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Surgery for Seizure-related Structural Lesions of the Brain with Intraoperative Acute Recording(ECoG) and Functional Mapping

Eun-Ik Son, M.D., Sang-Do Yi, M.D.,* Si-Woo Lee, M.D.,
Hae-Chull Lee, M.D., Man-Bin Yim, M.D., In-Hong Kim, M.D.

*Department of Neurosurgery and Neurology**
Keimyung University School of Medicine, Taegu, Korea

Epilepsy surgery has been demonstrated to be an effective alternative treatment for intractable partial or localization related epilepsy. Primary intracranial neoplasms and other structural lesions of the brain are important etiological factors in patients with partial seizure disorders. A neuroimaging identified lesion in patients with seizures, not necessarily medically refractory, may also be an indication for surgery in selected patients.
Twelve patients operated on under local or general anesthesia for resection surgery underwent intraoperative recording(electrocorticogram) and/or functional mapping by electrical stimulation or somatosensory evoked potentials-(SSEPs) for identification of the secondary epileptogenic area and/or functional area ; 2 meningiomas, 5 astrocytomas, 1 gangliocytoma, 1 abscess, 1 small AVM, 1 cysticercosis and one gliosis by previous intracerebral hemorrhage with middle cerebral artery(MCA) aneurysm. Among these, additional corticectomy or anterior temporal lobectomy was performed in eleven patients. All the patients did well after surgery with good outcomes as seizure free in nine(75%) out of 12 patients with 11.9 months of follow-up period, without any neurological deficits.
Intraoperative recording and functional mapping of adjacent areas of the structural lesions of the brain are useful in surgery and can guide the extent of further resection.

Key Words : *Epilepsy Surgery, Lesionectomy, Electrocorticogram(ECoG), Brain tumor, Functional Brain Mapping, Electrical Stimulation, SSEPs.*

INTRODUCTION

In recent years, a more aggressive surgical resection for primary glial tumors and other structural lesions has been advocated as a means of potentiating adjuvant therapy and, ultimately, prolonging overall survival. Moreover, primary intracranial neoplasms and other structural lesions of the brain are important etiological factors especially in patients with partial seizure disorders(Spencer et al., 1984 ; Morris et al., 1989 ; Gilles et al., 1992). Simple, complex-partial, or secondarily generalized seizures constitute the presenting manifestation of

Address for correspondence : *Eun-Ik Son, M.D., Department of Neurosurgery, Keimyung University School of Medicine, 194 Dongsan-dong, Taegu, 700-310, Korea. Tel : (053)250-7306.*
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brain tumors in 37% to 92% of patients harboring supratentorial neoplasms(Low et al., 1965 ; Blume et al., 1982 ; Sjörs et al., 1993 ; Weber et al., 1993). The risk of developing seizures from a structural lesion depends on multiple factors such as lesion location, involvement of cortical mantle, and chronicity of lesion(Weber et al., 1993). In general, patients with lesions that are slow growing have the highest risk of seizures(Hughes et al., 1987) and more rapidly growing tumors are less epileptogenic ; notable exceptions include lipomas, which are slow growing tumors yet confer an unusually low risk of 21%, and faster growing anaplastic astrocytomas carry a higher risk of 68%. Other lesions of interest include meningiomas with a 49% risk, AVM with a 35% risk, and venous angiomas with a 5% risk (Weber et al., 1993).

The mechanism of epileptogenesis associated with intracranial structural lesions is unknown. Penfield suggested that impaired vascularization of the surrounding cerebral cortex may produce hypoxic-ischemic neuronal changes. Direct 'irritation' of the cortex by a tumor has also been proposed as the etiology of the seizure activity. Lesions may also produce 'denervation hypersensitivity' related to partial isolation and transection of a region of the cerebral cortex(Cascino, 1990). Changes in GABA-ergic synapse, the NMDA receptor-cation channel, or axonal calcium or chloride channels may be associated with the enhanced excitatory and/or attenuated inhibitory influences that may facilitate epileptogenesis. There is conflicting evidence regarding the importance of hereditary factors in the development of epilepsy in patients with brain tumors.

Surgical treatment of seizure patients with intracranial lesions can involve either simple excision of the lesion alone or seizure surgery with excision of the mass lesion and epileptogenic cortex. Seizure surgery adds to the complexity of an operation, and therefore, evidence of benefit must exist to justify its use.

MATERIALS AND METHODS

From December 1992 to December 1993, twelve consecutive patients operated on under local or general anesthesia for resection surgery at Keimyung University Hospital underwent intraoperative recording (ECoG) and/or mapping by electrical stimulation or SSEPs for identification of the secondary epileptogenic area and/or functional areas. In case of awake craniotomy, following injection of local anesthetics(lidocaine 0.5% and bupivacaine 0.25%) in the scalp, a newer agent, propofol(Diprivan, Stuart Phamaceuticals), may be administered during bone work as needed for patient comfort. Patients were able to perform language tasks, with preoperative ability, approximately ten minutes following cessation of propofol administration. Prior to resection, intraoperative assessments were performed to decide the extent of resection : 1) intraoperative electrocorticography (ECoG) to identify focal epileptic activity, 2) functional brain mapping with electrical stimulation(ES) and/or somatosensory evoked potentials(SSEPs) to identify essential non-resectable Rolandic and language cortex, and 3) intraoperative ultrasound(US) was utilized to define the tumor boundary. In case of temporal lobe lesion, second ECoG was performed to decide the extent of mesial temporal resection(Son et al., 1994). Categorization of the seizure-related structural lesion by location for intraoperative assessment is summarized in Table 1.

Resections were performed in a subpial fashion, utilizing the cavitron ultrasonic aspirator(CUSA). When approaching the insula mass via the mesial

Table 1. Categorization of the seizure-related structural lesion by location for intraoperative assessment.

	Ultrasound	ECoG	ES/SSEPs	Language mapping
Temporal lesion				
Lat temporal	+	+	+	+(D)
HIPP		+	+	
Insula	+	+	+	
Peri-Rolandic lesion				
Frontal(premotor, MII)	+	+	+	
Parietal	+	+	+	+(D)
Non-essential area	+	+		

ECoG : electrocorticogram, ES : electrical stimulation, SSEPs : somatosensory evoked potentials, HIPP : hippocampus, D : dominant hemispher.

temporal route(Fig. 1), insular cortex was entered between branches of the middle cerebral arteries. The pial surface and inside of the insular was stimulated in two cases during gentle resection with CUSA. Multiple subpial transection(MST) was acomplished in only one case due to tumor involvement of the Rolandic area.

RESULTS

Eight were male in total 12 patients ; the average age was 40 years (range 14-59 years). Among these, additional corticectomy or anterior temporal lobectomy were performed in eleven patients. Awake craniotomies were performed on six patients who had medically intractable epilepsy or dominant temporal or parietal lesion for language mapping and tailoring. Clinical characteristics and outcome are summarized in Table 2. The duration of follow-up ranged from 6 to 18 months(mean ; 11.9 months). Verified histopathology showed : two meningiomas, five astrocytomas, one gangliocytoma, one abscess, one small AVM, one cysticercosis and a MCA aneurysm with previous intracerebral hemorrhage. All the patients did well after surgery with good outcomes : seizure free in nine(75%) out of 12 cases, rare seizures in two(16.5%) and worthwhile improvement in one(8.5%) case who underwent subtotal resection. All the cases were tolerated well without any neurological deficits.

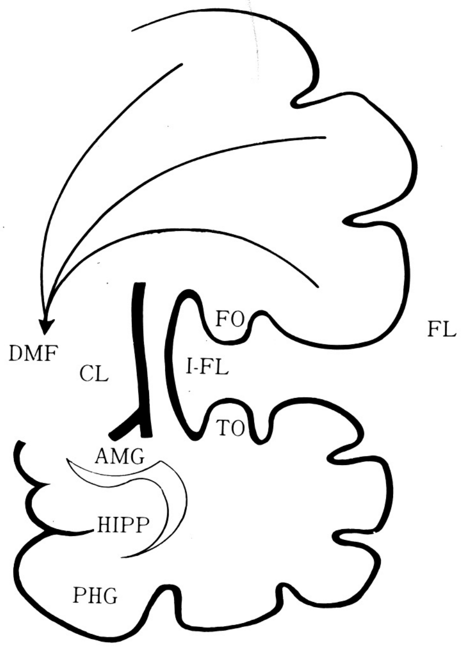

Fig. 1. Schematic coronal section at the level of amygdala demonstrating the descending motor fibers(DMF) just deep to the insular and claustrum(CL) which form the posterior-medial safe extent of resection. Lateral frontal lobe essential language cortex(FL) projects directly onto underlying insular cortex(I-FL). Both FL and I-FL are essential language areas which must not be damaged.

Table 2. Summary of consecutive 12 cases with seizure-related lesions.

Case	Sex/Age	Site	Seizure	Operation	Anes	ECoG/Map	Pathology	Outcome**
1	M/58	Rt F	CP	L+C	Gen	+ / −	Meningioma	I
2	M/59	Rt T	SP	L	Gen	+ / −	Meningioma	I
3*	M/36	Rt F	CP, G	L+C	L/P	+ / +	Small AVM	I
4*	F/20	Rt T	CP, G	L+ATL	L/P	+ / +	Astrocytoma	II
5*	F/14	Lt T,H	CP, G	L+ATL+H	L/P	+ / +LM	Astrocytoma	III
6	M/46	Rt F	CP, G	L+ C	Gen	+ / +	Abscess	II
7*	M/44	Rt I	CP	L+ATL+AH	Gen	+ / +	Astrocytoma	I
8	F/40	Rt I	CP, G	L+ATL+AH	Gen	+ / +	Astrocytoma	I
9*	M/51	Rt T	CP, G	Clip+TL+AH	Gen	+ / +	ICH, large AN	I
10*	M/16	Lt F	SP, G	L+C	L/P	+ / +	Cysticercosis	I
11	M/32	Lt P	CP, G	L+C	L/P	+ / +LM	Astrocytoma	I
12*	F/41	Rt Rol	SP	L+C+MST	L/P	+ / +	Gangliocytoma	I

Case* : medically refractory partial epilepsy.

Outcome** : according to the Engel's outcome classification(I -seizure free, II -rare seizure, III -worthwhile improvement, IV -no worthwhile improvement).

F : frontal, T : temporal, P : parietal, I : insula, Rol : Rolandic area, H : hippocampus, CP : complex partial seizure, SP : simple partial seizure, G : secondary generalization, L : lesionectomy, C : corticectomy, ATL : anterior temoral lobectomy, AH : amygdalo-hippocampectomy, MST : multiple subpial transection, ICH : intracerebral hematoma, AN : aneurysm, L/P : local anesthesia with Propofol, Gen : general anesthesia, LM : language mapping.

DISCUSSION

Tumor removal alone, or simple lesionectomy provides seizure relief in many patients. In various series of unselected brain tumor patients with coexistent seizures, between 31% and 66% were rendered seizure-free following surgery. The most important factor in determining successful seizure control following lesional surgery is complete removal of the lesion(Awad et al., 1991 ; Fried et al., 1993). In a recent series of patients with mass lesions undergoing computer-assisted stereotactic total lesionectomy, 63% were reported to be free of seizures postoperatively. Morrell demonstrated that 34% of 47 tumor patients had definite evidence of electrographically bilateral independent secondary foci, termed secondary epileptogenesis(Morrell, 1985).

Clinical and experimental observations concerning the relationship of a mass lesion to epileptogenic cortex are : 1)epileptogenic cortex can become functionally independent and 2)epileptogenic cortex is often distant from the structural lesion. In a report by Awad et al. 47 patients with intracranial lesions and intractable partial epilepsy had scalp and intracranial EEG recording and subsequently underwent resective surgery. Three different relationships of structural lesions to seizure foci were identified. The epileptogenic zone involved exclusively the region adjacent to the structural lesion in 11 patients. It extended beyond the area of the lesion in 18 patients. Eighteen other patients had remote noncontiguous zones of epileptogenesis (Awad et al., 1991). The commonest site of secondary foci is the ipsilateral mesial temporal lobe. There are numerous hypotheses to explain this phenomenon, including preferential spread of seizures through the limbic system leading to 'kindling', inherent increased epileptogenecity of the mesial structures and mesial sclerosis secondary to repeat injury during seizures. The earlier the age of onset of the seizures, the more rapid the development of the secondary focus(Rasmussen et al., 1983). The hippocampus is frequently involved in the seizure disorders of patients with structural lesions(Drake et al., 1987 ; Fish et al., 1991), prompting the designation 'dual pathology', indicating that these patients have pathologic changes in the hippocampus as well as structural lesions elsewhere.

Morrell described multiple subpial transection-(MST) as a surgical method of treating seizures arising from functionally important cortex(Morrell et al., 1989). The rationale is to impede cortical neuronal synchronization and seizure spread while preserving cortical function. In the present study, the MST surgery was acomplished in only one(case 12 ; gangliocytoma), due to tumor involvement beneath the Rolandic area. The tumor was removed by stereotactic-guided trajectory, and a part of the postcentral gyrus was verified as irritative zone consistent with semiology, intracranial recordings(ECoG) and stimulation mapping.

The precedent has been established for using cortical mapping techniques during ablative surgery for medically intractable epilepsy. Interictal epileptiform discharges as well as overt seizure activity may be recorded directly from the cortex using the method of ECoG. The epileptiform discharges do not originate within the tumor, and can usually be localized to brain tissue adjacent to the lesion. Drake et al. and Gonzales and Elvidge support the view that removing the lesion without the surrounding abnormal electrical foci may not lessen or prevent postoperative seizure activity. An attempt should also be made to further resect residual or new epileptiform discharges after tumor removal, especially when the foci involve the mesial temporal lobe. However, residual discharges in the insular cortex or diffuse activity over the frontal or parietal lobe should not be considered for further resection.

Brain mapping techniques(Berger et al., 1989 ; Ojemann, 1993) have also been quite useful for defining regions associated with speech function, especially when the language cortex is distorted or infiltrated by tumor. Standard measurements for resection dominant temporal lobe have been advocated to avoid language deficits. As Ojemann has early pointed out, however, there is considerable variability in the localization of the language cortex among individuals, and, thus, speech cannot be routinely assumed to occupy the posterior superior temporal gyrus or inferior frontal region. Additional variables such as sex and verbal intelligence have also been linked with speech localization(Ojemann et al., 1988). Another advantage of brain mapping is to localize the sensorimotor cortex and descending motor pathways during the tumor resection. Lueders et al. hypothesized the generation of cortical SSEP wave N_1 by a horizontal dipole produced in the posterior bank(area 3b) of the central sulcus(Lueders et al., 1983 ; Dinner et al., 1987). Recordings of somatosensory evoked responses to

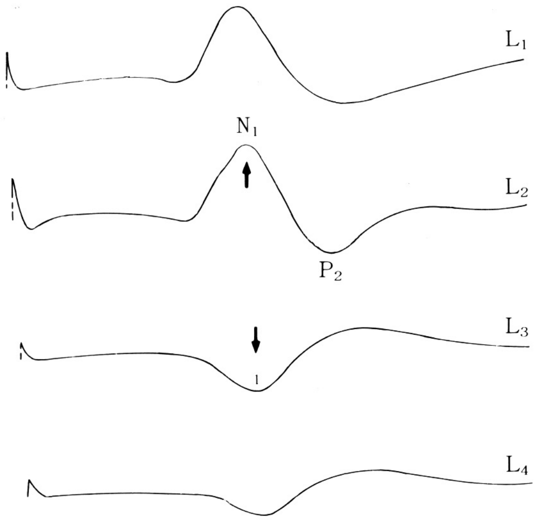

Fig. 2. Recordings of somatosensory evoked responses to controlateral median nerve stimulation(negative up). Phase reversal of N_1 and P_2 is observed between Electrodes 2 and 3.

controlateral median nerve stimulation(negative up) showed phase reversal (Fig. 2). In conclusion, intraoperative recording(ECoG) and functional brain mapping on adjacent areas of structural lesions of the brain are useful in surgery and can guide the extent of further resection to maximize tumor resection, minimize morbidity, and eradicate seizures.

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