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# *Retained Intracerebral Depth Electrode after Stereotactic Electroencephalography Monitoring: A Case Report*

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## Abstract

**Stereotactic electroencephalography (SEEG) is an increasingly popular surgical modality for localizing the epileptogenic zone. Robot-guided stereotactic electrode placement has been covered in Japan by National Health Insurance since 2020. However, several surgical devices, such as the anchor bolt (a thin, hollow, metal shaft that serves as a guide screw or fixing for each electrode), have not been approved. A 14-year-old female who underwent SEEG for intractable epilepsy and required additional surgery to remove a retained depth electrode from the skull after the SEEG monitoring was finished. She had uncontrolled focal seizures consisting of nausea and laryngeal constriction at the onset. After a comprehensive presurgical evaluation, robot-guided stereotactic electrode implantation was performed to evaluate her seizures by SEEG. Nine depth electrodes were implanted through the twist drill hole. The electrodes were sutured to her skin for fixation without anchor bolts. When we attempted to remove the electrodes after 8 days of SEEG monitoring, one of the electrodes was retained. The retained electrode was removed through an additional skin incision and a small craniectomy under general anesthesia. We confirmed narrowing of the twist drill hole pathway in the internal table of the skull due to osteogenesis, which locked the electrode. This complication might be avoided if an anchor bolt had been used. This case report prompts the approval of the anchor bolts to avoid difficulty in electrode removal. Moreover, approval of a depth electrode with a thinner diameter and more consistent hardness is needed.**

Keywords: intracerebral depth electrode, stereotactic electroencephalography, intractable epilepsy, anchor bolt, electrode removal

## Introduction

Stereotactic electroencephalography (SEEG) is an increasingly popular surgical modality for localizing the epileptogenic zone.[1)] SEEG utilizes intracerebral depth electrodes stereographically inserted through a twist drill or burr hole.[2)] SEEG can provide an accurate sampling of all cortical areas, not only at the hemisphere surface but also at the bottom of sulci or deep-seated structures, such as the insular cortex, cingulate gyrus, or medial temporal structures. When depth electrodes are densely implanted in a particular region, SEEG can provide a 3D assessment of the epileptogenic network.[3)] Talairach and colleagues first popularized SEEG in France in the 1950s.[4)] While SEEG has been performed and refined for several decades in Europe, SEEG is unfamiliar to physicians in other geographic areas.[5)] In the past few years, the development of commercially available surgical robot systems has prompted a renewed interest in SEEG. Therefore, SEEG has been adopted among epilepsy centers in North America and other areas.[6-8)]

A robotic system for stereotactic electrode implantation was approved in Japan in 2020. However, several devices related to electrode placement, such as the anchor bolt

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Table 1 Plannning of trajectories for intracerebral depth electrode implantation

| | Electrode name | Number of contacts | Assigned number for SEEG | Entry | Target | Trajectory length (mm)* |
|---|---|---|---|---|---|---|
| 1 | Insula 1 | 12 | 1-12 | F1 | Anterior insula | 79.0 |
| 2 | Insula 2 | 12 | 13-24 | F1 | Posterior insula | 77.0 |
| 3 | Inf C anterior | 12 | 25-36 | Inferior C (motor) | BOS | 30.4 |
| 4 | Inf C posterior | 12 | 37-48 | Inferior C (sensory) | BOS | 32.0 |
| 5 | Amy | 6 | 49-54 | T2 | Amygdala | 44.6 |
| 6 | Hip head | 6 | 55-60 | T2 | Hippocampal head | 42.7 |
| 7 | Hip body | 6 | 65-70 | T2 | Hippocampal body | 39.5 |
| 8 | Mid T T1 | 12 | 71-82 | T1 | Temporal operculum | 26.0 |
| 9 | Posterior T | 12 | 83-94 | Posterior T (T2) | BOS | 20.0 |

SEEG, stereotactic electroencephalography; F1, superior frontal gyrus; T2, middle temporal gyrus; T1, superior temporal gyrus; T, temporal region; BOS, bottom of sulcus
*distance between the inner table of skull bone and the target.

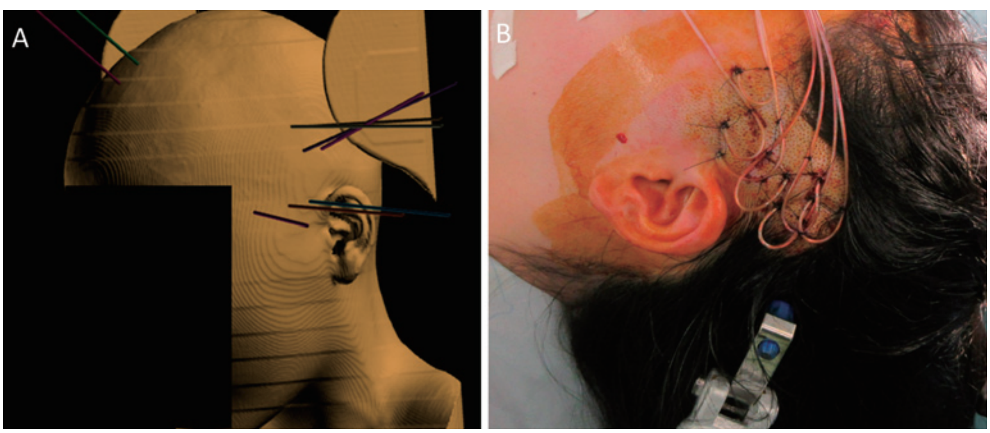


**Fig. 1**
**A: Trajectory planning. We created nine trajectories for the depth electrodes in a three-dimensional (3D) contrast-enhanced CT and MRI dataset to avoid crossing blood vessels. The entry and target of each trajectory are summarized in Table 1.**
**B: The electrode leads were sutured to the skin for fixation. Anchor bolts were not used.**

that serves as a guide screw or holds each electrode lead, have not been approved. Hence, the use of the anchor bolt is difficult for insertion and fixation of the electrodes. We herein present a patient with a retained electrode that required surgical removal.

## Case Report

A right-handed 14-year-old female with intractable epilepsy complained of daily focal seizures that had an onset at 10 years of age, even when treated with multiple antiseizure drugs. Based on scalp video EEG monitoring, the seizures consisted of nausea and laryngeal constriction at the onset, followed by impaired awareness with salivation. An ictal EEG was characterized by repetitive spikes and waves over the middle-to-posterior temporal region with phase reversal at T3 or T3-T5. Magnetoencephalography showed a cluster of equivalent current dipoles over the left inferior central region. There were no abnormal findings on MRI, fluorodeoxyglucose-positron emission tomography (FDG-PET), and $^{123}$I iomazenil (IMZ) single-photon emission computed tomography. The Wada test revealed left-sided predominance in language and memory. We hypothesized that the seizures originated from the left parietal operculum and spread to the insula or mesial temporal region.

Robot-guided stereotactic electrode implantation was performed using a Rosa One Brain system (Zimmer Biomet, Inc., Warsaw, Indiana, USA) under general anesthesia to evaluate the seizures using SEEG. As shown in Table 1 and Fig. 1A, we planned nine trajectories, which were registered to the robot system. A cranial percutaneous trephination was performed with a 2.4-mm twist drill to implant each electrode. The dura was perforated by low-current

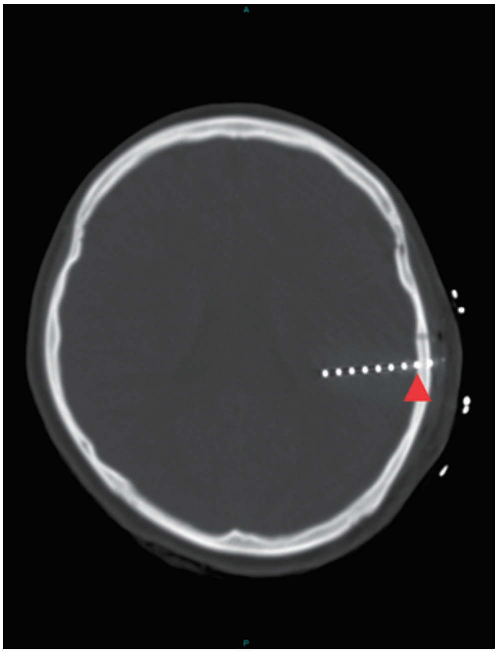

**Fig. 2 CT scan showing the retained depth electrode, suggesting that the eighth contact from the tip was caught in the internal table of the skull (arrowhead).**

monopolar coagulation. A platinum-iridium depth electrode (diameter, 1.5 mm; Unique Medical Co., Ltd., Tokyo, Japan) with an array of 12 (5-mm intervals) or 6 contacts (10-mm intervals) was inserted through the twist drill hole. Anchor bolts were not used for insertion and fixation of the electrodes. The leads of the electrodes were sutured to the skin for fixation (Fig. 1B).

Five seizures were captured during 8 days of SEEG monitoring. We confirmed the low-amplitude, fast activity localized in the posterior part of the left insula at seizure onset, which spread to the operculum of the left central region. Eight days after electrode implantation, we attempted to remove the electrodes. However, one of the electrodes (Inf C posterior, 12 contacts, 5-mm interval) was retained. A CT scan suggested that the eighth contact from the tip was caught in the internal table of the skull (Fig. 2). On the next day, the electrode was removed with an additional skin incision and small craniectomy under general anesthesia. After the skull was drilled out around the electrode, the electrode was removed with a bone fragment (Fig. 3A, B). Bone cement was placed to cover the defect. We confirmed the narrowing of the twist drill hole pathway in the internal table of the skull due to osteogenesis, which locked the eighth contact (Fig. 3C, D).

## Discussion

We herein report a case wherein an intracerebral depth electrode was retained due to narrowing of the twist drill hole pathway, which occurred after only 8 days of electrode placement. We confirmed osteogenesis in the internal table of the skull. A few studies focused on spontaneous osteogenesis after a large cranial defect in children and a young adult,[9-11] but no reports have focused on osteogenesis in a small twist drill hole. Three layers contribute to osteogenesis after a cranial defect: pericranium, dura matter, and adjacent diploë.[12] Fujii et al.[13] histologically confirmed intramembranous ossification 7 days after a pericranium was harvested from the calvaria and grafted into the muscle in rats. Gosain et al.[14] investigated osteogenesis in the autologous bone grafts with no, dural, pericranial, or double barriers in rabbits. The total new bone formation was greater in the bone grafts without dural barriers, suggesting that dural contact was more effective for osteogenesis than pericranial contact. These in vitro studies could account for the predominant osteogenesis involving the dural side of the drill hole 8 days after the surgery in our case.

Under the current status of regulatory approval in Japan, two major factors are believed to be the cause of the retained electrode. First, this complication may have been avoided if an anchor bolt, a thin, hollow, metal shaft that is threaded on both ends, had been used. In Europe and North America, the SEEG systems currently in use rely on an anchor bolt, which is also known as a guide screw or bolt, to fix each depth electrode and to maintain the appropriate trajectory.[15] Indeed, there have been few reports of retained depth electrodes from Europe and North America. Cossu[16] reported 1 case (0.0004%) with a retained broken electrode from 2,666 stereotactic electrode implantations in 211 patients using hollow pegs for the insertion and fixation of the electrodes (0.8 mm in diameter). Miller et al.[17] reported 3 (0.2%) retained electrodes of 1,603 electrodes in 152 cases, wherein the diameter of the electrodes was not ascertained. In our institute, the occurrence rate of retained electrodes is 1 (0.8%) in 124 electrodes, which is higher than that reported from Italy and the United States. Notably, use of an anchor bolt is difficult in Japan because the device is not approved. Thus, it is assumed that electrodes are sutured to the skin to achieve fixation in most of the institutes in Japan. In addition to the retained electrode presented in this case report, other complications, such as an intracerebral hemorrhage, can occur due to unstable electrode fixation.

Second, we used depth electrodes with a maximum diameter of 1.5 mm, which is larger than that used in Europe and the United States. Depth electrodes typically used for SEEG have 4-18 contacts spaced 2-10 mm apart and a diameter <1.0 mm.[18] Furthermore, we used electrodes with uneven hardness. The contact part, which consists of metal, is harder and larger in diameter than the noncontact part, which consists of a wire bundle. This uneven structure may be the cause of a retained electrode.

The electrode was inserted in a near orthogonal orientation to the skull. Although the use of a larger twist drill

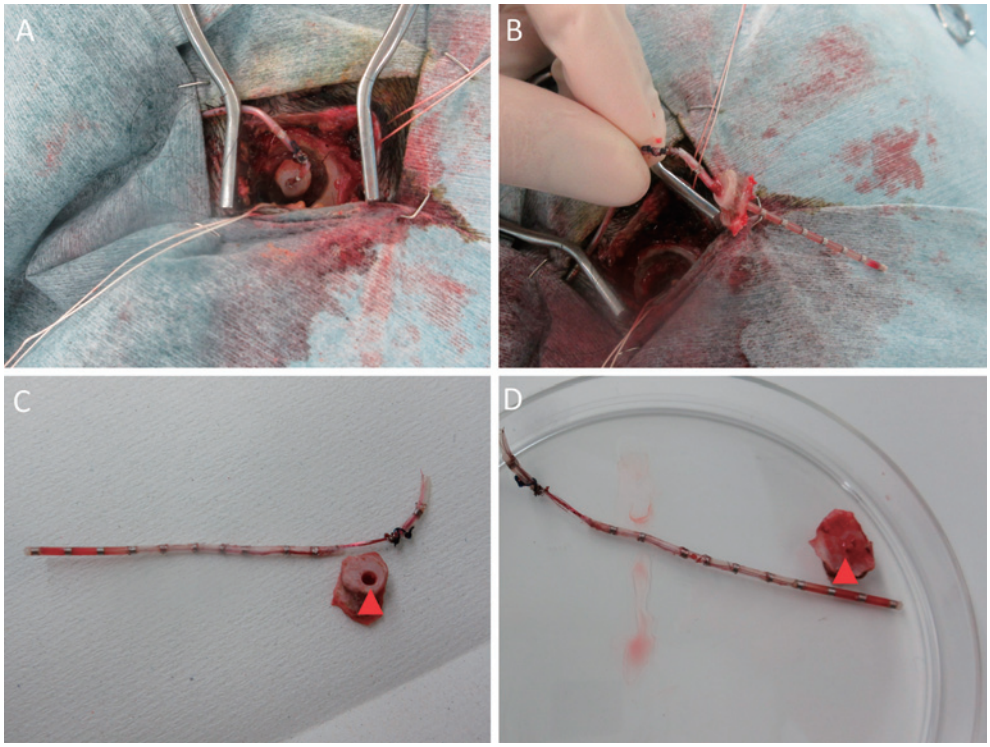


**Fig. 3**
**Operative findings to remove the retained electrode. After the skull was drilled out around the electrode (A), the electrode was removed with a bone fragment (B).**
**C: The twist drill hole pathway was open in the external table of the skull (arrowhead).**
**D: Narrowing of the twist drill hole pathway was confirmed in the internal table of the skull due to osteogenesis (arrowhead). The distance between the eighth and ninth contacts was decreased because the eighth contact was locked in the internal table of the skull.**

hole may be an option to avoid retained electrodes, a larger hole may cause unstable electrode fixation. There is no failsafe way to avoid retained electrodes with technical improvement. Under these circumstances, the risk of a retained electrode should be addressed during informed consent of the patients and guardians before surgery. SEEG-related surgical device approval is desirable.

## Conclusion

Safety in electrode implantation and SEEG monitoring depends on the robot system and the surgical devices. We hope that this case report will prompt the approval of anchor bolts to avoid difficult electrode removal. Moreover, approval of depth electrodes with thinner diameters and more uniform hardness is also needed.

## Abbreviations

SEEG: stereotactic electroencephalography
EEG: electroencephalography
MRI: magnetic resonance imaging
CT: computed tomography

## Informed Consent

The patient and her guardian provided written informed consent.

## Conflicts of Interest Disclosure

The authors declare no conflicts of interest and have registered online self-reported COI disclosure statement forms on the *JNS* member website.

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