microdysgenesis, focal cortical dysplasia, and mildly dysplastic cortex. The remaining eight patients had no pathological diagnosis. There were no serious complications, such as death, infection, intracranial hemorrhage, aphasia, or motor deficits, in our study population.

Discussion

What are the reasons for the poor results of surgical treatment of FLE?

The results of surgical treatment of intractable FLE, especially non-lesional FLE, are generally unsatisfactory compared with those of TLE. Specific seizure patterns do not necessarily arise in specific discrete regions of the frontal lobe.[29] It has also been reported that epileptic discharges are not accurately reflected on interictal and ictal scalp EEG in many cases.[30,31] The surgical outcomes after detailed presurgical studies for non-lesional FLE have been reported previously. Hong et al.[32] reported good surgical outcomes (seizure-free rate of 39%) in 41 non-lesional neocortical epileptic patients, including 16 with FLE, who underwent preoperative analyses, such as ictal scalp EEG, interictal ^{18}F-fluorodeoxyglucose-PET, and ictal technetium-99m hexamethylpropyleneamine oxime SPECT. Yang et al.[33] reported that presurgical evaluation using 3D-iEEG monitoring led to better surgical outcome (seizure-free rate of 48.9%) in FLE patients, including those who were MRI-negative. According to a meta-analysis, Englot et al.[5] concluded that abnormal preoperative MRI was the only presurgical evaluation associated with being free of seizures postoperatively. The use of advanced electrophysiological diagnostic testing, such as long-term video-EEG monitoring or intraoperative ECoG, was not associated with good surgical outcome.[5] One reason for the difficulty in diagnosis is the rapid propagation of epileptic discharges to the contralateral frontal lobe.[30] Diagnosis of medial and mediobasal frontal lobe epilepsy by general EEG is often difficult.[30] The large frontal lobe epileptogenic zone is also one of the main reasons for the unsatisfactory results of surgical treatment for FLE.[31,34] After the primary operation, secondary and tertiary epileptic zones become more active, and therefore seizures are not controlled.[33,35]

Two patients were classified as Engel class III after the operation, which was likely due to the limitation of focus diagnosis. Neither of these patients should other epileptogenic foci on preoperative examination. There are two additional possible explanations for this poor outcome, i.e., postoperative recurrent seizures occurring at the margins of previous resections,[36] or an epileptogenic zone remaining in the eloquent area reactivating other areas, such as the temporal lobe, via the white matter network.[37]

Unfortunately, we did not use magnetoencephalography (MEG) in our study, but a previous study suggested that MEG can detect deep brain regions, such as the orbitofrontal cortex.[38] Complete seizure freedom was achieved in 25% and 66% of MRI-negative FLE patients.[39,40] Stereoelectroencephalography (SEEG) was equally effective in the presurgical evaluation of MRI-negative and positive epilepsy. It is possible that a new modality, such as MEG or SEEG, would enable localized resection even in non-lesional FLE.

Advantages and disadvantages of eFL

In general, frontal lobectomy is performed for limited frontal lobe lesions, such as poorly defined low-grade gliomas, cerebral contusions, and cerebral hemorrhage, depending on their size. However, frontal lobectomy for treatment of intractable epilepsy should be performed as extensive frontal lobe resection. In a sense, eFL is to non-lesional FLE what maximal frontal lobectomy is to poorly defined glioma. We always perform eFL in non-lesional FLE patients. Wen et al.[41] first reported the details of frontal lobe decortication for epilepsy patients performed with the goal of maximizing gray matter removal, sparing primary and supplementary motor areas, and preserving the frontal horn. Our study emphasized complete removal of the subcallosal area and the orbital gyrus preserving the anterior perforated substance.

Our surgical technique leads to better surgical outcomes compared with previous reports regarding non-lesional FLE. One of the benefits of eFL is that it allows resection of a wide primary epileptogenic zone. In addition, the main reason for satisfactory outcome after surgery is that the surrounding secondary and tertiary epileptic zones are removed together with the primary epileptogenic zone. iEEG is always used to determine the epileptogenic zone for non-lesional FLE. However, it was reported that intracranial recording has a complication rate of approximately 10%.[42,43] Complications related to subdural electrodes included osteomyelitis, subdural hemorrhage, cerebral infarction status epilepticus, transient neurological deficits, significant CSF leakage, cerebral edema, and death.

In contrast, it is important to understand the disadvantages of eFL. The prefrontal cortex was considered “a silent area” in the absence of clinically discernible neurological deficits following its damage. Indeed, it has been reported that the vast majority of adults who undergo frontal lobectomy for treatment of pharmacoresistant epilepsy show good cognitive outcomes. However, a small subset of patients are at risk of more widespread cognitive decline, and the risk factors for this outcome are not yet clear.[44]

Although parts of the IFOF and UF were disconnected by eFL, none of the patients had speech disorders. Damage to the white matter did not always cause dysfunction by itself. Figure 1D shows a coronal cross-section of the frontal lobe as for eFL. It is possible that the cavity remaining after removal of a large amount of frontal tissue caused some long-term complications, such as infection. Not only frontal resection but also frontal disconnection are standard approaches for refractory frontal lobe epilepsy with extensive or multiple lesions restricted to one frontal lobe. In the frontal disconnection technique, there are no complications linked to the cavity effect. However, the frontal disconnection technique requires accurate transection in narrow surgical fields. Therefore, patients without atrophy (e.g., hemimegalencephaly) and with distorted anatomy may cause further complications in the intraoperative orientation.[45] Unfortunately, there have been few reports regarding surgical outcomes after frontal disconnection.

The eFL should not be performed in all FLE patients, but it represents a good surgical technique for non-lesional FLE following detailed presurgical evaluation.

Conclusion

The eFL is a good surgical technique for the treatment of intractable non-lesional FLE. To treat epilepsy by eFL, it is important to resect the non-eloquent area of the frontal lobe as much as possible with preservation of the eloquent cortex, e.g., the motor area, premotor area, SMA, and speech area. Complete removal of the orbital gyrus and the subcallosal area is also believed to play an important role in the good surgical outcome associated with this technique.

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Conflicts of Interest Disclosure

All authors have no conflicts of interest.

All authors have registered online Self-reported COI Disclosure Statement Forms through the website for JNS members.

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