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The Circular Grid 360 Electrocorticography Monitoring During Awake Brain Surgery

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Introduction

Epilepsy is common among patients with the supratentorial brain tumors; approximately 40-70% of patients with glioma develop brain tumor-related epilepsy (BTRE).
Intraoperative localization of electrical neuronal patterns for the epileptogenic foci may assist with intervention techniques in patients with epilepsy and brain tumor-related epilepsy. The accuracy of localization of the epileptogenic signals requires a high-density spatial organization of the recording electrodes. We describe a 360 degree high-density ring-shaped cortical electrode assembly device titled "Circular Grid" (Figure 1) that is capable of simultaneous and continuous recording of the epileptiform activities [including high-frequency oscillations (HFOs), after-discharges (AD), and periodic-focal-epileptiform-discharges (PFEDs) from the cortical brain regions] while permitting surgical resection of pathological brain tissue. We also demonstrate the safety and feasibility of the intraoperative use of the Circular Grid during awake brain procedures.

Methods

Of our eighteen subjects, four were female and fourteen were male, with age range from 30 and 74 years of age. All subjects except one presented with epilepsy and were candidate for surgery based on either medically refractory seizures or brain tumor-related seizures. The circular grid placement was on the frontal lobe in seven subjects, temporal lobe in four subjects, parietal lobe in four subjects, and on insular, occipital and parietal-temporal lobe in one subjects each.

Results

The circular grid captured the spatial organization of the ECoG signals in a 360-degree manner. Anteriorly in two patients (11%), anterior-superiorly in two patients (11%), anterior lateral/ posterior lateral in one patient (6%), inferiorly in three patients (17%), inferior-posteriorly in one patient (6%), posteriorly in one patient (6%), posterior-inferiorly in two patients (11%), superior-anterior in one patient (6%), superior medial in two patients (11%), and three patients didn't have any spatial organization of the signals (17%).
Two clinical neurophysiologists interpreted ECoG patterns, with one unblinded intraoperatively and a separate blinded one postoperatively (with 100% inter-rater reliability). The mean duration of recording was 9.75 minutes. HFOs spikes were captured in nine patients (50%) and PFEDs signals in ten patients (56%) (Figure 2B, 2C). The superimposition of PFEDs and HFOs were observed in six patients (33%) (Figure 2D).

Conclusions

The circular grid is reliable for monitoring intraoperative ECoG and recording of electrical signals, e.g., ADs, HFOs, and PFEDs, while permitting safe surgical resection. More extensive prospective studies are needed to establish the clinical utility of the circular grid in intraoperative recording, mapping and resection and to further personalize surgical resections.

Learning Objectives

1. The circular grid's unique spatial design allows intracranial electrical activity monitoring in a 360o degrees fashion with direct visual and surgical access to the desired brain areas.
2. The circular grid is reliable for monitoring intraoperative ECoG and recording of electrical signals during awake craniotomies, e.g., ADs, HFOs, and PFEDs.
3. The Circular grid permits safe surgical resection while recording of the brain electrical signals which allows early detection seizure detection during awake craniotomies.

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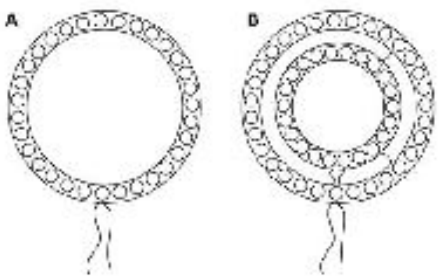
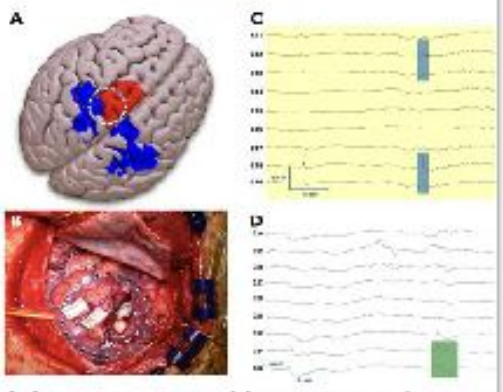
Figure 1



(A) A diagram showing the circular grid. (B) A diagram showing the modular model of the circular grid.

Figure 2



(A) A reconstructed brain image showing the fine motor cortex in blue and the lesion in red color with the circular grid being used over the lesion for a 360-degree monitoring. (B) Minor corridor corticectomy surrounded by the cortical and subcortical eloquent brain areas. (C) Unfiltered EEG with extended time scale showing HFO highlighted in blue color. (D) An EEG showing the detection of PFEDs with an increase in the periodicity in green region.