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Original Article

Mandibular and chin electrodes as a supplemental recording for detection of epileptiform discharges in mesial temporal lobe epilepsy

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ABSTRACT

Background: We previously demonstrated the usefulness of periorbital electrodes in supplemental recording to detect epileptiform discharges in patients with mesial temporal lobe epilepsy (MTLE). However, eye movement may disturb periorbital electrode recording. To overcome this, we developed mandibular (MA) and chin (CH) electrodes and examined whether these electrodes could detect hippocampal epileptiform discharges.

Methods: This study included a patient with MTLE, who underwent insertion of bilateral hippocampal depth electrodes and video-electroencephalographic (EEG) monitoring with simultaneous recordings of extra- and intracranial EEG as part of a presurgical evaluation. We examined 100 consecutive interictal epileptiform discharges (IEDs) recorded from the hippocampus and two ictal discharges. We compared these IEDs from intracranial electrodes with those from extracranial electrodes such as MA and CH electrodes in addition to F7/8 and A1/2 of international EEG 10-20 system, T1/2 of Silverman, and periorbital electrodes. We analyzed the number, rate of laterality concordance, and mean amplitude of IEDs detected in extracranial EEG monitoring and characteristics of IEDs on the MA and CH electrodes.

Results: The MA and CH electrodes had nearly the same detection rate of hippocampal IEDs from other extracranial electrodes without contamination by eye movement. Three IEDs, not detected by A1/2 and T1/2, could be detected using the MA and CH electrodes. In two ictal events, the MA and CH electrodes detected the ictal discharges from the hippocampal onset as well as other extracranial electrodes.

Conclusion: The MA and CH electrodes could detect hippocampal epileptiform discharges as well as A1/A2, T1/T2, and peri-orbital electrodes. These electrodes could serve as supplementary recording tools for detecting epileptiform discharges in MTLE.

Keywords: Chin electrode, Electroencephalography, Epileptiform discharge, Mandibular electrode, Mesial temporal lobe epilepsy

INTRODUCTION

The mesial temporal lobe is a key structure that is involved in epileptiform discharges, particularly the hippocampus. However, extracranial detection of electroencephalographic (EEG) activity from the mesial temporal lobe is sometimes difficult to detect with standard surface electrodes placed according to the international 10–20 EEG system, such as F7/F8 and A1/A2, because the conduction of deep brain activity is easily attenuated by the skull.[3,4,10] A sphenoidal (Sp) electrode technique has been developed and is widely used to monitor epileptiform discharges in the mesial temporal lobe through the foramen ovale.[3,4,10] The Sp electrode is inserted beneath the zygomatic arch, and the electrode tip is usually placed at an anteroventral position within the basal temporal region. The drawback is that the insertion of the Sp electrode is often associated with pain.[5] To overcome this, we[10] previously developed periorbital electrodes, which are noninvasive and do not induce pain, and demonstrated that periorbital electrode recording can detect the ictal discharges in the mesial temporal lobe as effectively as the Sp and standard temporal surface electrodes, including the T1/T2 electrodes of Silverman.[11] Although the periorbital electrode recordings are rarely obscured by muscle activity, unlike other standard temporal surface electrodes, they are disturbed by eye movement.[10] To overcome this, we also developed noninvasive mandibular (MA) and chin (CH) electrodes, which are placed on the bilateral MA angles and on the CH at the midline of the mandible, respectively. In the present case study, we examined whether MA and CH electrodes could detect the epileptiform discharges in the mesial temporal lobe using simultaneous recording with bilateral hippocampal depth electrodes.

MATERIALS AND METHODS

Patient information

A 51-year-old right-handed man was admitted to our institution. The patient developed focal impaired awareness seizures 2 years before admission, which became resistant to optimal doses of anti-seizure medications (ASMs) including valproate, levetiracetam, and lacosamide. EEG demonstrated independent interictal epileptiform discharges (IEDs) and ictal discharges in the bilateral temporal regions. Magnetic resonance imaging was normal. ^{18}Fluorodeoxyglucose-positron emission tomography showed a slightly hypometabolic region in the right medial and lateral temporal lobe. The Wada test suggested left hemispheric dominance for language but bilateral for memory. He underwent stereotactic insertion of bilateral hippocampal depth electrodes with four contacts (electrodes no. 1–4 and 7–10) at 5 mm intervals and two contacts (electrodes no. 5–6 and 11–12) at 10 mm intervals [Figure 1a]. The electrode positions were confirmed by computed tomography and X-ray [Figure 1b]. The electrodes no. 1–3 and 7–9 were located in the left and right hippocampi, respectively. We captured two ictal events during intracranial EEG monitoring and observed the onset of both events from the right hippocampus. The patient underwent right anterior temporal lobectomy with hippocampectomy with the guidance of intraoperative electrocorticography. Postoperative EEG showed the disappearance of the paroxysmal activity in the right temporal region. With reduced doses of ASMs, he remained seizure free during the 2 years of follow-up. The histological findings of the hippocampus revealed diffuse astrogliosis and no evidence of hippocampal sclerosis.

This study was approved by the Ethics Committee of our institution (No. 2021-370). The patient provided written informed consent.

Simultaneous extra- and intracranial EEG recording

For extracranial EEG recording, disc electrodes were placed over the scalp according to the international 10–20 EEG system. Moreover, T1/T2 electrodes[11] and periorbital electrodes (supraorbital lateral: SOL, infraorbital lateral: IOL, and infraorbital medial: IOM)[10] were placed [Figure 1a]. The MA electrodes were placed on the MA angles on both sides and the CH electrode was placed on the CH at the midline of the mandible [Figures 1a and b]. CH and MA electrodes are farther from the mesial temporal lobe compared to other extracranial electrodes [Figures 1a and b]. He underwent simultaneous recordings of extra- and intracranial EEG as part of a presurgical evaluation, as described previously.[2,7-9] EEG recordings were collected using a digital EEG recorder (Neurofax: Nihon Kohden, Tokyo, Japan).

Extra- and intracranial EEG data analysis

We examined IEDs detected in extracranial EEG monitoring, including those from the MA and CH electrodes, along with 100 consecutive IEDs detected from intracranial EEG monitoring. The IED amplitude was calculated by measuring the difference between the positive peak and the negative peak. We analyzed the number, the rate of laterality concordance, and mean amplitude of IEDs detected in extracranial EEG monitoring. The relationship between the appearance of IEDs on extracranial EEG and the appearance and the amplitude of the corresponding IEDs on intracranial EEG was analyzed retrospectively by two board-certified electroencephalographers (T.S. and A.S.) who were blinded to the clinical data. No differences in the electroencephalographers' interpretations were noted

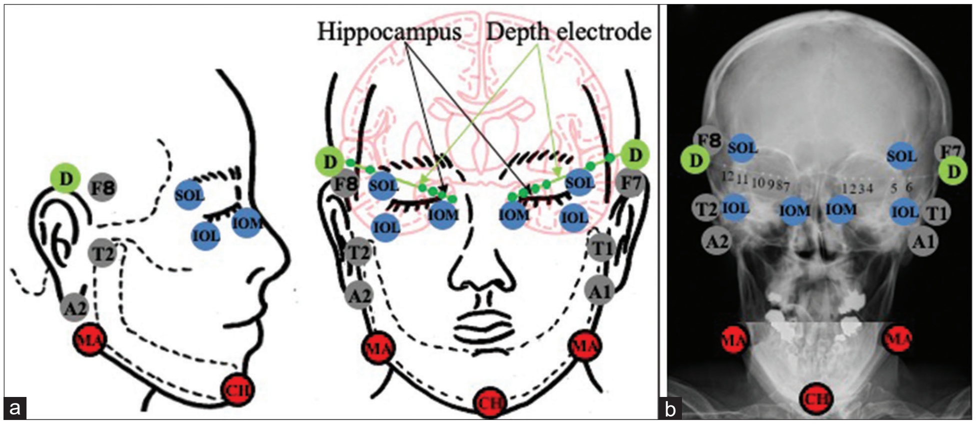

Figure 1: Schematic drawing (a) and plain craniogram (b) showing the anatomical relationship between the standard extracranial anterior temporal electrodes placed according to the international EEG 10-20 system (F7/8 and A1/A2), T1/T2 of Silverman, periorbital electrodes (supraorbital lateral, infraorbital lateral and infraorbital medial), and the mandibular and chin electrodes, and bilateral hippocampal depth electrodes (D) with six contacts (1–6 on the left side and 7–12 on the right side). SOL: Supraorbital lateral, IOL: Infraorbital lateral, ÏOM: Infraorbital medial, MA: Mandibular, CH: Chin.

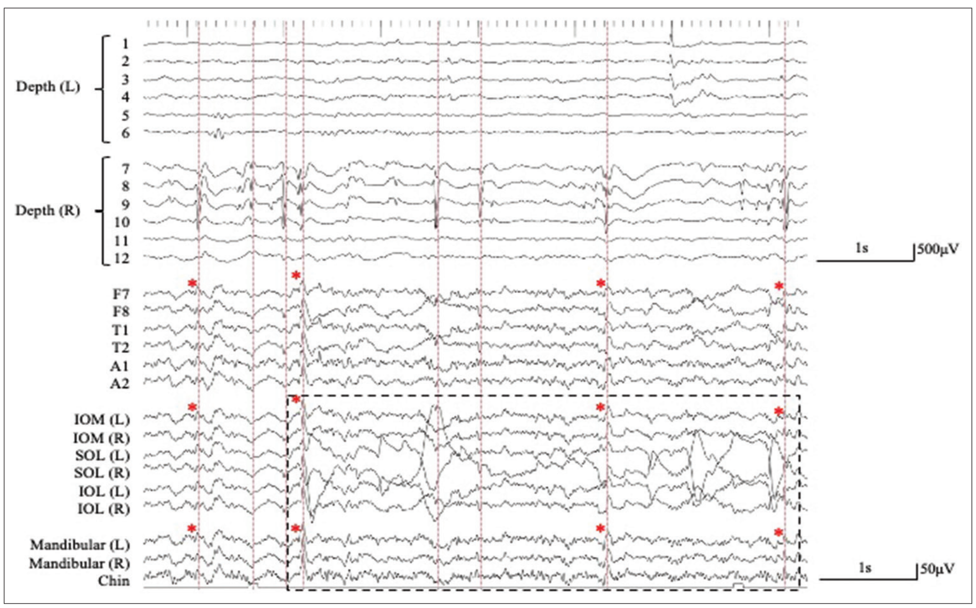

Figure 2: Simultaneous extra- and intracranial (bilateral hippocampal depth electrodes with six contacts; 1–6 on the left (L) side and 7–12 on the right (R) side) EEG recording. The interictal epileptiform discharges (IEDs) detected in extracranial EEG monitoring (lower traces) correspond to IEDs detected in the bilateral hippocampus as intra-cranial EEG monitoring (upper traces) (red dashed lines). A number of the depth electrodes are indicated on Figure 1. (Pz, averaged reference). The IEDs detected on the extracranial recording are shown with red asterisks. The artifact associated with eye movement is recorded by the periorbital electrodes, but not by the mandibular + chin electrodes (black dashed square). SOL: Supraorbital lateral, IOL: Infraorbital lateral, IOM: Infraorbital medial.

in the independent assessment. A Pz electrode was used as the reference electrode for the amplitude measurement. Amplification sensitivity and filter settings were changed when necessary. The amplitude from the peak to baseline of the IED was measured using a digital scaling system (Nihon Kohden Tokyo, Japan).

RESULTS

The number of the extracranial IEDs recorded concurrently with 100 consecutive hippocampal IEDs

We counted the number of the IEDs recorded from each extracranial EEG electrode, including F7/8, A1/2, T1/2, SOL (Left [L]/Right [R]), IOM (L/R), IOL (L/R), and MA (L/R)+CH, corresponding to 100 consecutive hippocampal IEDs [Figure 2, red dashed lines]. The periorbital electrode recordings showed artifact associated with eye movement, but the MR+CH electrodes did not show any artifact [Figure 2].

Figure 3 is an example of the simultaneous intra- and extracranial EEG recordings with an expanded time-scale. Corresponding to a negative component of an IED recorded from the right hippocampus (7–9), negative IEDs were recorded from F7, T1, A1, IOM (l), SOL (l), IOL (l), MA (L/R), and CH [Figure 3 dagger, blue dashed line]. Corresponding with the predominantly positive component of the IED from the right hippocampus (7–9), a corresponding negative IED was recorded at F7/8, T1/2, A1/2, IOM (L/R), SOL (L/R), IOL (L/R), MA (L/R), and CH [Figure 3, double dagger, green dashed line], whereas the predominantly positive components were detected at F8, T2, IOM (r), SOL (r), and IOL (r). However, IEDs were not detected from the MA and CH electrodes [Figure 3 asterisk, red dashed line].

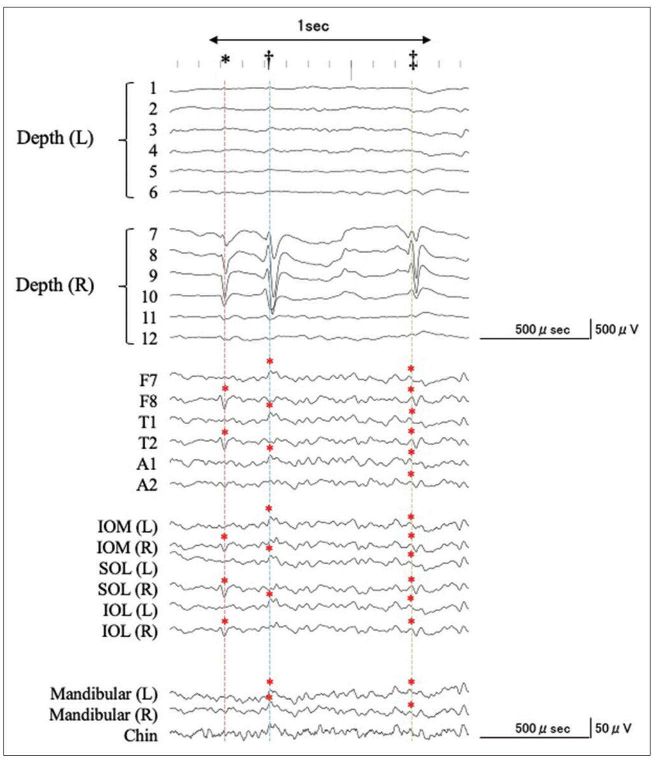

Figure 3: An example of the simultaneous intra- and extracranial EEG recording with expanded time-scale. See details in the text. Corresponding to a negative component of an IED recorded from the right hippocampus (7–9), negative IEDs were recorded from F7, T1, A1, IOM (L), SOL (L), IOL (L), MA (L/R), and CH (dagger, blue dashed line). Corresponding with the predominantly positive component of the IED from the right hippocampus (7–9), a corresponding negative IED was recorded at F7/8, T1/2, A1/2, IOM (L/R), SOL (L/R), IOL (L/R), MA (L/R), and CH (double dagger, green dashed line), whereas the predominantly positive components were detected at F8, T2, IOM (R), SOL (R), and IOL (R). However, IEDs were not detected from the MA and CH electrodes (asterisk, red dashed line).

The MA and CH electrodes had the almost same detection rate as the hippocampal IEDs obtained from A1/2 and T1/2, that is, out of 100 intracranial IEDs, 41 IEDs were detected by electrodes at F7/8, 49 at A1/2, 53 at T1/2, 53 at SOL, 60 at IOM, 47 at IOL, and 51 at MA+CH (11 by MA and 40 by CH) [Table 1]. Thus, the detection rates from the MA and CH electrode recordings were superior to the standard temporal surface electrode recordings, whereas they were slightly inferior to those at the T1/2 and periorbital electrodes.

There were three hippocampal IEDs with predominantly positive components not detected by A1/2 and T1/2, but they were slightly by the MA and CH electrodes [Figure 4].

The detection rate of IED potentials by MA and CH electrodes compared with intracranial EEG

We divided the amplitude of IEDs detected in hippocampal EEG into three groups: 0–499 μV (39 IEDs, mean 441.0 μV) (Group A), 500–999 μV (32 IEDs, mean 710.9 μV) (Group B), and over 1000 μV (29 IEDs, mean 1089.7 μV) (Group C). Extracranial EEG recordings demonstrated that 30 IEDs in

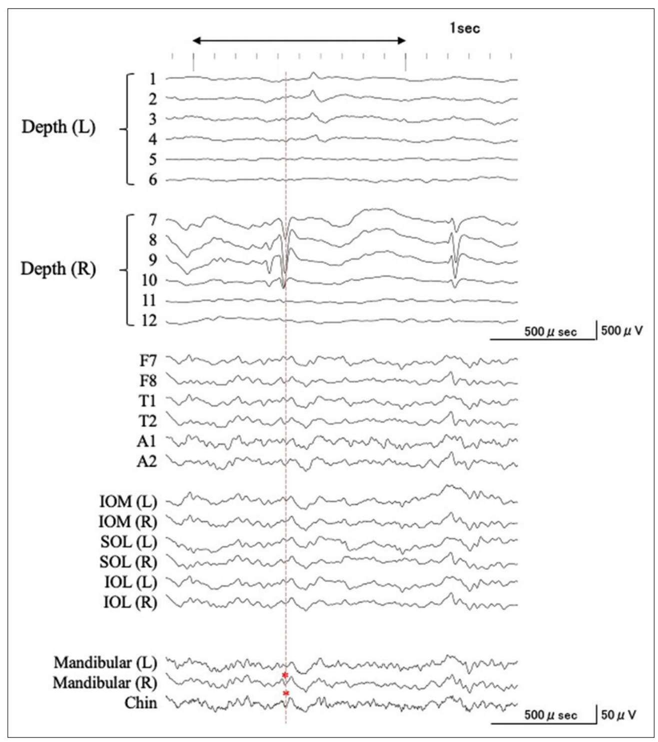

Figure 4: Simultaneous extra- and intra-cranial EEG recording shows a positive interictal epileptiform discharge (IED) not detected by A1/2 and T1/2 but by the mandibular and chin electrodes (red asterisks), corresponding to positive IED in the hippocampus (red dashed line).

Table 1: The number of the extracranial IEDs recorded concurrently with 100 consecutive hippocampal IEDs.

	F7/8	A1/2	T1/2	SOL	IOM	IOL	MA+CH
IED	41	49	53	53	60	47	51 (MA11, CH40)

IED: Interictal epileptiform discharge, SOL: Supraorbital lateral, IOM: Infraorbital medial, IOL: Infraorbital lateral, MA: Mandibular, CH: Chin

Table 2: The detection rate of IED potentials by mandibular and chin electrodes compared with intra-cranial EEG.

The amplitude of IEDs in depth electrode (n, mean μV)	The number of IEDs detected in MA+CH electrodes	% of IED detection in MA+CH electrodes
0–499 μV (39, mean 441.0 μV) (Group A)	30	76.9
500–999 μV (32, mean 710.9 μV) (Group B)	26	81.3
1000 μV≦ (29, mean 1089.7 μV) (Group C)	28	96.6

IED: Interictal epileptiform discharge, MA: Mandibular, CH: Chin

Group A, 26 in Group B, and 28 in Group C were detected [Table 2]. The rates of IED detection by MA+CH electrodes were 76.9% in Group A, 81.3% in Group B, and 96.6% in Group C. Thus, the hippocampal IEDs with higher amplitudes showed an increased detection rate at the MA+CH electrodes.

The mean amplitude of the IEDs in extracranial EEG compared with IED potentials in intracranial EEG

The relationship between the mean amplitudes of the IEDs in intra- and extracranial EEGs are described on Table 3. The higher the amplitude of the intracranial IED, the amplitudes of extracranial IEDs at F7/8, A1/2, and T1/2 were higher. However, the amplitude of extracranial IEDs at the MA and CH electrodes was not generally proportional to the amplitude of the intracranial IEDs.

The laterality concordance between extra- and intracranial IEDs

The IEDs detected on the extracranial EEG were divided into two groups: those that matched the side of the intracranial IEDs and those that did not [Figure 3]. The simultaneous intracranial EEG recordings revealed that 21 (51.2%) IEDs at F7/8, 44 (89.7%) at A1/2, 46 (86.8%) at T1/2, 8 (15.1%) at SOL, 13 (21.6%) at IOM, 8 (17.0%) at IOL, and 5 (45.5%) at MA were detected [Table 4]. A1/2 and T1/2 had a high rate of laterality concordance. Thus, the detection rates at the MA electrodes were inferior in terms of side match to those of the standard temporal electrodes and T1/2, while superior to that of the periorbital electrodes.

Simultaneous ictal extra- and intracranial EEG recording

Two ictal events were recorded. Corresponding to the positive wave at the ictal onset from the right hippocampus, a negative potential following desynchronization with amplitude attenuation was recorded at all electrodes of the extracranial EEG [Figure 5, black arrowhead and red dashed line]. Subsequent ictal discharges were recorded at F7/8, A1/2, T1/2 (blue lines), also recorded at SOL, IOM, IOL (green lines), and MA+CH electrodes (red lines).

DISCUSSION

Two major reasons for the limited sensitivity of the extracranial recording to IEDs from the mesial temporal lobe are due to the rapid decay of the hippocampal IEDs due to the volume conduction and smearing effect of the skull, as we demonstrated in our previous reports.[2,7-9] While MA and CH electrodes can be attached easily without the need for measurement, they are at a greater distance from the hippocampus than the other extracranial electrodes and the volume-conducted hippocampal IEDs should be greatly attenuated on the MA bone. In the present study, however, the MA and CH electrodes had nearly the same detection rate of the hippocampal IEDs as other extracranial electrodes. Moreover, it should be noted that there were three IEDs, which were not detected by the A1/2 and T1/2 electrodes that could be recorded with the MA and CH electrodes. Furthermore, higher amplitudes of the intracranial IED increased the detection rate of IEDs at the MA+CH electrodes. Thus, we speculated that the hippocampal IEDs conducted to the MA and CH electrodes through the multiple foramina at the medial part of the middle cranial fossa, such as the foramen ovale, foramen spinosum, foramen lacerum, and foramen rotundum, are like a breach effect. Another possibility is that the hippocampal IEDs with a vertical vector are thought to be easier to record from lower locations like the MA and CH electrodes.

However, the amplitude of extracranial IEDs from MA and CH electrodes was not generally proportional to the amplitude of the intracranial IED, whereas the higher the amplitude of the intracranial IED, the higher the amplitude of the extracranial IED at F7/8, A1/2, and T1/2. These findings suggest that the relationship between the intra- and extracranially detected IEDs is not straightforward[2] and factors other than volume

Table 3: The relationship between the mean amplitudes of the IEDs in intra- and extracranial EEGs.

The amplitude of IEDs in depth electrode (n, mean μV)	The mean amplitude of IEDs in extracranial electrode (μV)							
	F7/8	A1/2	T1/2	SOL	IOM	IOL	MA	CH
Group A	16.2	16.2	15.9	14.9	14.4	15.1	17.2	19.2
Group B	19.1	20.0	21.3	17.8	17.2	19.4	22.2	21.9
Group C	20.0	22.8	22.8	16.9	18.3	20.3	20.7	21.7

IED: Interictal epileptiform discharge, SOL: Supraorbital lateral, IOM: Infraorbital medial, IOL: Infraorbital lateral, MA: Mandibular, CH: Chin

Table 4: The laterality concordance between extra-and intra-cranial IEDs.

	F7/8	A1/2	T1/2	SOL	IOM	IOL	MA
Side match of IEDs	21	44	46	8	13	8	5
Laterality concordance of IEDs (%)	51.2	89.7	86.8	15.1	21.6	17.0	45.5

IED: Interictal epileptiform discharge, SOL: Supraorbital lateral, IOM: Infraorbital medial, IOL: Infraorbital lateral, MA: Mandibular

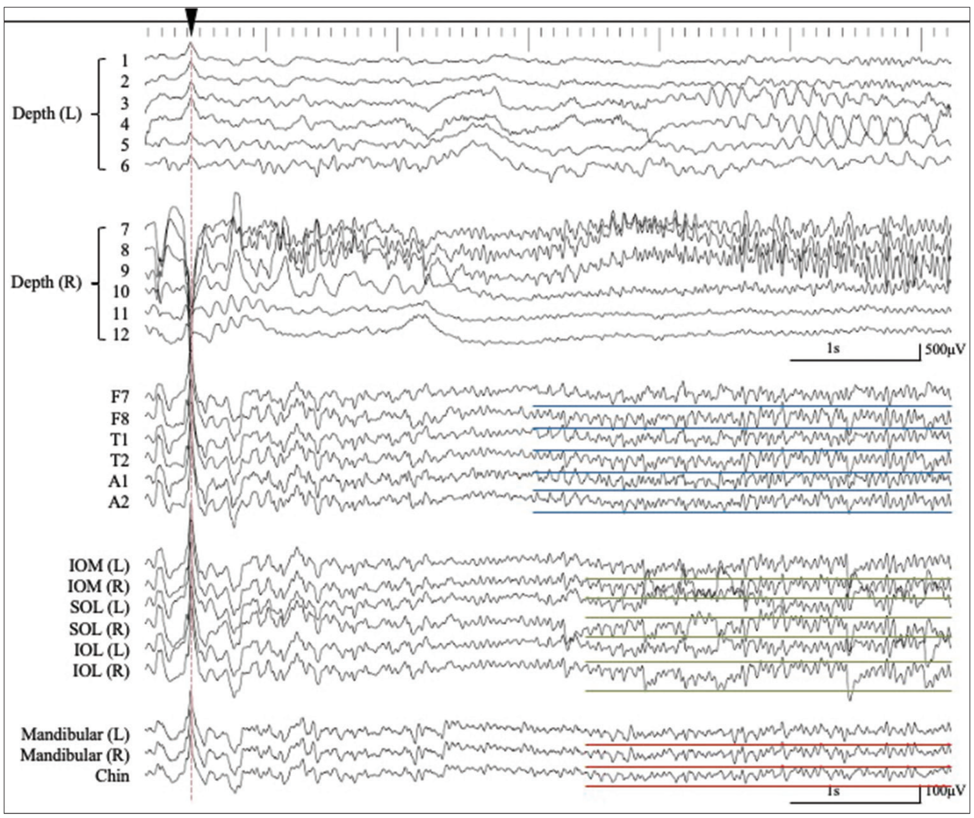

Figure 5: Simultaneous ictal extra- and intra-cranial EEG recording. Corresponding to the positive wave with the amplitude of more than 1500 μV at the ictal onset from the right hippocampus, a negative potential is recorded by all electrodes of the extracranial EEG (black arrowhead and red dotted line). Subsequent ictal discharges are recorded at F7/8, A1/2, T1/2 (blue lines), and 0.4 s later, also recorded at SOL, IOM, IOL (green lines), and MA+CH electrodes (red lines). SOL: Supraorbital lateral, IOM: Infraorbital medial, IOL: Infraorbital lateral, MA: Mandibular, CH: Chin.

conduction, smearing and breach effects, and direction of vector are involved.[6] A glossokinetic artifact that is characterized by dynamically moving polarity attributed to the direction of tongue movement[1] is one of the possible factors.

In terms of the ictal discharges, the MA and CH electrodes also could detect ictal events from the hippocampal onset, the same as other extracranial electrodes. Our previous report[7] demonstrated that highly synchronized intracranial ictal discharges with high amplitudes >1500–2000 μV in the mesial temporal lobe could be recorded by the extracranial electrodes as ictal extracranial EEG discharges through volume conduction. It is considered that the sensitivity of ictal discharge detection of MA and CH electrodes is also comparable to other extracranial electrodes.

The drawback of the MA and CH electrodes is that the rate of laterality concordance was inferior to those of the standard temporal surface electrodes and T1/2, though superior to that of the periorbital electrodes. This is again thought to be due to the fact that the MA and CH electrodes are far from the mesial temporal lobe. It is also expected that the diagnosis of laterality will be difficult when the IEDs originating from the hippocampus located near the midline are recorded from below.

The present study had several limitations. First, this study was performed in only one patient with MTLE. MTLE patients undergo epilepsy surgery without invasive examination in our institution and we rarely have the chance to perform simultaneous intra- and extracranial recordings.[7] Second, we examined the IEDs detected in extracranial EEG monitoring during 100 consecutive IEDs and only two ictal discharges. Hence, we could only discuss the sensitivity but not the specificity of MA and CH electrodes. More long-term studies are needed for a more detailed analysis.

CONCLUSION

The MA and CH electrodes could detect IEDs in MTLE and were not inferior to A1/A2, T1/T2, and periorbital electrodes. These electrodes could serve as supplementary recording tools for detecting epileptiform discharges in MTLE.

Acknowledgments

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Declaration of patient consent

The authors certify that they have obtained appropriate patient consent.

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Conflicts of Interest

There are no conflicts of interest.

REFERENCES

1. Bayram AK, Spencer DD, Alkawadri R. Tongue as a wire? Glossokinetic artifact and insights from intracranial EEG. J Clin Neurophysiol 2022;39:481-5.
2. Hashiguchi K, Morioka T, Yoshida F, Miyagi Y, Nagata S, Sakata A, *et al*. Correlation between scalp-recorded electroencephalographic and electrocorticographic activities during ictal period. Seizure 2007;16:238-47.
3. Kanner AM, Parra J, Gil-Nagel A, Soto A, Leurgans S, Iriarte J, *et al*. The localizing yield of sphenoidal and anterior temporal electrodes in ictal recordings: A comparison study. Epilepsia 2002;43;1189-96.
4. Kissani N, Alarcon G, Dad M, Binnie CD, Polkey CE. Sensitivity of recordings at sphenoidal electrode site for detecting seizure onset: Evidence from scalp, superficial and deep foramen ovale recordings. Clin Neurophysiol 2001;112:232-40.
5. Krauss GL, Lesser RP, Fisher RS, Arroyo S. Anterior "cheek" electrodes are comparable to sphenoidal electrodes for the identification of ictal activity. Electroencephalogr Clin Neurophysiol 1992;83:333-8.
6. Lee S, Wu S, Tao JX, Rose S, Warnke PC, Issa NP, *et al*. Manifestation of hippocampal interictal discharges on clinical scalp EEG recordings. J Clin Neurophysiol 2021;40:144-50.
7. Mukae N, Shimogawa T, Sakata A, Uehara T, Shigeto H, Yoshimoto K, *et al*. Reflection of the ictal electrocorticographic discharges confined to the medial temporal lobe to the scalp-recorded electroencephalogram. Clin EEG Neurosci 2021;54:173-8.
8. Sakai Y, Nagano H, Sakata A, Kinoshita S, Hamasaki N, Shima F, *et al*. Localization of epileptogenic zone in temporal lobe epilepsy by ictal scalp EEG. Seizure 2002;11:163-8.
9. Sakata A, Mukae N, Morioka T, Tanaka S, Shimogawa T, Shigeto H, *et al*. Simultaneous electroencephalographic and electocorticographic recordings of lateralized periodic discharges in temporal lobe epilepsy. Clin EEG Neurosci 2022;53:61-9.
10. Shigeto H, Sakata A, Morioka T, Takase K, Hagiwara K, Kamada T, *et al*. Peri-orbital electrodes as a supplemental recording for detection of ictal discharges in medial temporal lobe epilepsy. Neurol Asia 2011;16:303-7.
11. Silverman D. The anterior temporal electrode and the ten-twenty system. Electroencephalogr Clin Neurophysiol 1960;12:735-7.

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