Intra-operative electrocorticography in lesional epilepsy


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Summary Intra-operative electrocorticography (ECoG) is useful in epilepsy surgery to delineate margins of epileptogenic zone, guide resection and evaluate completeness of resection in surgically remediable intractable epilepsies. The study evaluated 157 cases (2000–2008). The preoperative evaluation also included ictal SPECT (122) and PET in 32 cases. All were lesional cases, 51% (81) of patients had >1 seizure/day and another 1/3rd (51) had >1/week. Pre and post resection ECoG was performed in all cases. A total of 372 recordings were performed in 157 cases. Second post-operative recordings (42) and third post-operative recordings (16) were also performed. Site of recordings included lateral temporal (61), frontal (39), parietal (37), hippocampal (16) and occipital (4). 129/157 cases (82%) showing improvement on ECoG, 30/42 cases showed improvement in 2nd post resection, 8/16 showed improvement in the 3rd post-operative ECoG. 116/157 (73%) patients had good outcome (Engel I and II) at follow up (12–94 months, mean 18.2 months). Of these, 104 patients (80%) showed improvement on post-operative ECoG. 12 had good outcome despite no improvement on ECoG. The improvement in ECoG correlated significantly with clinical improvement [Sensitivity: 100% (95% CI; 96—100%); specificity: 68.3% (95% CI; 51.8–81.4%); positive predictive value: 89.9% (95% CI, 83.1—94.3%); negative predictive value: 100% (95% CI, 85—100%)]. The level of agreement was 91.72% (kappa: 0.76). Concluding, pre and post resection ECoG correlated with its grade of severity and clinical outcome.

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Introduction

Electrocorticography along with cortical stimulation mapping was perhaps first described by Penfield (1939). Using this, they demonstrated that stimulation of the supplementary area resulted in simultaneous movements and tonic posturing of both proximal and distal muscles along with speech arrest.
The hypothesis for a successful epilepsy surgery is based on the principle that removal of both lesional as well as the surrounding epileptogenic area is necessary for achieving seizure freedom (Luders and Awad, 1991). Hence, it is important that, both should be delineated before surgery. However, epileptogenic zones are often difficult to identify, because they may be found in and around the margin of, or remote from a lesion (Cascino et al., 1992; Awad et al., 1991a,b; Wennberg et al., 1999). The scalp EEG is helpful but may not be precise enough to localize the epileptogenic area (Westmoreland, 1998). For greater precision, either intra-operative or extra-operative subdural electrocorticography (ECoG) is often used to guide surgical resection of both the lesion and the epileptogenic zone (Pathak and Blume, 1997; Pilcher et al., 1993; Tran et al., 1997).

The area of interictal spiking or the irritative zone is often wider than the ictal onset zone (area where the seizure originates) which is considered as a gold standard for localizing the epileptogenic zone (Luders et al., 1993). Failure of seizure freedom following surgery could be due to a variety of causes and varies from patient to patient. In the majority of cases, incomplete resection of the epileptogenic zone immediately adjacent to the resected area was thought to be the single most common cause until a few years ago (Awad et al., 1991a,b; Wyler et al., 1989).

Intra-operative electrocorticography (ECoG) is widely utilized for electrical mapping of the epileptogenic zone during epilepsy surgery. It is useful to delineate the margins epileptogenic zone, guides the surgeon in achieving resection and is also of value to evaluate the completeness of resection. It has been found to be particularly useful in resective surgeries of neocortical foci (especially developmental lesions like cortical dysplasias) and for tailored resections in hippocampal sclerosis (Ojemann, 1992). The ECoG can be a valuable tool during multiple subpial transections (MST).

The technique of ECoG, was pioneered by Penfield and Jasper in the early 1950s to map focal interictal spiking and to determine the extent of the resection (Penfield and Jasper, 1954). The obvious advantages of the intra-operative ECoG's are: (i) they allow placement of recording and stimulation electrodes; (ii) recordings can be performed before and after each stage of resection to assess the completeness of surgery; (iii) it allows direct electrical stimulation of the brain so that the regions involved in functions may be spared by the resection (e.g. eloquent cortex) (iv) no risks associated with long-term placement e.g. infection (Zumsteg and Wieser, 2000). The major limitations of ECoG are: (i) the limited sampling time; (ii) spontaneous epileptiform activity consists exclusively of interictal spikes and sharp waves, and seizures are rarely recorded. Thus in most of the cases, localization of the ictal focus is based on a hypothesis that it corresponds to the interictal activity, which is yet to be proven (iii) it is difficult to distinguish primary epileptiform discharges from secondarily propagates discharges arising at a distant epileptogenic site; (iv) both, the background activity and epileptiform discharges may be altered by the anesthetics, narcotic analgesics and by the surgery itself (Zumsteg and Wieser, 2000).

About 80–84% of epilepsy surgery centers around the world still perform ECoG in some or all of their patients with partial epilepsy (Engel, 1987). Despite its common use, only a few studies are available to prove its worthiness and establish evidence justifying its necessity (Keene et al., 2000).

In this paper, we present our experience with ECoG to determine if it provided useful information for predicting surgical success and review the current role and controversies of ECoG in surgery for surgically remediable epilepsy and also review the existing literature.

Material and methods

The present study reviewed all the ECoG recordings, patient imaging and electrophysiological data from January 2000 till October 2008 performed at our center.

All the patients underwent a standard work up for medically intractable epilepsy. Inclusion criteria for this series included only those cases with a MRI substrate i.e. lesional cases with intractable epilepsy with concordance seen on video EEG, MRI, PET and/or ictal—interictal SPECT. In patients, where no concordance was found were subjected to invasive video EEG. Similarly in hippocampal sclerosis, the present series included only unilateral pathology with concordance. The frequency of seizures were >1/day in 51% (81 cases), >1/week in 31% (51 cases), >1/month in 12% (19 cases) and >1/year in only 6 cases. This included a detailed clinical history, interictal EEG's, long-term video EEG (VEEG), epilepsy protocol MR imaging, and SPECT. Ictal SPECT in addition was performed in 122 cases and PET in 32 cases. Patients were selected for ECoG guided resection only if there was a concordance of at least 3/4 parameters i.e. VEEG, MRI, interictal/ictal SPECT, and PET (flurodeoxyglucose). PET was not usually done for lesions seen on MR imaging unless there was discordance between the VEEG, SPECT and MR imaging data. PET was preferred for lesions like cortical dysplasias, tuberous sclerosis and patients with substrates negative' pathologies.

The ECoG recordings in the earlier part of the study were performed using a 32-channel machine (Nihon Kohden). Since 2007, we have been using a 64-channel machine (Nicolet, Viisys). Recording from neocortical surfaces were usually performed by using a large grid (32 contacts) to cover the entire area representing the lesion its perilesional areas. Recording from the hippocampus (in mesial temporal sclerosis) was done after performing a antero lateral temporal lobectomy, by placing 1 × 4 strip electrode over the hippocampus. Post-operative recordings were done both from the margin of the area and nearby exposed normal brain parenchyma. The reference electrode was placed over the forehead. The recordings were performed both by the referential and bipolar derivations.

All the ECoG interpretation was done by a single neurologist who was blinded to the anatomical location of the grid. The ECoG in all cases was performed under standard anesthetic conditions with induction using isoflurane. After craniotomy and dural opening, anesthesia was maintained with nitrous oxide and intravenous narcotics with reduction (to 0.5% of isoflurane) inhalational agents. Core body temperature was maintained above 35.5 °C. The low-frequency filter was set at 1 Hz, the high frequency filter at 70 Hz, and sensitivity was between 300 and 5000 μV/mm depending on the amplitude of the background and discharges. ECoG abnormalities were graded using the following score that emphasized changes in background frequencies along with the presence of interictal or ictal epileptiform activity.

Method of grading

We preferred to use the grading described by Mathern et al. (Mathern et al., 2000; Cepeda et al., 2005, 2006). The scoring system was prospectively performed in 62 patients. In the rest of the patients, the ECoG
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**ECoG Score 1**: Normal background of mixed gamma, beta and alpha frequencies of moderate to low amplitude (i.e., usually <20—30 mV). A few low amplitude spikes could be observed.

**ECoG Score 2**: Loss of fast (>20 Hz) background frequencies, but otherwise a background of mixed alpha, beta and delta frequencies of low to moderate amplitude. Repeated but non-continuous spikes, polyspikes or paroxysmal fast activity of medium amplitude often observed.

**ECoG Score 3**: Mostly 6—20 Hz background frequencies with some localized nearly continuous interictal epileptiform features of moderate amplitude or persistent repetitive spiking. Very rarely, electrographic seizures can be captured.

**ECoG Score 4**: Slow (<6 Hz) background frequencies with continuous synchronous features of moderate to high amplitude. Multiple independent epileptiform abnormalities (polyspikes, paroxysmal fast activity and electrographic seizures) could be recorded.

**ECoG Score 5**: Slow rhythmic usually synchronous background (<4 Hz), often of high amplitude. Continuous synchronized or independent high amplitude epileptiform abnormalities in multiple cortical sites could be observed. Ictal discharges were rarely recorded but observed in surrounding cortex.

An ECoG score of 2–5 is considered abnormal and these areas should always be included within the resective zone. An ECoG Score 1 is considered relevant depending on its relation to the lesion. For instance, if there was widespread activity consistent with ECoG Score 1 activity, then ‘chasing the spikes’ was avoided and the maximally abnormal area was resected. If this activity is more focal and amenable to surgical resection, then it was utilized for guiding surgical resection. Surgery always included wide resection, making sure that the subcortical white matter was also included in the resection. A post resection ECoG was always performed. If significant abnormal activity was still noted from the margins, further resection was performed.

The final post-operative recording was considered improved if the recording was normal or showed ECoG score 1 in certain situations as described above.

Preoperatively, intra and post-operatively, patients were continued on the same antiepileptic drugs (AED’s) monitored with appropriate serum levels.

The outcome was classified using Engel grading (Engel, 1987) at 12 months follow up. All patients underwent a 30 min EEG at 3, 6, and 12 months at follow up.

**Results**

All the patients were preoperatively evaluated in Neurology Unit I. All the ECoG’s were interpreted by the same neurologist and operated by a single surgeon. The study included 157 cases who underwent a total of 372 recordings each for about 30 min. post-operative recordings were performed in all, 2nd post-operative recordings in 42 (28%) and third post-operative recordings in 16 cases (6.7%). Sites of recordings included temporal (61 cases; with frontal overlay in 8 cases), frontal (39 cases; with a small temporal overlay in 4 and parietal overlay in 3 cases), hippocampal (16) and occipital in 4 cases.

A total of 129/157 patients (82%) had satisfactory improvement on post resection ECoG. A total of 116/157 (73%) had a good outcome (Engel grade I and II) at a follow up varying from 12 to 94 months (mean 18.2 months). As per location, patients with good outcome included lateral temporal (46/61; 75%), frontal (25/39; 64%), parietal (27/37; 72%), hippocampal (15/16; 93%), and occipital was 3/4. Of the 116 patients with good outcome, 104 (89%) patients showed electrical improvement at surgery. The distribution of these patients included (with both electrical and clinical good outcome) temporal: 44/61; 72%, frontal: 20/39; 51%, parietal: 24/37; 64%, hippocampal: 14/16 and occipital 2/4. 12 patients thus had a good clinical outcome despite having no intra-operative electrical improvement.

Analyzing the scoring system, out of 157 preoperative recordings, 124 (78%) had scores of 2 & 3. 21 (13%) cases had a score of 4 and only 12 (7%) had a score 5.

The pathologies included cortical dysplasias [54], tuberous sclerosis [11], mesial temporal sclerosis [16], tumors: [29] (dysembryoplastic neuroepithelial tumor (DNT): 19 cases, gangliogioma: 7 cases, pilocytic astrocytoma: 3 cases). There were 11 tuberculomas and 5 neurocysticercosis. Thirty-two (20.9%) specimens showed dual lesions, majority (84%) of which were focal cortical dysplasia (FCD) with coexisting gangliogioma (GG-15 cases) or DNT (12 cases), while the others were mesial temporal sclerosis (MTS) in conjunction with parasitic cysts (2 cases) and with cavernoma (1 case). Other less common, yet significant findings in terms of causative etiologies of seizures included subpial gliosis (19 cases), old haemorrhage (7 cases), non-specific changes (5 cases). Three of the five had normal MR imaging, however ictal discharges were rarely recorded but observed in surrounding cortex.

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**Discussion**

According to Rasmussen (1983), the removal of the “epileptogenic zone” consisting of the lesion and a surrounding critical mass of tissue is required for a successful surgical outcome. ECoG has been reported to provide useful information for the localization of this area at the time of surgery (Engel, 1987; Green et al., 1949; Walker, 1949; Gloor, 1975; Chatrian and Quesney, 1997; Walker et al., 1960; T sai et al., 1993a,b).

While there have been a number of publications related to ECoG, most of them have been case reports or series without a proper control group. Hence the role of the technique has been questioned (Walker et al., 1960).

The potential advantages of ECoG are mentioned below with the corresponding literature review.

**Potential advantages of ECoG**

The ECoG activity is similar to that recorded from the scalp electroencephalogram, consisting of isolated spikes, brief bursts of spikes or runs of sharp waves. However, they look more magnified as they are recorded directly from the
Propagation of the epileptiform discharge was commonly seen from the hippocampus, to and from the subtemporal cortex (Kanazawa et al., 1996; Graf et al., 1984; Alarcon et al., 1997). In the present study, only 20% of patients had ictal patterns, while a majority of patients (78%) had interictal patterns. Prolonged sustained ictal activity was recorded in only 7% of cases.

One study (Panet-Raymond and Gotman, 1990) has suggested that in addition to these epileptiform discharges, delta wave activity might also give useful information as to the location of the epileptiform tissue in patients in whom spikes were not found on ECoG. \([n=40] \). However, the authors do suggest caution when using this method in individual cases.

Devinsky (2004) found new epileptiform discharges on ECoG in 24% of temporal lobe epilepsy, which were not previously found by scalp electroencephalograms even with the use of sphenoidal electrodes. On the other hand, Engel et al. (1976) did not obtain any additional information from the ECoG compared to the preoperative scalp EEG.

ECoG seldom records ictal events, but rather interictal epileptiform activity. The relationship between the epileptic zone (area of origin of the epileptic seizure) and the irritative zone (area of maximum interictal epileptiform discharge) is not completely understood. In particular, the degree to which the two zones overlap, especially on the parietal cortex (with frontal, parietal overlay) has been of questionable value in the localization of the epileptogenic zone. (Penfield and Jasper, 1954; Gloor, 1975; Chatrian and Quesney, 1997; Stefon et al., 1991; Tsai et al., 1993a,b).
The role of the ECoG in determining the surgical outcome is unclear. McBride et al. (1991) and Engel (1987) did not find an association between the site of dominant intra-operative ECoG epileptiform discharge and the surgical outcome. Correlation between the location of discharge and underlying pathology was also not found (Engel et al., 1976).

Bengzon et al. (1968) noted a significant difference in the surgical outcome between patients with residual spikes compared to spike-free post resection recordings. Thirty-six percent of patients who were seizure-free post-surgery had residual spike; whereas 75% of patients who were not seizure-free had residual spikes on post resection ECoG. These findings were similar to those reported by others (Penfield and Jasper, 1954; Fiol et al., 1993; Wyllie et al., 1987; Tanaka et al., 1996; McBride et al., 1991).

Other investigators have not been able to confirm the relationship between the degree of epileptiform discharges seen on the post resection ECoG and the outcome (Walker et al., 1960; Falconer, 1958; Fenyes et al., 1961; Gibbs et al., 1958; Gallentine and Mikati, 2009). This was especially the case in patients whom selective amygdalo-hippocampectomy was performed. In this situation, new epileptiform discharges were often recorded from the temporal cortex after completion of the procedure. These discharges were found to have no predictive value (Cendes et al., 1993; Blume et al., 1997; Ojemann, 1992). However, one interesting study did demonstrate progressive decrease in the abnormality of ECoG with progressive excision of the amygdala and hippocampus (Oliveira et al., 2006).

A possible explanation for the lack of consensus in the usefulness of ECoG to predict seizure outcome may lie in the surgical procedure itself. While most centers that have reported the use of ECoG-performed standardized temporal lobe resections, only a few actually tailored the resection according to ECoG findings (Ojemann, 1992; McKhann et al., 2000).

In the present series, of a total of 157 cases, 77 (49%) were operated for temporal foci. Of these 61 (42%) had a good clinical outcome (Engel I and II). In 58 (95%) of these cases, ECoG showed a significant improvement following resection. However we do agree that while we did perform repeat resections for lateral temporal lesions, tailored resections were not performed for hippocampal lesions. While hippocampal recordings were performed in cases of mesial temporal sclerosis, resection of amygdale and hippocampus was done as per standard procedure.
Lesional, temporal and extratemporal resections

Evidence supporting usefulness of ECoG in extratemporal resections is scanty. Most of the literature usually pertains to lesional cases. Some studies (Quesney, 1992; Sadanova et al., 1992) have pointed out that in patients whose seizures originated in the frontal lobes, showed no clear relationship between the amount of epileptogenic tissue removed and a successful surgical outcome. Similar findings have been noted in ECoG recordings of patients with seizures arising from the centroparietal region and occipital areas (Quesney, 1992; Sadanova et al., 1992).

These findings suggest that for non-lesional extratemporal epilepsies, the best solution may to use subdural grids. Another approach may involve the use of other imaging techniques, for example positron emission tomography along with more recent techniques with MR imaging (Olson et al., 1990; Chandra et al., 2006).

Lesional, temporal and extratemporal resections

The use of ECoG in patients with structural lesions on imaging studies remains one of its best used indications albeit being controversial. Earlier studies from Montreal Neurological Institute suggest a good outcome when the lesion is removed with the surrounding epileptogenic cortex as determined by ECoG (Sadanova et al., 1992; Rasmussen, 1975). This point of view has been supported by Pilcher et al. (1993) who found that eleven out of twelve patients who underwent surgery for ganglioglioma, were seizure-free at 3.1 years post-surgery compared with a literature control of 21 out of 39 (54%) patients with ganglioglioma in whom only the lesion was resected. They noted that the epileptogenic zone was topographically distinct from the region of the tumor-involved brain and its removal increased the chance of a better outcome.

Another series also (Berger et al., 1993) reported patients with intractable epilepsy, associated with low grade tumors undergoing surgery with better outcome under ECoG-guidance. Forty-one out of 45 of these patients (91%) became seizure-free and the use of ECoG was advocated. Similar findings were reported with cavernous hemangiomas (Cohen et al., 1995). Other studies also reported greater control of seizures in both children and adults when performed under ECoG guidance (Gonzalez and Elridge, 1962; Drake et al., 1987).

These studies have been based on retrospective review of case series. Comparison between ECoG-guided resections and non-ECoG-guided resection for similar groups of lesions have not been prospectively done. There was one report of an attempted (Tran et al., 1997) controlled retrospective series review in which patients with structural lesions present underwent resection of the lesion to normal tissue margins. ECoG was recorded pre- and post resection, but not used to determine the amount of surgical resection. Patient outcome was based upon seizure-free state. ECoGs were analysed for spike distribution and spike discharge rate. Spike distribution in the pre resection ECoG did not correlate with outcome. On post resection ECoG, spikes were noted along the edge of the resection as well as extra-marginally in equal amounts between patients who became seizure-free post resection and those who did not. These findings support the use of lesionectomy as the first step in seizure control in lesional cases. In the present study though not prospective, post resection ECoG was performed in all cases (157); 28% requiring a second post resection recording and 6.7% requiring a third post resection recording.

Palmini et al. (1995) have reported long runs of epileptiform discharges on ECoG consisting of repetitive electrographic seizures, repetitive bursting discharges or continuous rhythmic spiking which were often co-localized with MR imaging. The completeness of resection of the epileptiform activity on ECoG correlated with the surgical outcome. (Tripathi et al., 2008; Wennberg et al., 1999).

The experience presented here represents ECoG from all pathologies collected from a single center. Though this seems heterogeneous in approach, a much larger sample size will be required to validate comparisons between individual pathologies. This paper represents day to day practice of applicability of ECoG over heterogeneous etiologies.

Electrical stimulation and cortical mapping

Electrical stimulation during ECoG recordings for epilepsy surgery under local anaesthesia was first performed and developed by Penfield and Jasper in the early 1950s (Penfield and Jasper, 1954). This procedure provided insight into the functional anatomy of brain, particularly towards location of language, motor and sensory areas. Electrical stimulation still forms a key procedure for localization of these areas thus preventing neurological deficits following resection of an epileptogenic focus. Another important usefulness is reproduction of the patient’s habitual aura and partial seizures by local cortical or depth electrode stimulation.
If the area that triggers the patient’s habitual attack and coincides with the region of active spiking, this clearly delineates the epileptogenic zone (Quesney and Niedermeyer, 1993). In a study comprising 30 randomly selected patients with medically refractory TLE (Stefan et al., 1996), found that that ECoG provides reliable intra-operative mapping of epileptogenic brain tissue to be resected. All patients underwent intra-operative ECoG as well as electrical stimulation using cortical and acute depth electrodes prior to temporal lobectomy. Special emphasis was placed on the reproduction of patient’s warning by electrical stimulation of mesial temporal lobe structures. A strong correlation was found between the symptoms induced by stimulation and the patient’s habitual warning, thus providing additional intra-operative localizing evidence regarding the anatomical substrate involved in the genesis of habitual seizure.

Another important utility of intra-operative electrical stimulation is to assess the cortical sites involved in memory functions, thereby providing further insight into the mechanisms of memory and also to avoid memory deficits after surgery (Ojemann and Dodrill, 1985).

Identification of the central sulcus, which can be difficult visually when anatomy becomes distorted by pathology, can either be identified by motor mapping or by somatosensory-evoked potentials (phase reversal technique) (Sala et al., 2002). The latter is often most helpful in children younger than 5 years (Berger, 1995), when direct electrical stimulation of the motor cortex often requires higher intensities of current than that needed to elicit an AD (Goldring and Gregorie, 1984). Intra-operative mapping for language requires an awake patient, and can really only be performed in the adolescent patients. Younger children require placement of subdural electrodes and extra-operative functional mapping.

### Limitations of ECoG

The epileptiform activity seen on ECoG exclusively consists of interictal discharges. An hypothesis for lateralization and localization of the epileptogenic foci is essential before placement of ECoG electrodes. That is the reason, they are best suitable in lesional cases where concordance has been established with other investigations before surgery.

However, it should be emphasized that the irritative zone, the area generating interictal activity may have different localization depending on the different type of investigation. For instance, a scalp EEG gives the best overview but cannot delineate the margins and is least sensitive. The subdural electrodes while can accurately map the margin will provide only a limited overview as its area of coverage is limited. In contrast, the depth electrode defines irritative zone has practically no value. ECoG electrodes, due to their close proximity, permit a direct identification of the boundaries of the generator. This recording can explore only a limited surface of the brain and no overview of the whole brain, as obtained with scalp electrodes, is possible. The other limitation of ECoG is the potential misinterpretation of clinically non-relevant sharp transients. The new epileptiform discharges not recorded on pre resection ECoG presumably emerges from (1) surgical injury to irritated cortex, thought to be of no clinical significance (Penfield and Jasper, 1954), (2) partial excision which may lead to postoperative seizures, or (3) from cortical isolation which is also considered benign (Wennberg et al., 1997; Wennberg et al., 1999).

### Conclusion

ECoG while being widely used in epilepsy surgery is but still controversial in its efficacy and utility. This is particularly so as there are no prospective randomized studies. Despite its limitations, it remains a necessary tool in epilepsy surgery. In our study, of a total of 73% (116/157) had a good outcome following resective surgeries, 90% showed electrical improvement in post resection ECoG. More than a third of our patients seemed to have benefitted from 2nd and 3rd post resection recording which allowed the surgeon to extend the degree of resection. The improvement in ECoG correlated significantly with clinical improvement. However the conclusion should be taken with caution as we do agree upon certain short coming in this paper (1) The same scoring system was used for all pathologies i.e. cortical dysplasias (CD) vs. others. It is expected that in CD, the pre resection ECoG scores would be more abnormal e.g. 3—4. (2) The “shock effect” on ECoG following surgical resection which may provide a false post resection score. (3) In contrast to this, transient excitatory effect of the surrounding cortex following resection may not require resection as this may subside on its own. However with a background of a majority of our patients having a high seizure frequency (51% with >1 episode/day) encouraged us to perform this study. This relatively unique scenario provided us a back ground to understand the relationship of the lesional MRI pathologies to quantitative abnormalities seen on ECoG pre and post resection and to further correlate it with the clinical outcome.

We also agree to the fact that an adequate resection in lesional epilepsy usually leads to a good outcome and may not exactly reflect the usefulness of ECoG. However the authors would also like to reiterate that there are few such large studies reported in literature, and this can form the basis of initiating prospective studies e.g. randomizing patients with or without post resection ECoG and evaluating the outcome.

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### References


