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Technical Notes

The fence post depth electrode technique to control both brain tumors and epileptic seizures in patients with brain tumor-related epilepsy

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ABSTRACT

Background: To control brain tumor-related epilepsy (BTRE), both epileptological and neuro-oncological approaches are required. We hypothesized that using depth electrodes (DEs) as fence post catheters, we could detect the area of epileptic seizure onset and achieve both brain tumor removal and epileptic seizure control.

Methods: Between August 2009 and April 2018, we performed brain tumor removal for 27 patients with BTRE. Patients who underwent lesionectomy without DEs were classified into Group 1 (13 patients) and patients who underwent the fence post DE technique were classified into Group 2 (14 patients).

Results: The patients were 15 women and 12 men (mean age, 28.1 years; median age 21 years; range, 5–68 years). The brain tumor was resected to a greater extent in Group 2 than Group 1 ($P < 0.001$). Shallower contacts showed more epileptogenicity than deeper contacts ($P < 0.001$). Group 2 showed better epilepsy surgical outcomes than Group 1 ($P = 0.041$).

Conclusion: Using DEs as fence post catheters, we detected the area of epileptic seizure onset and controlled epileptic seizures. Simultaneously, we removed the brain tumor to a greater extent with fence post DEs than without.

Keywords: Brain tumor, Fence post depth electrode technique, Invasive monitoring, Medically refractory epilepsy, Neuronavigation guided

INTRODUCTION

Brain tumor-related epilepsy

Epileptic seizures are one of the most common comorbidities in patients with brain tumors.[5,6,20] Difficulties in controlling brain tumor-related epilepsy (BTRE) have been reported and are likely due to lack of an interdisciplinary approach.[16,19] To control BTRE, both epileptological and neuro-oncological approaches are required.[10]

Brain tumors and the fence post catheter technique

Many reports have shown that radical resection is required to control brain tumors.[11,21,22] Thus, both gross total removal (GTR) and the absence of epileptic seizures are ideal goals in patients with BTRE. The neuronavigation-guided fence post catheter technique is one procedure[4,7,13,22] that assists in performance of GTR.

Hypothesis and purpose of this study

We hypothesized that using depth electrodes (DEs) as fence post catheters, we could detect the area of epileptic seizure onset and achieve both removal of tumors and control of epileptic seizures in patients with BTRE. In this study, we considered patients who underwent tumor removal surgery without fence post DEs as the control group and compared the outcomes in the control group to those in patients in whom fence post DEs were used.

METHODS

Patients

Between August 2009 and April 2018, we performed brain tumor removal surgery in 47 patients. The patient inclusion criteria in this study were as follows: (1) development of medically refractory epilepsy, (2) surgery was performed by the same surgeon (AF), and (3) follow-up for ≥6 months. Patients who had brain arteriovenous malformation, brain cavernous angioma, subependymal giant cell astrocytoma of tuberous sclerosis complex, or patients who underwent tumor removal without DEs first and then underwent the fence post DE technique for residual seizures during the follow-up period were excluded from the study.

Among these, 27 patients with BTRE met the criteria. We introduced the fence post technique for BTRE in our hospital in August 2013. Thus, patients who underwent lesionectomy without DEs were classified into Group 1 (13 patients; all treated before August 2013). Patients who underwent the fence post DE technique were classified into Group 2 (14 patients; all treated after August 2013).

All patients had undergone presurgical evaluation, including a detailed clinical history and magnetic resonance imaging (MRI).

Clinical information

We reviewed sex, age at surgery, follow-up period, age at epileptic seizure onset, postoperative brain tumor prognosis, location of the brain tumor, the type of brain tumor, and brain tumor removal rate (we defined the removal rate of the brain tumor as GTR: ≥100%; subtotal removal (STR) 90%–<100%; and partial removal (PR) <90%), which DE contacts suggested the seizure onset area, subsequent epilepsy surgery outcome, and complications associated with the fence post DE technique. We evaluated the outcomes of surgery at the end of the follow-up period based on Engel classifications I–IV (Engel I: free of disabling seizures; Engel II: rare disabling seizures; Engel III: worthwhile improvement; and Engel IV: no worthwhile improvement).[17]

Fence post DE technique

For Group 1, we only used a neuronavigation system to find the tumor location during the operation without using the fence post technique. For Group 2, we used the neuronavigation-guided fence post DE technique. To avoid locational error due to brain shift associated with the neuronavigation system and to allow precise resection of the tumor, we placed the DEs as fence post catheters. A schematic of the fence post procedure is shown in Figure 1. First, we preoperatively assumed that a cuboid completely contained the tumor mass as seen with iPlan Station (Cranial surgical planning software, Brainlab AG). We planned that each side of the cuboid would cover the most anterior, most posterior, most medial, and most lateral regions of the tumor. According to the location of the tumor, DEs were placed as follows:

1. If the tumor was in a superficial area [Figure 1a], we placed three to four DEs to contain the tumor in the cuboid.
2. If the tumor was in a medial (interhemispheric) area [Figure 1b], we placed two to three DEs to contain the tumor in the cuboid on the interhemispheric side.
3. If the tumor was in a lateral (polar) area [Figure 1c], we placed two to three DEs to contain the tumor in the cuboid on the polar side.
4. If the tumor was in the skull base area [Figure 1d], we placed two DEs to contain the tumor in the cuboid on the skull base side.
5. If the tumor was in an area involving the hippocampus or amygdala [Figure 1e], we directly inserted the DEs into these regions.
6. If the tumor was in an avascular area judging from MRI and/or an angiogram, we inserted the DEs directly into the inside of the tumor.

Second, we inserted DEs as fence posts according to guidance from the navigation system (Curve™ Neuronavigation System, Brainlab AG, Munich, Germany). The insertion of a DE was performed before dural incision to avoid brain shift. We used two types of DEs made from silicon, one with a 5-mm interval and one with a 10-mm interval. Each DE has six contacts, and the outer diameter of DE was 1.5 mm (Unique Medical Co., Komae, Japan). DEs were chosen depending on the tumor size. If some contacts were located outside the parenchyma, we only used the intraparenchymal contacts for the neurophysiological study.

Long-term DE monitoring

After implantation of electrodes, all patients in Group 2 underwent extra operative monitoring for 2–7 days to

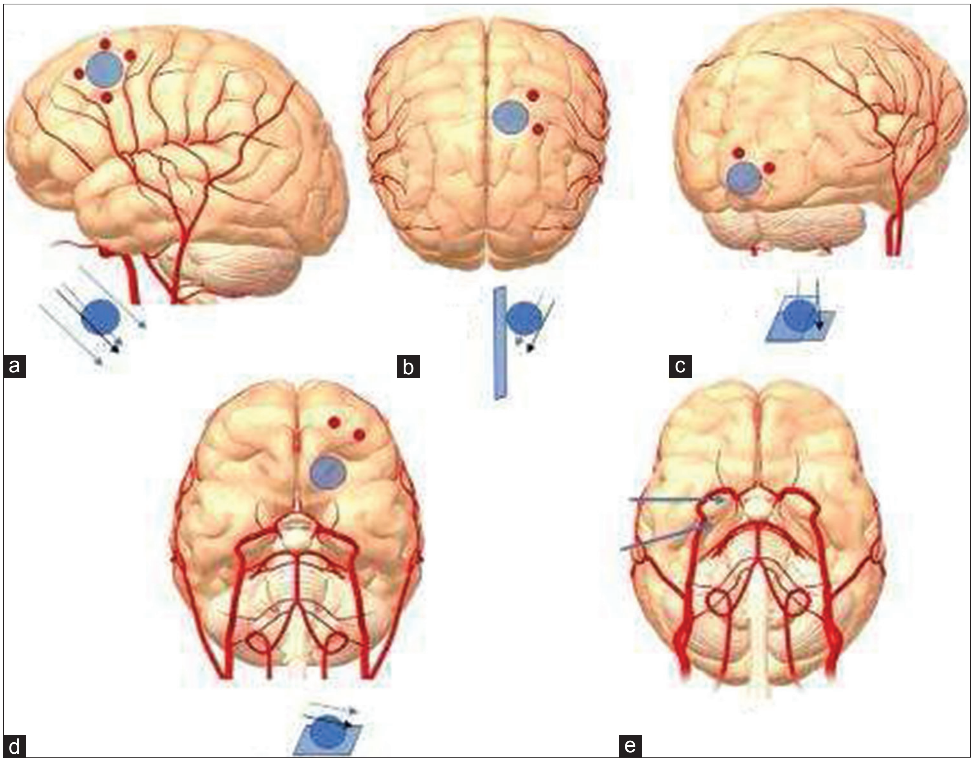

Figure 1: Fence post depth electrode placements. (a) A superficial area tumor. We placed three to four depth electrodes (DEs) to contain the tumor within the cuboid. (b) A medial (interhemispheric) area tumor. We placed two to three DEs to make one side of the cuboid. The other side of the cuboid was already on the interhemispheric side. (c) A lateral (polar) area tumor. We placed two to three DEs to make one cuboid side. The other side of the cuboid was already on the polar side. (d) A skull base area tumor. We placed two DEs to make one cuboid side. The other side of the cuboid was already on the skull base side. (e) An area involving the hippocampus or amygdala. We directly inserted the DEs into these regions.

capture recurring seizures at least twice. We evaluated which DE and which contact was involved most in the ictal onset zone.

Surgery

For Group 1, we removed the brain tumor using neuronavigation assistance. For Group 2, once we identified the ictal onset zone, we performed both tumor removal and focus resection. After dural incision, resection of the cuboid containing the tumor mass was performed according to fence post guidance.[12,22]

Statistical analysis

We used the Mann–Whitney rank-sum test and Fisher's exact test for statistical analyses of surgical outcomes. Statistical significance was set at $P < 0.05$. Analysis was done using Sigma Plot 14 (Systat Software, Inc., San Jose, CA, USA).

Ethical approval

Written informed consent was obtained from all patients for procedures performed in this study in accordance with the principles of the Declaration of Helsinki. This study was approved by the Ethics Committee of Seirei Hamamatsu General Hospital.

RESULTS

Clinical information

All clinical information for patients in Groups 1 and 2 are shown in Table 1. Patients included 15 women and 12 men (mean age, 28.1 years; median age 21 years; range, 5–68 years). Group 1 included 13 patients and Group 2 included 14 patients [Table 1].

Fence post DE technique and DE monitoring

We used 50 DEs and 300 contacts for Group 2. No complications resulted from the procedure.

The location of the brain tumors and placement of the DEs for the fence post technique are shown in Table 2.

In Group 1, seven of 13 patients achieved GTR, five achieved STR, and one achieved PR. In Group 2, 13 of 14 patients achieved GTR and one achieved STR [Table 1]. The

Table 1: Clinical information and surgical outcome.

	Pt. No.	Age at operation (years)	Sex	F/U period (months)	Epilepsy onset age (years)	Brain tumor	Current status	Removal rate	Epilepsy surgery outcome
Group 1	1	59	F	4	58	GBM	Dead	STR	I
	2	21	F	90	14	PNET		STR	I
	3	48	F	52	46	Lower-grade glioma		GTR	I
	4	10	F	10	10	GBM	Dead	PR	II
	5	68	M	14	68	Met	Dead	GTR	I
	6	37	F	82	36	Oligodendroglioma		GTR	I
	7	11	F	88	9	Lower-grade glioma		GTR	I
	8	38	M	63	35	Lower-grade glioma		GTR	I
	9	8	F	61	6	Lower-grade glioma		STR	I
	10	7	F	87	5	DNET		GTR	I
	11	7	M	52	2	Lower-grade glioma		STR	III
	12	30	F	50	8	Lower-grade glioma		STR	III
	13	50	M	60	49	Lower-grade glioma		GTR	II
Group 2	14	26	M	46	18	DNET		GTR	I
	15	14	F	53	28	Lower-grade glioma		GTR	I
	16	18	M	53	13	DNET		GTR	I
	17	8	M	43	13	Lower-grade glioma		GTR	I
	18	5	F	25	5	Lower-grade glioma		GTR	I
	19	13	F	23	2	DNET		GTR	I
	20	15	M	21	2	DNET		GTR	I
	21	24	F	19	13	Lower-grade glioma		GTR	I
	22	58	F	17	6	DNET		GTR	I
	23	46	M	14	47	Lower-grade glioma		GTR	I
	24	18	F	11	10	DNET		GTR	I
	25	57	M	1	55	Met		GTR	I
	26	45	M	10	43	Anaplastic astrocytoma		GTR	I
	27	18	M	31	8	Lower-grade glioma		STR	I

Pt.: Patient, F/U: Follow-up, GBM: Glioblastoma multiforme, PNET: Primitive neuroectodermal tumor, DNET: Dysembryoplastic neuroepithelial tumor, Met: Metastatic tumor, GTR: Gross total removal, STR: Subtotal removal, PR: Partial removal

Table 2: Tumor location, cuboid formation, and seizure onset electrode.

	Pt. No.	Tumor location	Fence post depth electrode placement	Seizure onset electrode
Group 2	14	Temporal base	2 Cuboid, 1 hippocampus	Hippocampus
	15	Occipital base/interhemispheric	2 Cuboid, 1 hippocampus	Hippocampus
	16	Medial temporal	1 Hippocampus, 2 amygdala	Hippocampus
	17	Temporal base	3 Cuboid, 1 hippocampus, 1 amygdala	Hippocampus
	18	Occipital base/interhemispheric	4 Cuboid, 1 hippocampus	Superior 5/6, lateral 5/6
	19	Frontal superficial	4 Cuboid	Inferior 6, lateral 6
	20	Temporal base	4 Cuboid, 1 hippocampus	Posterior 6
	21	Temporal base	4 Cuboid, 1 hippocampus	Hippocampus
	22	Frontal/interhemispheric	2 Cuboid, 1 intra tumor	Inferior 3
	23	Medial temporal	1 Hippocampus, 1 amygdala	Hippocampus
	24	Frontal superficial	4 Cuboid	Anterior 2/3
	25	Frontal superficial	4 Cuboid	Posterior 3/4, anterior 6, medial 6
	26	Frontal polar	3 Cuboid	Posterior 4/5
	27	Frontal/interhemispheric	2 Cuboid	Posterior 6

We placed DEs depending on the tumor location. The contacts that suggested the seizure onset area were significantly shallower. We used the Mann–Whitney rank-sum test for this analysis

difference in the removal rate between Group 1 and Group 2 was statistically significant ($P < 0.001$).

The difference between DE contact that suggested epileptogenicity and a contact that did not suggest epileptogenicity was statistically significant ($P < 0.001$). Shallower contacts showed more epileptogenicity than deeper contacts.

Among the DEs, the location where the DEs were placed did not significantly affect the assessment of epileptogenicity. This procedure did not result in any complications.

Surgical outcome

In Group 1, nine patients were classified as Engel I (70%), two as Engel II (15%), and two as Engel III (15%). In Group 2, all patients were classified as Engel I (100%). The difference between Group 1 and Group 2 in seizure outcome was statistically significant ($P = 0.041$).

Illustrative case (Patient No. 25)

A 57-year-old right-handed man with lung adenocarcinoma had exhibited left face and hand twitching due to metastasis to the right frontal brain. He underwent radiotherapy and chemotherapy for the metastatic brain tumor and was receiving levetiracetam and brivaracetam. Although the metastasis and seizures had remained for 5 months, he exhibited status epilepticus, and MRI at the time revealed tumor regrowth and peritumoral edema. Just before the BTRE operation, he continuously exhibited left arm twitching every 4 h that lasted for an hour.

Due to increased intracranial pressure (IICP), we could not place a subdural grid in this patient. We placed four DEs to form the cuboid containing the metastatic tumor [Figure 2]. Extra operative DE monitoring showed epileptogenicity in the peritumoral area. We removed the cuboid area including the tumor and epileptogenic area. Postoperatively, he has been free from epileptic seizures for more than a month.

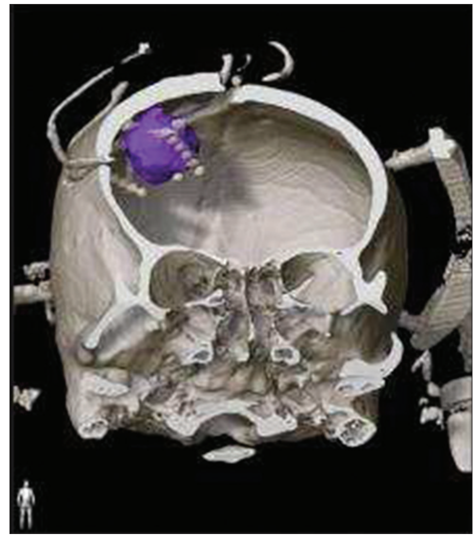

Figure 2: Illustrative case (Patient No. 25). A 57-year-old man with lung adenocarcinoma exhibited left arm and face twitching. The blue area in the right frontal area shows the metastatic tumor. We placed four depth electrodes in the anterior, medial, lateral, and posterior regions of the tumor as fence posts.

DISCUSSION

BTRE requires treatment due to both the brain tumor and epilepsy.[15] Management of BTRE involves treatments that are complex and diverse, depending on the facility.[10,16,18] When a patient with BTRE experiences medically refractory epilepsy, the epilepsy may affect his or her daily life, even if the tumor is under control.[19] Therefore, removing the brain tumor as much as possible and simultaneously controlling epileptic seizures are key for patients with BTRE to have a better quality of life.[3]

To control medically refractory epilepsy, invasive monitoring to detect epileptogenicity is required. However, placement of a subdural grid for patients with BTRE is difficult due to IICP.[1] Thus, we used DEs to locate the site of epileptogenicity without creating IICP, and simultaneously, we performed GTR of the brain tumor. We utilized DEs for both the fence post technique and invasive epilepsy monitoring. Use of this procedure allowed better removal of the brain tumor and better seizure control. No complications resulted from the procedure.

The contacts that detected the epileptogenicity were shallower and tended to be located more often in the hippocampus than in other structures. This is probably due to the strong epileptogenicity that is present more in the cortex and hippocampal regions[2,14] than in white matter. In most patients with temporal lobe epilepsy, the epileptogenic focus involves the mediobasal structures of the temporal lobe including the hippocampus, amygdala, uncus, and parahippocampal gyrus.[8,9] Thus, if the tumor is adjacent to medial temporal structures, possible epileptogenicity of the hippocampus should be considered.

CONCLUSION

Using DEs as fence post catheters, we identified the area of epileptic seizure onset and were able to remove the tumor in patients with BTRE, resulting in control of epileptic seizures.

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Authors' contributions

Neurosurgical operation: AF; Acquisition of data: AF, TO, YM, KS, and MN. Analysis and interpretation of data: AF, TO, and HE.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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