Original article

Epileptic Disord 2014; 16 (2): 175-84

Intraoperative electrocorticography-guided microsurgical management for patients with onset of supratentorial neoplasms manifesting as epilepsy: a review of 65 cases

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Received October 26, 2013; Accepted April 27, 2014

ABSTRACT – *Aim*. We reviewed the surgical procedures guided by intraoperative electrocorticography and outcome of 65 patients with onset of supratentorial neoplasms manifesting as epilepsy. *Method*. Clinical data were obtained for 65 patients with supratentorial neoplasms who received surgery, with the aid of intraoperative electrocorticography to screen epileptogenic foci before and after removal of neoplasms, and depth electrodes when needed. According to electrocorticography findings, appropriate surgical procedures were performed to treat the epileptogenic foci. In the control group, 72 patients received simple lesionectomy. Postoperative seizure outcomes were documented and analysed retrospectively. *Results*. In the case group, 33 patients received lesionectomy only, while the other 32 patients underwent intraoperative electrocorticography-guided tailored epilepsy surgery. In total, 57 patients (87.7%) in the case group and 38 patients (52.8%) in the control group were seizure-free (Engel Class I). Comparing outcomes of patients with temporal lesions between the two groups, 80.0% patients (12/15) in the case group and 20.0% (3/15) in the control group were seizure-free. Furthermore, comparing the seizure outcomes of patients who finally underwent tailored epilepsy surgery and simple lesionectomy (33 after electrocorticography and 72 without electrocorticography), intraoperative electrocorticography-guided tailored epilepsy surgery demonstrated superiority over lesionectomy (Engel Class I; 87.5% *vs*. 63.8%, respectively). *Conclusions*. Electrocorticography plays an important role in the localisation of epileptogenic foci and evaluation of the effects of microsurgical procedures intraoperatively. Isolated lesionectomy

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doi:10.1684/epd.2014.0662

is not usually sufficient for better postoperative seizure outcome. In addition, for patients with temporal tumours, especially in the non-dominant hemisphere, a more aggressive strategy, such as an anterior temporal lobectomy, is recommended.

Key words: electrocorticography, epilepsy, microsurgery, neoplasm, epileptogenic focus

Epileptic seizure is a common presenting symptom and substantially impairs quality of life (QOL) in patients harbouring brain tumours (Spencer *et al*., 1984a; Zentner *et al*., 1997; Josephson *et al*., 2011; You *et al*., 2012a). Although seizures in children are rarely due to brain masses, seizures occurring for the first time in adults are generally caused by intracranial lesions. Epilepsy accompanies primary brain tumours in over 30% of the cases (Luyken *et al*., 2003; Hildebrand *et al*., 2005; van Breemen *et al*., 2007; Van Gompel *et al*., 2010; Maschio and Dinapoli, 2012). In patients with brain tumours, epileptic seizures may be the first or even the only symptom. Intracranial neoplasms include various types and each type may cause epileptic seizures, especially when supratentorial (Smith *et al*., 1991; Zentner *et al*., 1997; Luyken *et al*., 2003; van Breemen *et al*., 2007; Danfors *et al*., 2009). Besides epilepsy as a primary disease, it also contributes to increased morbidity and decreased QOL in this population. Therefore, brain tumour surgery aims not only to improve survival through reducing the tumour mass, but also to ameliorate tumour-related epilepsy. Resection of the neoplasm typically results in seizure remission, but some patients who have an initial successful surgery may subsequently develop chronic epilepsy without neuroimaging evidence of tumour growth or recurrence (Tian *et al*., 2011). The reason may be that the epileptogenic focus does not always correspond to tumour location (van Breemen *et al*., 2007; Loiacono *et al*., 2011). It is critical to manage the epileptogenic lesions cautiously with microsurgical techniques and intraoperative electrocorticography (ECoG) may provide additional findings in a considerable number of cases, thereby guiding neurosurgeons to treat the epileptogenic foci near a lesion or even at completely lesion-free areas (Awad *et al*., 1991; Berger *et al*., 1993; Voorhies and Cohen-Gadol, 2013) in order to achieve a better postoperative seizure outcome. In the current study, we reviewed 65 patients with onset of supratentorial neoplasms which manifested as epilepsy, who underwent microsurgical removal of the primary foci. In addition, guided by intraoperative ECoG, extra-lesional epileptogenic foci were screened and treated accordingly. The experiences reported here might help to better understand the mechanism of seizures as the initial symptom in patients with supratentorial neoplasms, and to find appropriate management for this population.

Material and methods

Patient population

From March 2009 to March 2010, a total of 1,674 patients with intracranial lesions were admitted for pre-surgical diagnosis and subsequently underwent surgery at the Department of Neurosurgery, First Hospital of China Medical University. Of the patients, 203/1,674 (12.1%) presented epilepsy as the initial symptom. After exclusion of non-tumoural lesions (cavernous angiomas, glial hyperplasia, and pseudotumour, *etc*.) and metastasis, a total of 137 cases were included in this study. The study was approved by the Research Review Boards of China Medical University and informed consent was obtained from each patient. The clinical data were reviewed retrospectively, as listed in *table 1*. Before confirmation of the lesions or decision to receive surgical treatments, 117/137 (85.4%) patients had taken AEDs regularly and 98/137 (71.5%) patients suffered from long-standing pharmacoresistant epilepsy. Each patient had routinely at least one preoperative long-term EEG, video-EEG monitoring, enhanced brain MRI and/or CT, and functional MRI if necessary.

Surgical procedure

The surgery was divided into two major categories: lesionectomy and epilepsy surgery. The aim of surgery was to remove the tumour and/or epileptogenic zone and to render the patient seizure-free, however, epilepsy surgery might also include more invasive craniotomy and resection, in addition to the lesion itself. These cases were consecutive, and the selection of surgical procedures ultimately depended on the patients' and their families' or guardians' decisions. Sixty-five patients underwent lesionectomy assisted by intraoperative ECoG, followed by tailored epilepsy surgery if necessary, whereas the other 72 patients received only lesionectomy without intraoperative ECoG and were defined as the control group. The surgical strategy was defined as "tailored epilepsy surgery" if the lesion was removed and cortex of abnormal discharges treated accordingly, and "simple lesionectomy" if only the lesion was removed.

All surgery was performed by two senior neurosurgeons, Prof. Shaowu Ou and Prof. Bo Qiu. The

Table 1. Patient population and lesion characteristics.

Characteristics	Cases (65)	Controls (72)
Gender (male/female)	34/31	40/32
Age (mean)	5-66 y (37.7 y)	7-65 y (37.2 y)
Duration (mean)	2 m-18 y (3.1 y)	1.5 m-16 y (3.2 y)
Seizure type		
Partial seizures (%)	51 (78.5)	53 (73.6)
Simple partial seizures	9	10
Complex partial seizures	31	36
Secondary generalisation	11	7
Generalised seizures (%)	14 (21.5)	19 (26.4)
Status epilepticus (%)	5 (7.7)	7 (9.7)
IEDs (%)	41 (63.1)	43 (59.7)
Pathology		
Glioma	39	42
Meningioma	24	28
PNET	2	2
Lesion location		
Frontal lobe (%)	27 (41.5)	30 (41.7)
Parietal lobe (%)	17 (26.2)	21 (29.2)
Temporal lobe (%)	15 (23.1)	15 (20.8)
Occipital lobe (%)	6 (9.2)	6 (8.3)
Surgical procedure		
Lesionectomy	33	72
Tailored epilepsy surgery	32	-
Temporal neoplasm (lesionectomy + ATL or CTC and/or MST)	15	-
Non-temporal neoplasm (Lesionectomy + ECoG-guided resection or + MST and/or CTC)	17	-
EOR		
GTR (%)	62 (95.4)	69 (95.8)
NTR (%)	1 (1.5)	3 (4.2)
STR (%)	2 (3.1)	0 (0)
Follow-up (mean)	19-47 m (32.7 m)	18-45 m (31.9 m)

y: year(s); m: month(s); IEDs: interictal epileptiform discharges; PNET: primitive neuroectodermal tumor; ATL: anterior temporal lobectomy; ECoG: electrocorticography; MST: multiple subpial transection; CTC: cortex thermocoagulation; EOR: extent of resection; GTR: gross total resection; NTR: near total resection; STR: subtotal resection.

principle of lesionectomy was consistent in both groups, regardless of the use of ECoG. Ten minutes before ECoG monitoring, the anaesthetist began to maintain a light and steady level of anaesthesia and a 4×5-electrode grid or one 1×6 strip was then placed on the cortex. Registration was performed during several minutes, at least until the ECoG (displayed with 70-Hz low-pass filter, 10 seconds a page) showed a continuous pattern (no burst suppression). The ECoG was recorded with a 32-channel EEG system (NicoletOne, Care Fusion, San Diego, CA, USA). During tailored epilepsy surgery, careful ECoG analysis for all exposed cortex was performed before and after lesion resection, and sites of abnormal discharges (usually spikes or spike-slow waves) were labelled, and then the pre- and post-resection electrographic spikes were compared. If epileptiform discharge still existed after removal of extra-temporal lesions, appropriate procedures such as ECoG-guided extended resection for non-functional areas, multiple subpial transection (MST), or cortex thermocoagulation (CTC) for functional areas were performed. With the help of the anaesthetist, ECoG analysis and treatments of epileptogenic foci were alternately repeatedly applied, until the ECoG analysis was normal or almost normal (*e.g.* occasional spikes). Depth electrodes were also used to target the hippocampus and amygdala in patients with temporal lobe epilepsy (TLE). If additional epileptogenic foci were found, appropriate surgical techniques, such as ECoG-guided extensive resection, MST, CTC, or anterior temporal lobectomy (ATL), were performed to treat the epileptogenic foci.

Gross total resection (GTR) was performed whenever possible on the basis of preservation of intact vascular and neurological function. A transsylvian approach was used for lesions located in the anterior and/or medial temporal region with TLE. Besides a simple lesionectomy, an additional ATL was performed in the case group based on the site and extent of the temporal neoplasms, as well as the findings of intraoperative ECoG and/or depth electrodes. A routine ATL in our practice was performed as described by Spencer *et al.* (1984b) and by Spencer and Burchiel (2012). However, there was little modification of all or most of the superior temporal gyrus on the language-dominant side, avoiding damage to the language processing regions, as well as preservation of the posterior part of the hippocampus to prevent postoperative impairments of memory, cognition, or language function.

Postoperative management

The pathological diagnosis of each resected specimen was confirmed by two chief neuropathologists according to World Health Organization criteria.

AEDs were routinely used after surgery; usually valproic acid and addition of levetiracetam if necessary. Different adjuvant therapies, such as chemotherapy and/or radiotherapy, were advised for patients according to pathological diagnosis.

Outcome assessment

Patients were regularly examined at 3 months, 6 months, and 12 months after surgery and at yearly intervals thereafter. Telephone interviews with patients and their families were also used. The postoperative seizure outcome at last follow-up visit was graded according to Engel's classification (Engel *et al.*, 1993). Neuropsychological assessment and EEG were repeated according to standard protocol during each follow-up visit until three years, and follow-up CT and/or MRI were performed to evaluate the extent of resection (EOR) and surgical strategy.

Statistical analysis

We analysed the data using the SigmaPlot 11.0 software (Systat Software, San Jose, CA, USA) to perform Pearson χ^2 test; $p<0.05$ was considered statistically significant.

Results

General information

The data corresponding to age, gender, duration, seizure type, and location of neoplasms between the two groups were comparable. The demographic characteristics of the patients are listed in *table 1*.

Neuroimaging and EEG findings

In either the case group or control group, >40% neoplasms were located in the frontal lobe. In both groups, 47.7% (31/65) and 46.7% (35/72) of patients had mass effect, respectively. Several types of neoplasm onset manifesting as epilepsy are illustrated in *figure 1*. Interictal epileptiform discharges (IEDs) were present in 41 (63.1%) and 43 (59.7%) patients in the two groups, respectively. Preoperative interictal EEG abnormalities correlated well with lesion location (82.9% and 81.4%, respectively).

Surgical and pathological results

Seventy-two patients in the control group received only lesionectomy. Intraoperative ECoG was used in all 65 patients of the case group. Most extra-lesional epileptogenic foci were within the range of 2-4 cm surrounding the tumours (*figure 2*). Depth electrodes were used to target the hippocampus and amygdala for all 15 patients with temporal neoplasms, and ECoG-guided lesionectomy plus modified ATL was performed in 14/15 patients (93.3%) because epileptiform discharges of the hippocampus and/or amygdala were detected.

Postoperative pathological examination showed that the most common neoplasms were gliomas (81 cases, including 55 low-grade and 26 high-grade gliomas), followed by meningiomas (52 cases, including 16 endotheliomatous, 12 fibrous, 12 transitional, 8 angioblastic, and 4 psammomatous meningiomas) and primitive neuroectodermal tumours (PNETs; 4 cases including 3 CNS PNETs and 1 ependymoblastoma), as listed in *table 1*.

Table 2. Outcomes.

Outcome (Engel)	Cases (%)	Controls (%)
Engel I	57 (87.7)	38 (52.8)
Engel II	7 (10.8)	13 (18.1)
Engel III	1 (1.5)	18 (25.0)
Engel IV	0	3 (4.2)
Sum	**65**	**72**

Outcome evaluation

No patient died during the hospitalisation period, and the common complications included transient hemiparesis or aphasia in 10 patients, pulmonary infection in 4 patients, and delayed healing of skin incision in 3 patients, which was successfully treated after symptomatic medication. One patient who underwent resection of mesial temporal structures developed postoperative loss of verbal memory, and gradually improved at five months. GTR was achieved in 62 patients (95.4%) of the case group and in 69 patients (95.8%) of the control group. AEDs were prescribed and tapered after the patients became seizure-free. Follow-up was achieved in 52 of 65 patients in the case group with an average period of 32.7 months (range: 19-47 months). In the control group, 17 patients were lost during follow-up, and the median duration of follow-up was 31.9 months (range: 18-45 months). Seizure outcome data were collected and are listed in *tables 2, 3,* and 4.

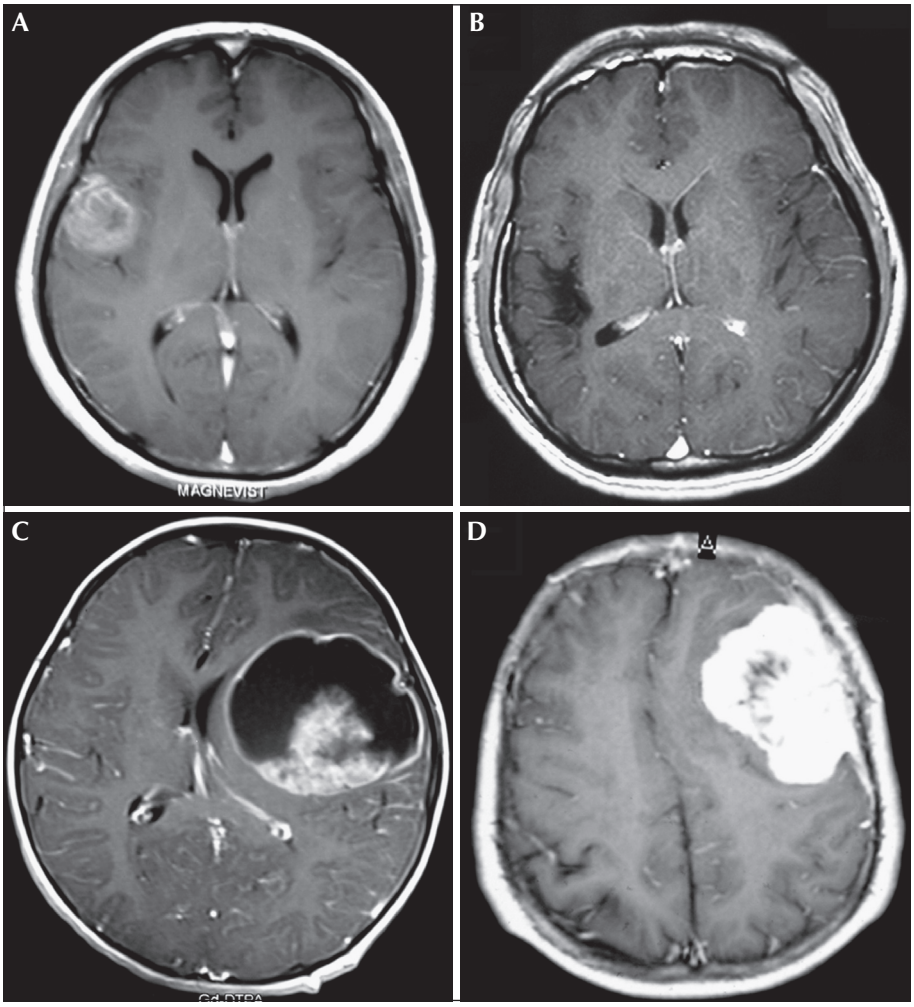

Figure 1. Illustration of onset of supratentorial neoplasms manifesting as epilepsy.
(A) Glioma in the right frontal lobe. (B) Glioma of the right temporal lobe. (C) PNET of the left frontal lobe. (D) Meningioma of the left frontal lobe.

Statistical analysis

We used two classification methods to compare seizure outcomes between the two groups. In method one, patients were categorised within a seizure-free group (Engel class I) or seizure group (Engel classes II- IV). In method two, Engel classes I and II were grouped together as satisfactory outcome (64 and 51 cases, respectively), while Engel classes III and IV were grouped as unsatisfactory seizure relief (1 and 21 cases, respectively). The same classification

Table 3. Outcomes of temporal neoplasms.

Outcome (Engel)	Cases (%)	Controls (%)
Engel I	12 (80.0)	3 (20.0)
Engel II	2 (13.3)	5 (33.3)
Engel III	1 (6.7)	5 (33.3)
Engel IV	0	2 (13.3)
Sum	**15**	**15**

Table 4. Outcomes of ECoG-guided tailored epilepsy surgery and lesionectomy

Outcome (Engel)	Cases (%)	Controls (%)
Engel I	28 (87.5)	67 (63.8)
Engel II	3 (9.4)	17 (16.2)
Engel III	1 (3.1)	18 (17.1)
Engel IV	0	3 (2.9)
Sum	**32**	**105**

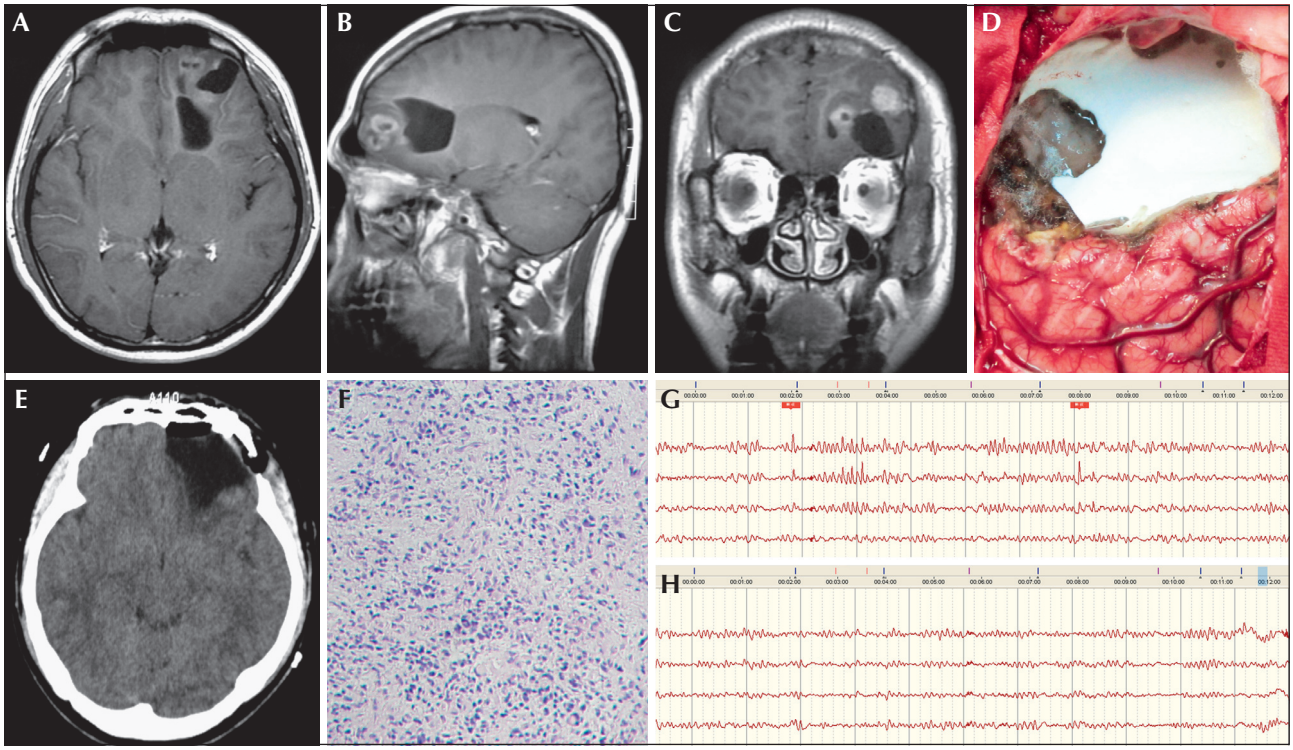

Figure 2. Epilepsy surgery for a left frontal glioma.
(A-C) MRI showed a lesion in the left frontal lobe. (D) After ECoG-guided extensive resection of the left frontal lobe, adjoining cortex received CTC to control the abnormal discharges. (E) Postoperative CT examination proved the satisfactory extent of excision. (F) Pathological diagnosis of the neoplasm was a diffuse astrocytoma (WHO grade II; haematoxylin-eosin staining; magnification: ×200). (G) Frequent spike waves could still be detected by intraoperative ECoG in the neighbouring areas after a simple lesionectomy. (H) After application of CTC, spikes were eliminated and ECoG showed normal waves.

methods were also adopted to categorise outcomes of temporal neoplasms in both groups, followed by statistical comparison.

In our series, the seizure-free rates in the case group and control group were 87.7% (57/65) and 52.8% (38/72), respectively. The differences were statistically significant (χ^2=17.981 with 1 degree of freedom; p<0.001), indicating the important role of intraoperative ECoG-guided epilepsy surgery. Besides, the comparison of satisfactory seizure control rates also revealed significant differences between both groups of patients (98.5% *vs.* 70.8%; χ^2=17.349 with 1 degree of freedom; p<0.001).

When simply comparing seizure outcomes of patients with temporal neoplasms, we still found positive significance of ECoG-guided resection plus modified ATL for these patients. Either the seizure-free rates (80.0% *vs.* 20.0%; χ^2=8.533 with 1 degree of freedom; p<0.01) or the satisfactory outcome rates (93.3% *vs.* 53.3%; χ^2=4.261 with 1 degree of freedom; p<0.05) between two groups were statistically different, indicating that an additional ATL after lesionectomy improves the seizure outcome in patients with temporal neoplasms.

Furthermore, we also compared the seizure outcome of the 32 patients who underwent ECoG-guided tailored epilepsy surgery with those who finally underwent lesionectomy (33 with ECoG and 72 without ECoG; *table 4*).

Both the seizure-free rates (87.5% *vs.* 63.8%; χ^2=5.408 with 1 degree of freedom; p<0.05) and the satisfactory seizure control rates (96.9% *vs.* 80.0%; χ^2=4.005 with 1 degree of freedom; p<0.05) were statistically different between the two groups, implying that ECoG-guided tailored epilepsy surgery offers a better prognosis.

Discussion

Epilepsy may be the first symptom in about 15-50% patients with intracranial neoplasms (Backus and Millichap, 1962; Smith *et al.*, 1991; Lynam *et al.*, 2007; Casazza and Gilioli, 2011; Maschio and Dinapoli, 2012; You *et al.*, 2012b). A clinical impression is widely held that epilepsy may even be the only manifestation of brain tumours which behave in a relatively benign manner for many years, regardless of their

benign or malignant nature. Once the epilepsy is confirmed to be symptomatic due to a brain tumour, a surgical resection is usually the optimal choice, both for oncological and epileptological considerations. At present, it remains controversial whether to choose isolated lesionectomy or tailored epilepsy surgery for this population (Zentner *et al*., 1997; Luyken *et al*., 2003; Clusmann *et al*., 2004; Giulioni *et al*., 2005; Giulioni *et al*., 2009; Garcia-Fernandez *et al*., 2011; Hu *et al*., 2012), hence the surgical strategy is of utmost importance for prognosis.

Evidence is accumulating that tailored epilepsy surgery, rather than lesionectomy, yields better seizure outcome for intracranial neoplasms (Ogiwara *et al*., 2010; Tripathi *et al*., 2010; Voorhies and Cohen-Gadol, 2013). Although it is still unclear if intraoperative ECoG is always necessary to identify the irritative zone adjacent to the neoplasms (Hu *et al*., 2012), and Englot *et al*. considered that the use of intraoperative ECoG is not singularly associated with improved seizure outcomes (Englot *et al*., 2011; Englot *et al*., 2012), many studies have proved its effectiveness for better postoperative seizure control (Zentner *et al*., 1997; Sugano *et al*., 2007; Ogiwara *et al*., 2010; Tripathi *et al*., 2010; Voorhies and Cohen-Gadol, 2013). Guided by intraoperative ECoG, tailored epilepsy surgery targets not only the lesion alone but also the extra or potential epileptogenic foci with abnormal discharges, indicating an aggressive surgical strategy. Therefore, the principal arguments for the aggressive treatment of neoplasms presenting with epilepsy are firstly to reduce mortality and secondly to improve control of medically refractory seizures (Smith *et al*., 1991). It is critical to decrease postoperative seizure attacks, and currently, advances in micro-neurosurgery can guarantee a safe GTR with a fairly low recurrence rate. Although gliosis at the resection site, incomplete resection, haemorrhage, residual cortical dysplasia, and neuronal injury may contribute to postoperative epileptic seizures, "coexistent pathology" or "dual pathology" are likely other plausible causes (Li *et al*., 1999; Khan *et al*., 2006; van Breemen *et al*., 2007; Kim *et al*., 2008; Prayson *et al*., 2010; Loiacono *et al*., 2011; Tian *et al*., 2011; Voorhies and Cohen-Gadol, 2013). In view of this, application of intraoperative ECoG, as well as following procedures to treat the extra epileptogenic foci, are essential and pivotal.

In our study, patients in the case group underwent intraoperative ECoG-guided "epilepsy surgery". Thirty-three cases eventually received simple lesionectomy, while the other 32 cases received tailored epilepsy surgery because extra-lesional epileptogenic foci were found even if the tumours had been completely removed. The outcomes were similar in both sub-groups of these patients in the case group, because the epileptogenic foci were detected using ECoG and then managed. Compared with the control group, the case group presented statistically significant improvement of postoperative seizure outcome, regardless of seizure-free rate or satisfactory seizure control rate. In non-temporal neoplasms, most epileptogenic foci were usually found 2-4 cm away from the visible border of the neoplasms, which is in accordance with the prevalent hypothesis that the lesions cause secondary changes to surrounding tissues and make them epileptogenic (van Breemen *et al*., 2007; You *et al*., 2012b). Based on this presumption, an isolated lesionectomy may not guarantee a good seizure control outcome. Many studies of paediatric patients reported that lesionectomy alone yielded satisfactory results (Kim *et al*., 2001; Giulioni *et al*., 2005), but other series of adult patients demonstrated that GTR or even extended resection improved seizure prognosis (Awad *et al*., 1991; Hildebrand *et al*., 2005; Chang *et al*., 2008; Englot *et al*., 2011; Englot *et al*., 2012; Garcia-Fernandez *et al*., 2011). It is possible that neoplasms, especially those with long duration, induce secondary epileptogenesis adjacent to or even distant to the original sites (van Breemen *et al*., 2007). Therefore, a reasonable explanation for better seizure outcome in children may be their shorter seizure history, with less opportunity of permanent secondary changes (You *et al*., 2012b). In our series, intraoperative ECoG provided evidence to localise epileptogenic foci, assess the effects of microsurgical procedures, and guide the extent of tailored surgery. After thorough evaluation of neuroimaging and electrophysiological results, tailored epilepsy surgery was preferred for those neoplasms with extra-lesional epileptogenic foci.

As a group of relatively special lesions, temporal tumours in the case group were treated more invasively. Location is known to be an important determinant of tumour-related epilepsy. Temporal lobe tumours are more likely to cause seizures than those in other locations, and data from our study are consistent with the literature (Engel, 1989; Chang *et al*., 2008). For temporal neoplasms, it is difficult and controversial to determine the optimal surgical extent, because the mesial temporal lobe, which is the most epileptogenic structure in the human brain, may be adjacent to, or be involved by, the lesions (Clusmann *et al*., 2002; Clusmann *et al*., 2004). Therefore, patients with temporal neoplasms in the present study were listed and compared separately. According to intraoperative electrophysiological findings, most patients with temporal neoplasms exhibited epileptiform discharges of temporal cortex and hippocampus and/or amygdala. Thus, the modified ATL was performed for this population after lesionectomy. Compared with their counterparts

in the control group, the seizure control outcome was more favourable (*table 3*). Moreover, although hippocampal sclerosis may be an important factor for TLE, hippocampal sclerosis was confirmed in only one TLE case. A possible explanation is that hippocampal sclerosis might be either a cause or result of TLE (Cavazos and Sutula, 1990; Blumcke *et al*., 2002; You *et al*., 2012b), and the absence of hippocampal sclerosis in this series was perhaps due to short duration (You *et al*., 2012b). In addition, it is reported that lesions in the posterior temporal lobe can be regarded as extra-temporal lesions in many aspects (Phi *et al*., 2009), and one posterior temporal tumour in the case group did not exhibit abnormal discharges of the hippocampus and/or amygdala after sufficient exposure of the lesion and anterior temporal lobe *via* an extended pterional approach. Thus, when only epileptiform discharges of adjoining temporal cortex were found, a decision of lesionectomy plus CTC and/or MST instead of ATL was made on the basis of thorough evaluation of neuroimaging and electrophysiological results, as well as the experiences of neurosurgeons. Despite the favourable seizure outcome without apparent neurological sequelae, the surgical strategy for temporal neoplasms should still be approached with care, because debate remains with regards to the necessary EOR, involving lesionectomy alone or additional amygdalohippocampectomy (Jooma *et al*., 1995; Cataltepe *et al*., 2005; Giulioni *et al*., 2005; Yeon *et al*., 2009). In our series, the anterior hippocampectomy was performed during ATL to avoid serious memory or cognition impairments, as suggested by Ogiwara *et al*. (2010), and a low rate of permanent neurological deficit was achieved. There were also limitations in our study, *e.g*. small number of patients, pathological heterogeneity, age distribution, and the extent of the lesion. Based on our institutional experience, we advocate a modified ATL including the amygdala and anterior hippocampus for temporal lesions on the basis of preoperative findings and intraoperative ECoG. Nevertheless, for temporal neoplasms of the dominant hemisphere, the EOR should be relatively conservative in order to avoid possible postoperative aphasia, hemianopia, or memory dysfunction (Spencer *et al*., 1984b; Clusmann *et al*., 2004; Sugano *et al*., 2007; Ogiwara *et al*., 2010; Spencer and Burchiel, 2012).

We also compared the seizure outcomes between patients who finally received intraoperative ECoG-guided tailored epilepsy surgery and pure lesionectomy (with or without ECoG), and the statistical results still showed superiority of tailored epilepsy surgery (*table 4*). In the case group, 33/65 patients did not show extra-lesional epileptogenic discharges after lesionectomy and received no further management, however, in 72 patients of the control group, a certain number of extra-lesional epileptogenic foci may have also existed despite the absence of intraoperative ECoG evidence. Perhaps this is the underlying reason for the statistical differences between the two groups. In other words, a proportion of the 72 patients of the control group indeed would have had the benefit of an ECoG-guided tailored surgery, provided that their potential extra-lesional epileptogenic foci were confirmed. On the other hand, the most common pathological types in 33 cases that underwent ECoG-guided tailored epilepsy surgery were intracerebral lesions (*e.g*. gliomas), indicating that intrinsic brain tumours may alter the neighbouring areas, both structurally and functionally, more easily and cause them to be epileptogenic, relative to the extrinsic tumours (*e.g*. meningiomas).

In the current study, most neoplasms were totally resected in both groups (95.4 and 95.8%, respectively). Because of a limited number of patients who did not receive GTR, we could not reach a conclusion regarding whether EOR has an impact on seizure prognosis. To our knowledge, GTR is important at least in an oncological perspective (Awad *et al*., 1991; Kim *et al*., 1995; Blumcke *et al*., 2002; Phi *et al*., 2009). Furthermore, several reports noted that complete tumour resection is the major factor influencing not only tumour recurrence, but also postoperative seizure control (Awad *et al*., 1991; Kim *et al*., 1995; Blumcke and Wiestler, 2002; Englot *et al*., 2011; Garcia-Fernandez *et al*., 2011; Englot *et al*., 2012; Phi *et al*., 2009).

Taken together, intraoperative ECoG played an important role to determine potential epileptogenic foci, besides the neoplasms themselves, in our series. Compared with isolated lesionectomy, ECoG-guided tailored epilepsy surgery may provide better seizure control outcome for the onset of supratentorial neoplasms manifesting as epilepsy. In temporal neoplasms, a modified ATL was superior to a simple lesionectomy with regards to better prognosis. Although there were limitations in our study and there are still many factors influencing postoperative seizure outcome, such as duration of epilepsy, EOR, extent of neoplasms or pathology, these results confirm the value of intraoperative ECoG to guide surgical procedure and to improve postoperative seizure control.

Acknowledgments and disclosures.

This work was supported by the Liaoning Provincial Natural Science Foundation of China (Bo Qiu; No. 2013021075), the Fund for Scientific Research of the First Hospital of China Medical University (Bo Qiu; No. fsfh1304), Liaoning Provincial Project on Social Development (Shaowu Ou; No. 2013225079), and the Science and Technology Program of Shenyang City (Shaowu Ou; No. F12-277-1-04).

The authors declare no conflicts of interests.

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