Electrocorticographic Monitoring as An Alternative Tool for the Pre-surgical Evaluation of Patients with Bi-temporal Epilepsy

Peng-Wei Hsu[3], MD; Hsien-Chih Chen, MD; Yin-Cheng Huang[3], MD; Chee-Ching Hsu[1], MD, PhD; Tony Wu[2], MD, PhD; Chen-Nen Chang, MD

Background: To analyze the surgical outcomes of patients with temporal lobe epilepsy with bilateral foci after one-week bilateral subdural strip electrocorticographic (ECoG) recording.

Methods: We retrospectively evaluated 12 patients with bilateral epileptic foci after scalp electroencephalography examination who underwent ECoG between May 1995 and July 2000. Subdural strips were implanted in the bilateral subtemporal regions for a one-week ECoG recording.

Results: All but one of the patients exhibited unilateral dominance of epileptogenic discharges (> 65%) and, following an anterior temporal lobectomy, the majority of patients (8 of 11) enjoyed a seizure-free life during the ensuing 3 years. No mortality or morbidity such as intracranial hemorrhage or wound infection was noted.

Conclusions: The dominance of an epileptic focus in patients with bitemporal epileptogenic discharges can thus be successfully recorded by electrocorticographic monitoring prior to anterior temporal lobectomy.
(Chang Gung Med J 2010;33:194-200)

Key words: anterior temporal lobectomy, bitemporal epilepsy, dominant epileptogenic discharges, electrocorticographic recording, temporal lobe epilepsy

Intractable seizures are defined as seizures which persist despite therapy with modern anticonvulsants at adequate serum levels. Surgical intervention is a safe and effective approach for patients with epilepsy who exhibit medically intractable seizures.(1-3) Seizures arising from mesial temporal structures, such as the amygdala, hippocampus, and parahippocampal gyrus, occur in more than 90% of the patients with temporal lobe epilepsy (TLE) and are most commonly ameliorated by anterior temporal lobectomy (ATL).(4,5)

Scalp electroencephalography (EEG), single-photon emission computed tomography (SPECT), brain magnetic resonance imaging (MRI), combined magnetoencephalography/EEG, and resting functional MRI have all been utilized to identify epileptic foci.(6,7) Video-EEG is currently considered an effective method to localize the epileptogenic zone and the site of seizure onset prior to surgery.(8) However, these non-invasive approaches often provide insuffi-

From the Brain Division of Neurosurgery, Department of Surgery; [1]Department of Anesthesiology; [2]Department of Neurology, Chang Gung Memorial Hospital at Linkou, Chang Gung University College of Medicine, Taoyuan, Taiwan; [3]Graduate Institute of Clinical Medical Sciences, College of Medicine, Chang Gung University, Taoyuan, Taiwan.
Received: Oct. 26, 2008; Accepted: Jun. 12, 2009
Correspondence to: Dr. Chen-Nen Chang, Brain Division of Neurosurgery, Department of Surgery, Chang Gung Memorial Hospital at Linkou. 5, Fusing St., Gueishan Township, Taoyuan County 333, Taiwan (R.O.C.) Tel.: 886-3-3281200 ext. 2412; Fax: 886-3-3285818; E-mail: ns3096@cgmh.org.tw

cient information about physiological processes at the cellular level.[9]

One factor which can substantially influence the outcome of the surgical treatment of TLE is the appearance of epileptic discharges arising from the bilateral temporal regions.[10] Electrocorticography (ECoG) is a neurophysiological technique used to record cortical potentials in the brain and to lateralize and accurately localize the site of origin of seizure activity.[11-15] In the current study, we evaluated the long-term surgical outcomes of patients with TLE and bilateral foci who underwent subdural ECoG monitoring for one week prior to an ATL, after which the majority of patients were seizure-free.

METHODS

We retrospectively reviewed the medical records of 12 consecutive patients (10 males and 2 females) with bilateral epileptic foci after scalp EEG examination who underwent ECoG between May 1995 and July 2000 at Chang Gung Memorial Hospital. All patients had medically recalcitrant seizures with an adequate serum level of at least two anticonvulsants and underwent comprehensive pre-surgical evaluations that included MRI, interictal scalp EEG recording, SPECT, and neuropsychological studies. Because the aforementioned modalities failed to determine the lateralization of the epileptic foci, the patients underwent subdural ECoG monitoring. An ATL was then performed on those patients with > 60% unilateral epileptogenic discharges, as determined by ECoG.

One week prior to the ATL, contact strips that permit ECoG recording were placed on the inferior surface of the temporal lobe. Under general anesthesia, burr holes were created through a small skin incision in the temporal bone bilaterally using a high-speed drill (Aesculap Company, Tuttlingen, Germany), and were placed 1 cm anterior to the tragus and just superior to the root of the zygoma. The dura was coagulated and then incised carefully to avoid cortical lacerations or contusions which could alter the ECoG recordings or lead to intraparenchymal strip placement. The subdural space was gently dissected with a Penfield dissector No. 3 to ensure an optimal working space for strip placement. Four contact strips were placed on the inferior surface of each temporal lobe from the lateral to the medial aspect. ECoG monitoring was conducted for one week to accurately identify the dominant epileptic focus.[5]

Thereafter, an ATL was performed by standardized resection of the temporal lobe perpendicular to the long axis of the temporal lobe.[16] A depth electrode was applied to record epileptic discharges from the hippocampus during surgery.

Post-surgical outcomes were categorized into four classes as previously described;[5] briefly, class I indicated a seizure-free state or the presence of auras only, class II corresponded to a near seizure-free state, class III was considered to be subjective improvement, and class IV patients had no subjective improvement.

The pre- and post-operative seizure frequency was recorded by the patients and their family. In order to analyze the surgical outcome, the post-operative seizure condition was adjusted to the average frequency per month. Statistical analyses were performed using the paired *t* test and values were significantly different when $p < 0.05$.

RESULTS

Pre-surgical evaluations using MRI did not disclose lesions in any of the study patients. However, interictal scalp EEG recordings demonstrated bitemporal epileptogenic discharges from the mesial temporal region, as well as from the subtemporal cortex.

ECoG monitoring (Fig. 1) for one week revealed that 11 (10 males and 1 female) of the 12 patients had > 65% unilateral epileptogenic discharges (Table 1). These patients ranged in age from 6 to 43 years (mean = 29.7 years), with a duration of epilepsy ranging from 4 to 29 years (mean = 16.8 years). The seizure frequency ranged from 0.5 to 60 episodes per month (mean = 9.1 episodes) and the duration of post-surgical follow-up ranged from 43 to 101 months (mean = 64.2 months).

During the ATL procedure, abnormal discharges from the hippocampus were documented in all 11 patients (Fig. 2), and amygdalohippocampectomies (AH) were thus performed in all patients. Subsequent pathologic evaluation demonstrated hippocampal sclerosis accompanied by a loss of more than 50% of the neurons. After the ATL was performed, eight subjects (73%) were free of seizures (class I), two (18%) were almost seizure-free (class II), and one (9%) showed no subjective improvement (class IV).

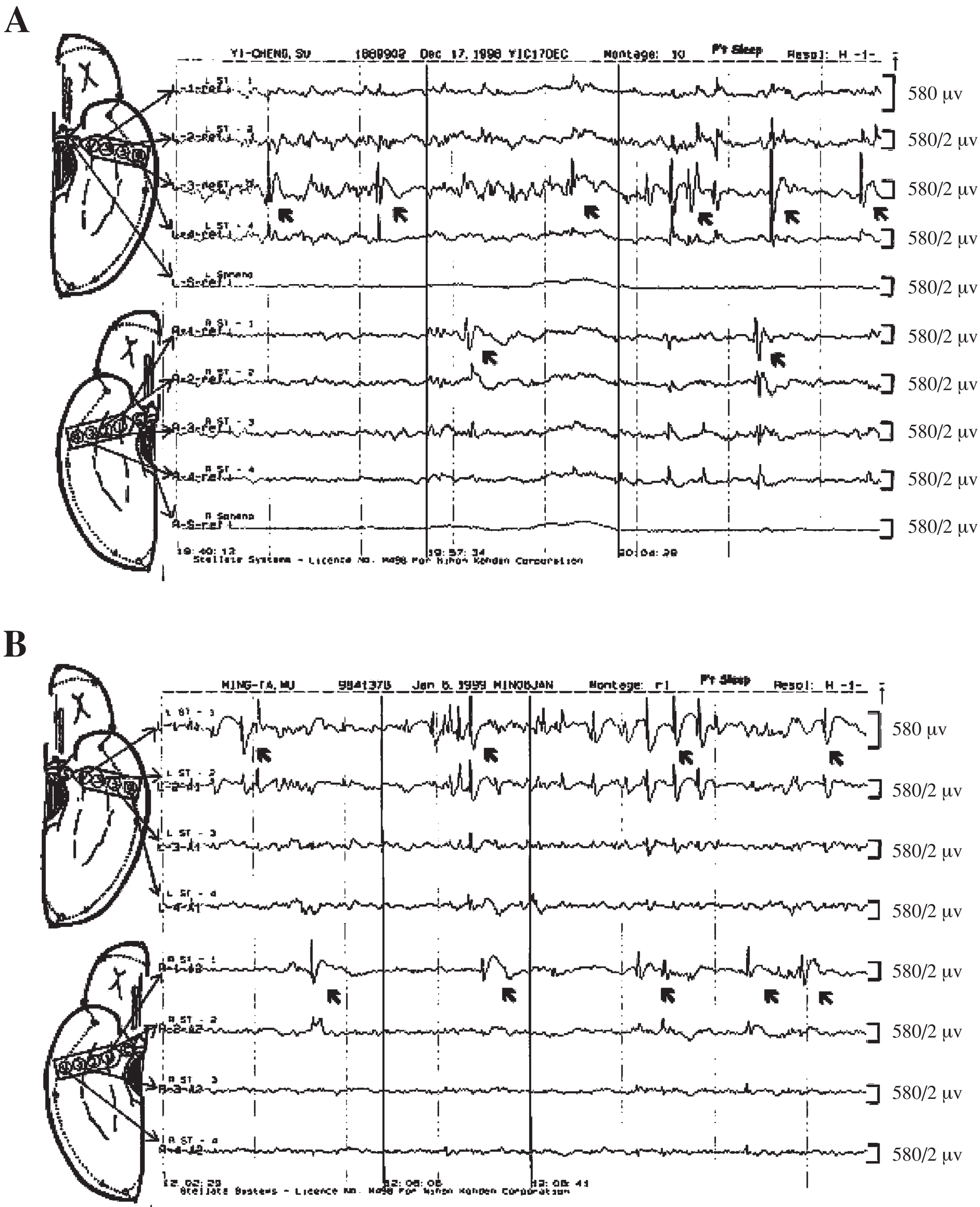

Fig. 1 (A) After chronic ECoG recording, left-sided epileptic focus dominance (70%) is revealed in patient no. 3. (B) No dominant side is evident after a recording conducted over a one week period in patient no. 12 (R't-52%). Arrows indicate seizure spikes.

Table 1. Patient Characteristics and Surgical Outcomes

Patient	Age/ Gender	Type	History (years)	Dominant %	Seizure frequency		Outcome class	Follow-up (months)	Medication	
					Pre/month	Post/year*			Pre-surgery (dose)‡	Post-surgery (dose)
1	26/F	CPS	13	L, 83	4	0	1	61	Phenytoin (200 mg bid)/ (18) Valproate (200 mg qid)/ (87)	Valproate (200 mg tid)
2	24/M	GTC	23	L, 81	2	0	1	51	Phenytoin (300 mg hs)/ (15) Topiramate (100 mg bid)	Topiramate (100 mg bid)
3	32/M	CPS+GTC	7	L, 70	0.5	0	1	101	Valproate (200 mg qid)/ (92) Phenytoin (100 mg tid)/ (19) Lamotrigine (50 mg hs)	Valproate (200 mg qid) Phenytoin (100 mg tid) Lamotrigine (50 mg hs)
4	33/M	CPS	26	L, 75	60	0	1	52	Carbamazepine CR (200 mg bid)/ (9) Topiramate (100 mg tid)	Topiramate (100 mg bid)
5	41/M	CPS+GTC	25	L, 71	5	0	1	100	Phenytoin (300 mg hs)/ (17) Gabapentin (300 mg bid)	Phenytoin (300 mg hs) Gabapentin (300 mg bid)
6	32/M	CPS+GTC	11	R, 85	4	0	1	69	Valproate (200 mg qid)/ (96) Gabapentin (300 mg bid)	Valproate (200 mg qid) Gabapentin (300 mg bid)
7	6/M	GTC	4	L, 79	60	0	1	52	Phenytoin (100 mg hs)/ (16) Phenobarbital (20 mg bid)/ (33)	Phenobarbital (20 mg bid)
8	24/M	GTC	16	R, 74	0.5	0	1	66	Lamotrigine (50 mg bid) Phenytoin (300 mg hs)/ (17)	Phenytoin (300 mg hs)
9	36/M	CPS+GTC	16	R, 69	12	2	2	51	Valproate (200 mg qid)/ (83) Phenytoin (300 mg hs)/ (19) Topiramate (100 mg tid)	Valproate (500 mg bid) Phenytoin (300 mg HS) Topiramate (100 mg tid)
10	43/M	CPS+GTC	15	L, 68	3	3	2	43	Valproate (200 mg qid)/ (95) Carbamazepine CR (200 mg bid)/ (11) Gabapentin (400 mg bid)	Valproate (500 mg bid) Carbamazepine CR (200 mg bid) Gabapentin (400 mg bid)
11	30/M	CPS+GTC	29	R, 68	3	8	4	60	Phenytoin (300 mg hs)/ (18) Carbamazepine CR (200 mg bid)/ (10)	Phenytoin (300 mg hs) Carbamazepine CR (200 mg bid) Topiramate (100 mg bid)
12†	15/M	GTC	12	R, 52	30	---	---	---	---	---

Abbreviations: M: male; F: female; R: right; L: left; CPS: complex partial seizure; GTC: generalized tonic-clonic seizure; History: pre-surgery duration of seizures; Pre: pre-surgical seizure frequency; Post: post-surgical seizure frequency; *: Significant difference compared to pre-surgical seizure frequency; †: This patient did not undergo surgery as there was no clear epileptic focus dominance; ‡: plasma medication concentration, ug/ml.

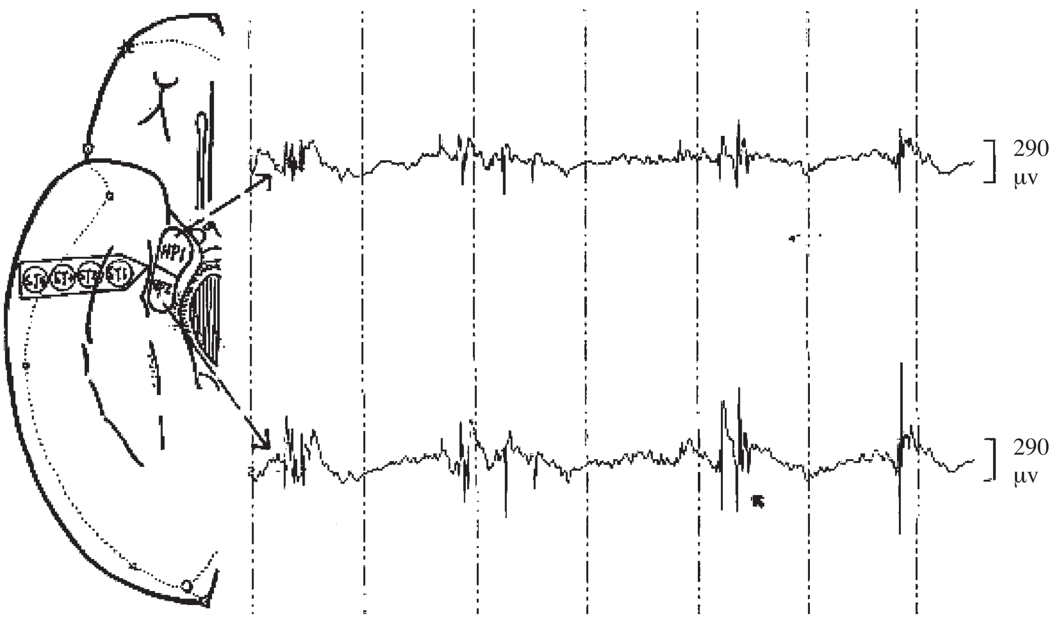

Fig. 2 Two depth electrodes were placed in the hippocampus of a patient. Epileptic discharges were recorded and an anterior hippocampectomy was performed. Arrows indicate seizure spikes.

A The dosage of anti-epileptic medications was reduced in five of the eight seizure-free subjects and remained unchanged in three subjects (Table 1). Moreover, the post-surgical seizure frequency was significantly decreased compared to the pre-surgical period (Table 1, $p < 0.05$). No mortality or morbidity, such as intracranial hemorrhage, wound infections or post- operative neurological deficits such as limbs weakness or aphasia, occurred in any of the patients.

DISCUSSION

Temporal lobe resection is a well-established treatment for patients with medically intractable temporal lobe epilepsy, because other approaches fail approximately 75% of the time.[17,18] Approximately 90% of patients who undergo temporal lobe resection become seizure-free.[19,20] The evaluation methods for the selection of MRI-negative, TLE patients for surgical treatment include scalp EEG, video-EEG, and SPECT, which can indicate patients who are expected to have a favorable post-surgical outcome.[21]

Bilateral independent epileptic discharges arising from the temporal regions are found in approximately 20 to 35% of patients and complicate the decision for surgical treatment of TLE.[13] Although most studies which have demonstrated that bitemporal patients are poor surgical candidates were based on scalp EEGs, examination using depth EEG has often shown that these patients exhibit a unilateral onset of seizure activity.[16,22] An alternative approach that uses foramen ovale electrodes appears to be reliable in lateralizing seizures that could not be recorded by surface EEG.[23] Furthermore, a recent study involving patients with bitemporal, independent seizures on scalp EEG revealed that commonly used non-invasive approaches do not reliably predict surgical outcome and suggested that intracranial EEG is necessary to localize seizure foci.[24] ECoG has been used to localize epileptogenic tissue, evaluate cortical functions, and determine the feasibility of surgery.[11] When EEG, MRI, SPECT, or similar diagnostic modalities fail, extended intracranial ECoG monitoring is required and advantageous, particularly in patients with bilateral foci, in order to lateralize and accurately localize the site of seizure origin.

We used subtemporal subdural strips herein to localize the lateralization of epileptic foci using long-term ECoG monitoring after failure to detect foci using non-invasive diagnostic modalities. In other series, an 80% cutoff was applied to separate patients with strong unilateral temporal predominance from those without.[10,25] Our results demonstrated that seizure-free (class I) treatment outcomes can be achieved in patients with a dominance > 70% on one side and a favorable outcome (class II) can be obtained in patients with a dominance > 65%; however, a larger TLE patient population is needed to confirm this finding. Our observations demonstrate the promising value of long-term pre-surgical ECoG monitoring as an alternative approach to detect unilateral dominant epileptic foci in patients with bitemporal epilepsy.

REFERENCES

1. Gilliam F, Kuzniecky R, Meador K, Martin R, Sawrie S, Viikinsalo M, Morawetz R, Faught E. Patient-oriented outcome assessment after temporal lobectomy for refractory epilepsy. Neurology 1999;53:687-94.
2. Jones JE, Berven NL, Ramirez L, Woodard A, Hermann BP. Long-term psychosocial outcomes of anterior temporal lobectomy. Epilepsia 2002;43:896-903.
3. Salanova V, Markand O, Worth R. Temporal lobe epilepsy surgery: outcome, complications, and late mortality rate in 215 patients. Epilepsia 2002;43:170-4.
4. Mathern GW, Adelson PD, Cahan LD, Leite JP. Hippocampal neuron damage in human epilepsy: Meyer's hypothesis revised. Prog Brain Res 2002;135:237-51.
5. Babb TL, Brown WJ. Pathological findings in epilepsy. In: Engel J Jr, ed. Surgical Treatment of the Epilepsies. New York: Raven Press Books, 1987:511-40.
6. Morgan VL, Price RR, Arain A, Modur P, Abou-Khalil B. Resting functional MRI with temporal clustering analysis for localization of epileptic activity without EEG. Neuroimage 2004;21:473-81.
7. Pataraia E, Lindinger G, Deecke L, Mayer D, Baumgartner C. Combined MEG/EEG analysis of the interictal spike complex in mesial temporal lobe epilepsy. Neuroimage 2005;24:607-14.
8. Sakai Y, Nagano H, Sakata A, Kinoshita S, Hamasaki N, Shima F, Morioka T. Localization of epileptogenic zone in temporal lobe epilepsy by ictal scalp EEG. Seizure 2002;11:163-8.
9. Engel AK, Moll CK, Fried I, Ojemann GA. Invasive recordings from the human brain: clinical insights and beyond. Nat Rev Neurosci 2005;6:35-47.
10. Holmes MD, Miles AN, Dodrill CD, Ojemann GA, Wilensky AJ. Identifying potential surgical candidates in patients with evidence of bitemporal epilepsy. Epilepsia 2003;44:1075-9.
11. Keene DL, Whiting S, Ventureyra EC. Electrocorticography. Epileptic Disord 2000;2:57-63.
12. Lieb JP, Engel J, Gevins A, Crandall PH. Surface and deep EEG correlates of surgical outcome in temporal lobe epilepsy. Epilepsia 1981;22:515-38.
13. So N, Gloor P, Quesney LF, Jones-Gotman M, Olivier A, Andermann F. Depth electrode investigations in patients with bitemporal epileptiform abnormalities. Ann Neurol 1989;25:423-31.
14. Hirsch LJ, Spencer SS, Williamson PD, Spencer DD, Mattson RH. Comparison of bitemporal and unitemporal epilepsy defined by depth electroencephalography. Ann Neurol 1991;30:340-6.
15. Sirven JI, Malamut BL, Liporace JD, O'Connor MJ, Sperling MR. Outcome after temporal lobectomy in bilateral lobe epilepsy. Ann Neurol 1997;42:873-8.
16. Spencer SS. Surgical options for uncontrolled epilepsy. Neurol Clin 1986;4:669-95.
17. Falconer MA, Taylor DC. Surgical treatment of drug-resistant epilepsy due to mesial temporal sclerosis. Arch Neurol 1968;19:353-61.
18. Spencer SS. When should temporal-lobe epilepsy be treated surgically? Lancet Neurol 2002;1:375-82.
19. So N, Olivier A, Andermann F, Gloor P, Quesney LF. Results of surgical treatment in patients with bitemporal epileptiform abnormalities. Ann Neurol 1989;25:432-9.
20. Kim YH, Chang KH, Park SW, Koh YW, Lee SH, Yu IK, Han MH, Lee SK, Chung CK. Hippocampal sclerosis: correlation of MR imaging findings with surgical outcome. Korean J Radiol 2001;2:63-7.
21. Sylaja PN, Radhakrishnan K, Kesavadas C, Sarma PS. Seizure outcome after anterior temporal lobectomy and its predictors in patients with apparent temporal lobe epilepsy and normal MRI. Epilepsia 2004;45:803-8.
22. Rasmussen T. Surgical aspects of temporal lobe epilepsy: results and problems. Acta Neurochir Supp 1980;30:13-24.
23. Velasco TR, Sakamoto AC, Alexandre Jr V, Walz R, Dalmagro CL, Bianchin MM, Araujo D, Santos AC, Leite JP, Assirati JA, Carlotti Jr C. Foramen ovale electrodes can identify a focal seizure onset when surface EEG fails in mesial temporal lobe epilepsy. Epilepsia 2006;47:1300-7.
24. Jenssen S, Liporace J, Nei M, O'Conner MJ, Sperling MR. Value of non-invasive testing when there are independent bitemporal seizures in the scalp EEG. Epilepsy Res 2006;68:115-22.
25. Hirsch LJ, Spencer SS, Spencer DD, Williamson PD, Mattson RH. Temporal lobectomy in patients with bitemporal epilepsy defined by depth electroencephalography. Ann Neurol 1991;30:347-56.

以大腦皮質電位記錄做為雙側性顳葉癲癇術前的評估工具

徐鵬偉[3] 陳先志 黃盈誠[3] 徐至清[1] 吳禹利[2] 張承能

背 景： 這個研究的目的在於探討雙側性顳葉癲癇經過為期一周的硬腦膜下皮質電位記錄後之手術結果及預後。

方 法： 經由回溯性的研究，我們分析了 1995 年 5 月至 2007 年 7 月間，於傳統頭皮腦波檢查顯示雙側性顳葉癲癇的十二位患者。在前顳葉切除手術之前，每位患者都接受了雙側硬腦膜下皮質電位記錄電極植入手術，以進行為期一周的大腦皮質電位記錄。

結 果： 除了一位患者以外，其他的十一名患者皆顯示了單側大腦癲癇波釋放的顯著性 (> 65%)；這十一名患者都接受了顯著側大腦的前顳葉切除術。在術後的追蹤期間，其中的八名患者可以達到無癲癇發作的第一級控制效果；同時手術也沒有導致任何併發症的產生。

結 論： 雙側性顳葉癲癇患者的大腦癲癇波釋放之顯著側，可以經由雙側硬腦膜下皮質電位記錄電極植入手術成功地辨別；而這也提高了前顳葉切除術後的癲癇控制效果。
(長庚醫誌 2010;33:194-200)

關鍵詞： 前顳葉切除術，雙側性顳葉癲癇，顯著癲癇放電，皮質電位記錄，顳葉癲癇

長庚醫療財團法人林口長庚紀念醫院 外科部 神經外科，[1]麻醉部，[2]神經內科；長庚大學 醫學院 [3]臨床醫學研究所
受文日期：民國97年10月26日；接受刊載：民國98年6月12日
通訊作者：張承能醫師，長庚醫療財團法人林口長庚紀念醫院 外科部 神經外科。桃園縣333龜山鄉復興街5號。
Tel.: (03)3281200轉2412; Fax: (03)3285818; E-mail: ns3096@cgmh.org.tw