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PROJECT REPORT

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MONTH & YEAR OF SUBMISSION: OCTOBER 2006

CERTIFICATE

I, *Dr.S. Raghavendra,* **hereby declare that I have actually carried out the project under report**

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Forwarded. He has carried out the project under report

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PROJECT REPORT

TITLE OF THE PROJECT: BILATERAL HIPPOCAMPAL DEPTH ELECTRODE MONITORING IN TEMPORAL LOBE EPILEPSY: EFFECTIVENESS, CLINICAL UTILITY AND FACTORS PREDICTING OUTCOME

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MONTH & YEAR OF SUBMISSION: OCTOBER 2006

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S. RAGHAVENDRA

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ABSTRACT

Introduction: Depth electrode monitoring is undertaken in patients with medically refractory temporal lobe epilepsy if 1) there is evidence of bilateral epileptogenicty with unilateral or asymmetric MRI abnormality in scalp video-EEG monitoring or 2) there is discordance between the clinical, radiological and electrical data. **Objectives**: To evaluate the role of invasive temporal depth electrode monitoring in localizing the ictal onset and analyzing the electrophysiological and neuroimaging features predictive of seizure outcome. **Methods**: From March 1995 through April 2005, 19 patients underwent bilateral temporal depth electrode monitoring for medically refractory temporal lobe epilepsy, of which 10 patients had a minimum of one-year follow-up after undergoing surgery. Mean duration of invasive monitoring was 8.3 days. Ictal and interictal data, imaging characteristics and other clinical features and their relation to surgical outcome were analyzed. **Results**: No major complications occurred. Seven patients had good outcome as defined by seizure frequency score of 2 or less. In three patients, no appreciable change in seizure frequency was noted. Early perinatal insults, antecedents like febrile seizures/meningoenephalitis/head trauma, age at onset and duration of epilepsy, presence of secondary generalized seizures and neuropsychological data were not predictive of seizure freedom. An experienced neuroradiologist blinded to the rest of the data was able to predict a good outcome in six with unilateral MTS. The ictal onset pattern, offset pattern and spread to contra lateral hemisphere were not different in both the groups. Prolonged interhemispheric propagation time (IPT) and presence of electrographic seizures were the only predictors of good outcome. Three patients with unilateral hippocampal sclerosis had contralateral surface ictal recording. Contrary to the common belief, none of these patients had extremes of atrophy or signal changes. **Conclusions**: Hippocampal depth electrode monitoring is highly rewarding in appropriately selected patients.

INTRODUCTION

Surgery offers a highly fruitful therapeutic option in the management of medically refractory epilepsy. In about two-thirds of patients, surgery can be offered after extensive presurgical evaluation including a detailed history, high resolution magnetic resonance imaging (MRI), neuropsychological evaluation, scalp electroencephalography (SEEG) followed by scalp video-EEG (S-VEEG) with or without additional semi-invasive electrodes like sphenoidal or foramen ovale electrodes, non-invasive methods like positron emission tomography (PET), single photon emission tomography (SPECT), subtraction ictal SPECT co-registered to MRI (SISCOM), and magneto encephalography (MEG). However, even after all these work up in a comprehensive epilepsy care program, it may become difficult to define the ictal onset zone clearly. In such patients invasive intracranial monitoring by placement of subdural strip or grid electrodes or stereo-tactically placed depth electrodes might become essential prior to embarking upon surgery. In temporal lobe epilepsy also, which forms the bulk of such patients subjected to epilepsy surgery world over, may also at times be difficult to be surgically tackled with the scalp recorded data alone. Such patients are then subjected to stereotaxic placement of depth electrodes on both sides either posteroanteriorly from the occipital region through the whole of the hippocampus or selectively into the hippocampus with additional ones to cover the temporal neocortex (stereo-EEG). In a developing country like ours, the first method is preferred where the electrode cost and surgery charges prohibit the use of multiple electrodes. Evaluating the cost effectiveness, utility, complications of the procedure and its long-term usefulness etc in a developing country therefore is very important for any epileptologist. To the best of our knowledge, such an attempt at evaluating the practical utility of depth electrodes has not been undertaken from India.

AIMS AND OBJECTIVES

We carefully analyzed the clinical, radiological, electroencephalographic (EEG) and follow-up data of 10 patients with refractory mesial temporal lobe epilepsy who require bilateral hippocampal depth monitoring prior to surgery. Our objectives were 1) to determine the factors which led on to the invasive monitoring, 2) assess whether any of the factors during the preliminary work up including imaging characteristics could independently predict the final outcome, and 3) ascertain the ictal and interictal patterns noted with depth electrodes which were predictors of seizure outcome.

MATERIAL AND METHODS

Study subjects

This study was conducted at the R. Madhavan Nayar Center For Comprehensive Epilepsy Care, at Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum. We did a detailed chart review of the data of 10 consecutive patients with temporal lobe epilepsy who underwent chronic intracranial EEG monitoring (CIEM) with bilateral hippocampal electrodes prior to standard temporal lobectomy from March 1995 to April 2005. All of them had completed at least a minimum of one-year follow-up. All the patients were interviewed personally to obtain the latest seizure frequency score and other details that were missing in the past records. These were then abstracted into a detailed, structured proforma. All of them had undergone an extensive presurgical evaluation including clinical evaluation, neuropsychological testing, speech and language assessment, MRI brain (1.5 Tesla) and scalp-VEEG monitoring. VEEG with sphenoidal electrode placement (blind fluoroscopic/ imaging guided) was performed prior to CIEM in majority. All patients had complex partial seizures that were refractory to maximally tolerated antiepileptic medications in various combinations.

Inclusion criteria

The seizures were classified as temporal in all the patients based on the clinical semiology, EEG findings, the ictal and the interictal data obtained during routine VEEG recording. The decision to subject the patients to chronic temporal depth electrode monitoring was taken when 1) there was evidence of bilateral epileptogenicty on noninvasive monitoring 2) bilateral but asymmetric MRI abnormality (mesial temporal sclerosis) or 2) there was discordance between the clinical, radiological and electrical lateralization. The decision to proceed with CIEM was taken by a group comprising of epileptologists, neurosurgeons, neuroradiolgists, a neuropsychologist, and speech therapist in a patient management conference.

Clinical characteristics

A detailed clinical history including early perinatal insults, congenital anomalies, history of febrile seizures, central nervous system infections, head injury with loss of consciousness or intracranial hemorrhage was noted. Any family history of seizures, other comorbidities including interictal psychiatric illness etc were also analyzed in detail. Age at onset of epilepsy was defined as the age at which habitual, unprovoked seizure started and the duration of epilepsy was defined as the time of first afebrile seizure to the time of surgery.

Neuropsychological assessment

All patients aged above 12 years underwent neuropsychological testing using Indian adaptation of the test batteries in the local Malayalam language, which encompassed the following domains: intellectual functions (Wechsler Adult Intelligence Scale), memory functions (Wechsler Memory Scale Subtests), visuospatial memory (Rey-Osterreith Complex Figure), attention and vigilance (Trail-making Tests), and verbal learning and memory (Rey Auditory Verbal Learning Test).[1] We do not have test batteries for neuropsychological testing in children. Neuropsychological test results were classified into concordant, discordant or bilateral depending on the side of surgery.

Electroencephalographic data

All patients had initial scalp VEEG recording performed with international 10-20 system with additional anterior temporal T1 and T2 electrodes. Sphenoidal electrodes were placed either blindly or by fluoroscopic or image (computed tomography, CT) guidance in the majority, if the ictal patterns were not well discernible by the other electrodes. Bilateral hippocampal depth electrodes (6 or 8 contacts) were implanted through the medial occipital lobe into hippocampus and amygdala by MRI guided stereotaxy by an experienced neurosurgeon. Patients in whom additional subdural strips or grids was used were excluded from the study. A post-placement CT was available in all the patients before they were taken up for electrode removal to note any migration of the electrodes and to assess the accuracy of placement. All patients had received prophylactic antibiotics after insertion of the depth electrodes

Computer assisted EEG monitoring with offline seizure analysis facility was utilized for analysis of the data. A VEEG monitoring system with 16-21 channels for scalp EEG and additional channels for the (6 contact and 8 contact) for the depth electrode monitoring was utilized. One investigator (ALR) reviewed all the VEEG data obtained in detail. In all patients, the antiepileptic drugs (AEDs) were slowly tapered during the VEEG monitoring. The electro clinical data was carefully assessed in relation to the tapering of the AEDs. Interictal discharges were classified as lateralized if more than 80% occurred on the side of ictal onset, bilateral if less than 80% was unilateral and contra lateral if more than 80% occurred on the side opposite to the side of maximum ictal onset.

Seizures were classified as localized, lateralized or of uncertain electrical onset depending upon the ictal pattern at the onset of seizures. Seizures were classified as localized if the ictal activity remained confined to one to two electrodes on one side throughout the seizure; lateralized if the ictal electrical change remained confined to all the electrodes on one side alone without any contra lateral spread till the seizure ends and of uncertain electrical onset if the at the onset of the electrical change during a seizure the activity was diffuse involving both the sides or it occurred well after the clinical semiology. The electrical data were also analyzed for ictal onset patterns and onset and offset of seizures and mean interhemispheric propagation time (IPT). Seizure onset was defined as the earliest change noted over one or more electrodes, where a distinct and persistent electrical change was noted in relation to the seizure onset. Seizure offset localization was defined as the area with the last discernible electrical abnormality. Interhemispheric propagation time (IPT) was defined as the time elapsed from the onset of first discernible ictal activity on EEG to that recorded from the contra lateral hippocampal depth electrode.

Neuroimaging characteristics

MRI brain was performed in all patients with a 1.5 T MRI scanner (Sigma Milwaukee). A neuroradiologist (CK) trained for the epilepsy program reviewed the MRI of all the patients. He was blinded to the clinical details of the patients, side of surgery and their final seizure outcome. The neuroradiologist was made to predict the side chosen for surgery if MRI alone was taken into consideration and also the outcome of surgery. The radiological abnormalities analyzed including hippocampal and parahippocampal volume and signal changes, temporal neocortical volume loss, temporal gray white matter differentiation abnormalities and fornicial and mammillary body changes. Patients with presence for any extra temporal changes or dual pathology were excluded from the study. During the time period of this study there was no provision of doing a hippocampal volumetry, T2 relaxometry or MR spectroscopy in our center. Other non-invasive investigations like SPECT or PET were not used in this study population.

Surgery

A standard anterior temporal lobectomy was performed in all the patients selected for surgery consisting of a resection 4.5 to 5 cm from the anterior temporal pole on the dominant side and 5-5.5 cms on the non-dominant side under general anesthesia. Amygdala and hippocampus was also removed. Intraoperative electrocorticography was performed in all the patients.

Pathology

Four-micrometer-thick histological sections were generated from 10% formalin fixed, paraffin-embedded tissue and stained with hematoxylin and eosin. We defined mesial temporal sclerosis as the loss of neuronal cell population of $\geq$ 30% in the CA1 sector of the hippocampal formation with or without neuronal loss and gliosis involving other mesial temporal lobe structures.

Seizure outcome

Seizure outcome was assessed through the follow-up records. The out come was assessed using seizure frequency scoring system[2] and Engel's scoring system [3]. Seizure free period was defined as if there was no seizure for more than a year if postoperative seizures occurred. Patients with seizures frequency score of two or less was considered as good outcome candidates and those with more than two were considered as poor outcome.

All the clinical data, neuropsychological results, MRI findings, noninvasive VEEG data, VEEG with sphenoidal electrode monitoring and CIEM data were evaluated with respect to seizure control after the surgery.

Statistical analysis

Quantitative data is summarized as mean $\pm$ standard deviation (SD). Fisher's exact test, Mann-Whitney test and t-test were used to evaluate the statistical significance of the association of different clinical, EEG and MRI characteristics with the seizure outcome at last follow-up. A *p*-value of ≤ 0.05 is considered for 2-tailed significance.

RESULTS

Electrophysiological findings and seizure outcome

A total of 19 patients were subjected to CIEM with hippocampal depth electrodes between March 2000 and April 2005. Of these, 10 patients underwent standard anterior temporal lobectomy based on the electrical data obtained after CIEM. A minimum of one-year follow-up was available for these patients. Five were not offered surgery after CIEM in view of bilateral temporal epileptogenicity or uncertain ictal onset. No major morbidity or mortality was observed in relation to the procedure. Following surgery five patients had quadrantnopia as the only neurological deficit.

Duration of follow-up ranged from 12 months to 48 months (31 $\pm$14 months). On follow-up, seven patients had good surgical outcome and three had no major changes in the seizure frequency, although in one (patient 9) there was change in seizure semiology and was suggestive of pseudoseizures in majority.

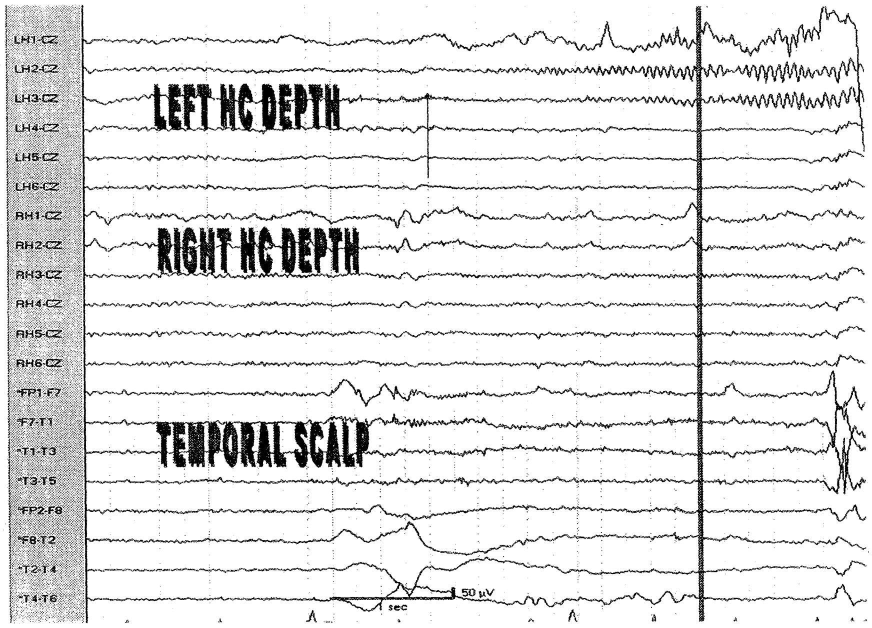
The mean age at onset, duration of epilepsy and presence of antecedent events were comparable between the two groups with good and bad outcome. There was an equal sex distribution. Mean number of 5$\pm$2.3 seizures was recorded with scalp VEEG. Seven patients had also undergone VEEG with sphenoidal electrode placement prior to undergoing CIEM (9.8±4.6 seizures recorded). CIEM with bilateral hippocampal electrode placement was done due to bilateral epileptogenic abnormalities seen during prior scalp-VEEG in six patients (patient 1, 2, 4, 7, 8, 10), discordant MRI and surface VEEG data in three patients (patients 5, 6, 9) and bilateral MRI abnormalities in one patient (patient 3).

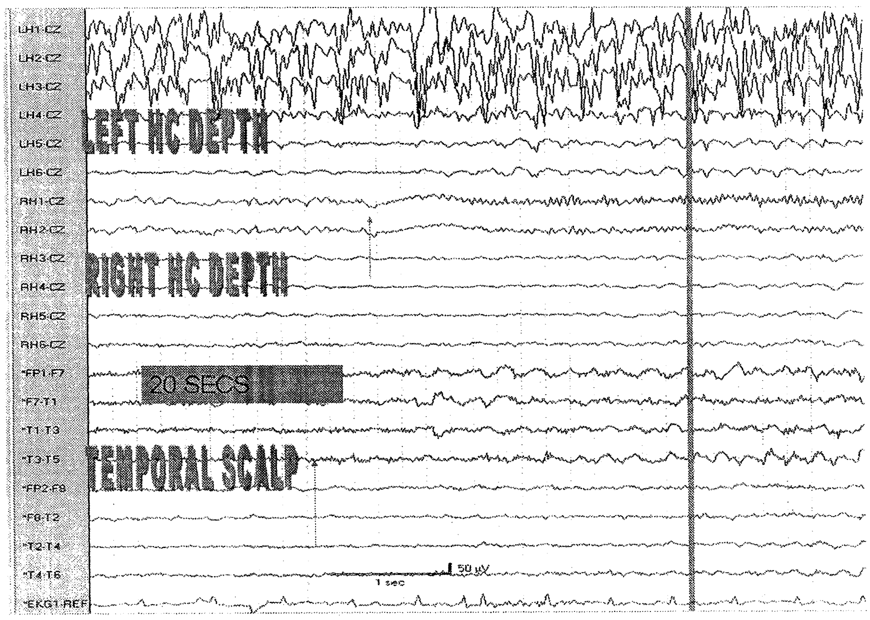
Mean duration of analysis with CIEM with hippocampal depth in situ was 8±3 days. An average of 3 to 27 (11±7) seizures were evaluated. Interictal discharges were bilateral in all patients (majority over the resected side) except in patient 5 where it was lateralized to the side of resection .A mean number of 12 ± 8 versus 10±4 seizures were recorded in patients with good outcome versus poor outcome.

The electrographic findings on hippocampal CIEM is shown in Table 2. The ictal onset patterns included beta activity (beta-buzz), spike wave discharges (SWD) and activity in the alpha range. The initial location of the ictal activity, transfer to the adjoining electrodes or the contra lateral hemisphere and offset pattern was evaluated. These findings did not have any bearing on the operative outcome. The mean duration of inter hemispheric propagation time (IPT) was 23 ±

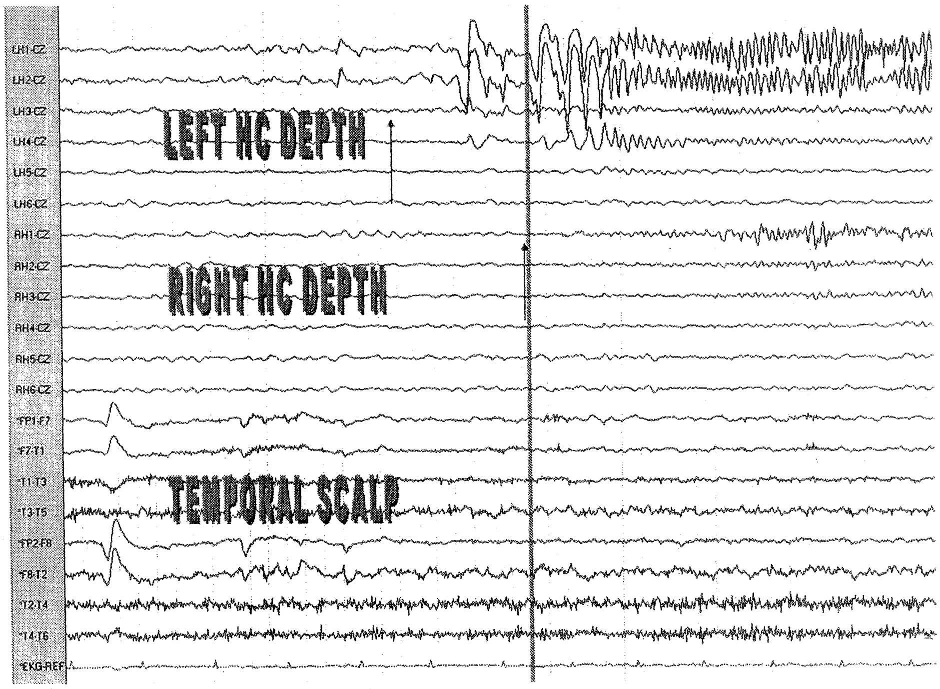
14 seconds. It was 31$\pm$7 seconds in patients with good outcome and 6$\pm$6 seconds with the poor outcome, which was significant (p=0.01). Electrographic seizures were observed in addition to the clinical seizures in five of the seven patients with good outcome (patient 1, 2, 3, 5, 7), but only one of the three patients with poor outcome (patient 8), (p=0.03). While none of the patients with good surgical outcome had undetermined seizure origin, five of the seizures were undetermined in origin in patients with poor outcome (patient 9, 10) (p=0.04).

PROTOTYPE OF A LONG INTERHEMISPHERIC PROPOGATION TIME (20 SECONDS)





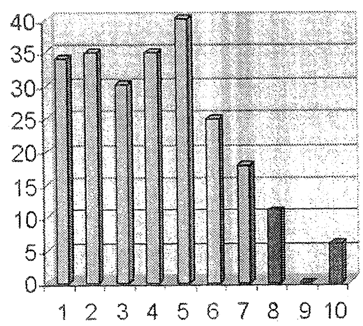
PROTOTYPE OF A SHORT INTERHEMISPHERIC PROPOGATION TIME (1.5 SECONDS)

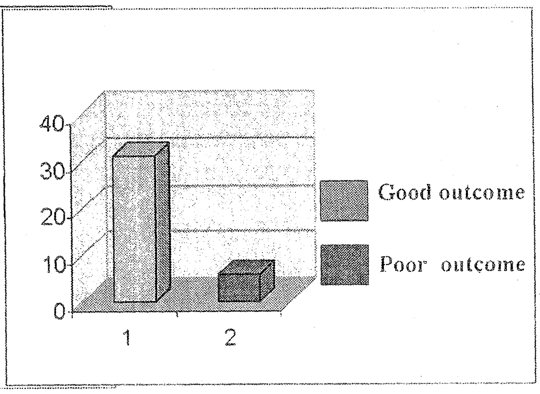


RESULTS

INTERHEMISPHERIC PROPOGATION TIME

- Mean duration of IPT: 23 ± 14 seconds
- 31±7 Vs. 6 ± 6 secs (good Vs. poor)= P=0.01





Neuropsychological data

The neuropsychological abnormalities were concordant in five patients and diffuse/bilateral in five patients. In patients with good surgical outcome, the abnormality was lateralized to the correct side in two patients and was diffuse in three. In poor outcome subgroup, the neuropsychological abnormality lateralized to the opposite side of surgery in two patients and was diffuse in one. Full scale IQ ranged from 61 to 105 in the whole group, with the average of 82.43 $\pm$ 17 in the good outcome group and 89.61$\pm$ 1.8 in the bad outcome group. Both were statistically not significant.

MRI characteristics:

The MRI abnormalities observed were unilateral MTS (7/10 patients; 6 on the right side) and predominantly unilateral (patient 3). Opposite mesial temporal structures were normal in 7 patients with MTS and showed signal changes alone in one (patient 3). MRI was normal in two patients. Mild neocortical gray white matter changes were observed in three patients (patient 1, 9, 10) of whom one had good surgical outcome. In this subgroup of patients with MTS, six had good postoperative seizure control. The patient with predominantly unilateral MTS also had good surgical outcome. Other changes observed included neocortical volume loss in three patients (outcome good and poor in one each). In two patients, the MRI was normal, one had a good outcome while another had poor outcome. There were no extra temporal changes or dual pathology observed in any of the patients. Radiologist was able to prognosticate the good outcome correctly in six patients with MTS. Of the patients in whom the radiologist failed to predict the outcome, one had unilateral MTS, (patient 7: predicted good outcome, but outcome was poor), one had predominantly unilateral MTS (patient 3 predicted a fair outcome, but surgical outcome was good) and predicted poor out come in normal MRI (one good and one poor) Prediction of the side of surgery and the final seizure outcome by MRI is detailed in Table 1.

Histopathological features

Histopathology was suggestive of hippocampal sclerosis in 8 patients and was normal in two patients. There was no other associated pathology identified.

DISCUSSION

Medically refractory temporal lobe epilepsy is one of the most common indications for epilepsy surgery. Most patients can be selected for surgery after a comprehensive presurgical non-invasive work up. However, in a small subgroup of patients additional investigations including invasive hippocampal depth electrode recording may be required to establish the lateralization of ictal onset prior to the surgery. Many previous studies have demonstrated the utility of hippocampal depth electrode monitoring in identifying a selected subgroup of patients with medically refractory complex partial seizures for surgery. [4, 5]

In this study, we analyzed the utility of hippocampal depth electrode data in 10 consecutive patients with medically refractory temporal lobe epilepsy subjected to temporal lobectomy after hippocampal depth electrode recording and had completed a minimum of one year post surgical follow-up.

Various factors including the history of febrile seizures and early onset of seizures have been shown to be associated with good surgical outcome in various studies earlier. [6, 7] However, in our study subgroup we could not demonstrate any such association. The highly selective subgroup of the study population and the small number of patients could be responsible for such a finding. The neuropsychology and routine S-VEEG failed to clearly predict the outcome in this group.

Our study further demonstrates the utility of hippocampal depth monitoring in appropriately selecting the patient for temporal lobectomy. Of the electrophysiological data, a longer IPT was significantly associated with better outcome after surgery. Several earlier reports have shown that shorter IPT is associated with poorer surgical outcome. [3, 8, 9, 10] In patients with mesial-temporal pathology, disruption of the normal anatomic connections between the two hemispheres has been suggested to be the cause of prolonged IPT. [11] The hypothesized cause of short IPT is the presence of bitemporal epileptogenicity whereby seizure can rapidly spread to the opposite hemisphere, it is thought that a structurally and physiologically intact hippocampus and its circuitry is unable to express the ictal activity.[9] Patients had different ictal onset patterns during the recording. No electrical pattern was consistently associated with good or bad surgical outcome. The variations in electrical onset patterns on depth electrode recording have been previously demonstrated. [12]

Patients with electrographic seizures during the depth monitoring were associated with better postoperative seizure outcome. A similar association of electrographic seizures with better surgical outcome was noted earlier, although the same authors had shown that electrographic seizures alone without clinical seizures were a poor predictor of localization.[13] A possible explanation is that the electrographic seizures may be present only in the focus and the depth electrode appropriately identifies the epileptogenic foci in these patients. [14]

Our results show that unilateral MTS is a strong predictor of the epileptogenic zone as determined by depth electrode recording (75% had good postoperative outcome). Several authors have shown that MRI identified hippocampal atrophy as a reliable indicator of epileptic temporal lobe. [15, 16, 17] Of the two patients with unilateral MTS with poor outcome, one had additional seizures with uncertain ictal origin suggestive of the presence of other epileptogenic foci.

In three patients with unilateral MTS, the ictal onset on scalp VEEG was from the predominantly opposite temporal lobe. (Patients 5, 6, 7, 9) Depth electrode monitoring showed ictal onset ipsilateral to the MRI abnormality. The occurrence of contra lateral temporal onset on surface ictal recordings has been commonly recognized with severe hippocampal wasting or signal changes and has been variably named as "wasted hippocampal or burnt-out hippocampal syndrome".[18] This occurrence of this has been attributed to lack of initial mesial temporal discharge being recorded on scalp tracing due to significant neuronal loss.[18] In contrast none of our patients with this phenomenon had severe atrophy or intense signal changes on MRI. The seizure pattern seen in these patients were either type I (spread to opposite depth electrode) or type III (spread to the opposite depth and the opposite temporal lobe prior to ipsilateral temporal lobe). Mean IPT in these patients was 13.5 seconds. Gloor et al demonstrated similar findings on depth electrode monitoring in patients with false scalp ictal lateralization.[19] The prolonged IPT has been suggested as due to a dorsal hippocampal commissure seizure propagation requiring neuronal recruitment. This propogation could be responsible for the discordant surface tracing. Interictal discharges are reported to be a more accurate predictor of epileptogenic zone in these patients.[17] In two of our patients the interictal discharges on scalp tracing were also discordant (patient 5, 6). Thus, other mechanisms like lack of sufficient neocortical neuronal recruitment to produce a visible scalp discharge prior to the propagation of the seizure to the contralateral temporal lobe may also be involved. Other factors like the size or functional prominence of the individual's dorsal hippocampal commissure, or the nature of local recruitment patterns within the mesial temporal lobe has also been postulated. Of these four patients, three patients had good surgical outcome. The fourth patient (patient 9) continued to get seizures that were confounded by pseudoseizures. This patient on depth electrode recording in addition to the ipsilateral complex partial seizures to MRI abnormality had seizures with uncertain electrical ictal onset in few complex partial seizures suggesting more diffuse or bilateral epileptogenic zones. Our study shows the utility of depth electrode monitoring in this scenario of surface ictal discordance with MRI abnormality in unilateral MTS.

In all patients with MRI abnormality of MTS, the side of ictal localization on depth was concordant with MTS in all the patients (100%). It is however important to note that all patients had unilateral or predominantly bilateral MTS. Cukiert et al prospectively subjected 100 patients with temporal lobe epilepsy to surgery on MRI criteria alone and had a good surgical outcome in more than 95% of the patients.[20] In two patients with normal MRI, one had a good outcome. Several authors have shown the utility of quantitative MRI techniques like volumetry, T2 relaxometry and MRS, which could not be done in our patients. These techniques likely would have added more information especially in patients with normal MRI. But in a developing country like ours where the cost factor is very important; an epileptologist may be forced to proceed with the available tools in diagnosis.

Utility and limitations

This is the first study demonstrating the utility of hippocampal depth electrode from our country. The major limitations of the study are the small sample size. Newer MRI techniques that have recently proven to be useful like T2 relaxometry; volumetric studies and spectroscopic studies were not utilized for lateralisation. Several other techniques like ictal SPECT or interictal PET may have added valuable information.

CONCLUSIONS

The study shows the utility of VEEG with invasive hippocampal depth electrodes in a carefully selected population with bilateral epileptogenesis, normal MRI or electrical and radiological discordance. Electrical parameters like longer IPT, presence of electrographic seizures and seizures with clear ictal onset are important predictors of good surgical outcome. Recording more number of seizures especially in patients with undetermined ictal onset may be helpful.

Table 1: Electrographic and radiological findings in patients with hippocampal depth electrode monitoring and surgical outcome

No	Extracranial VEEG lateralization: Interictal	Extracranial VEEG liberalization: ictal onset	VEEG with sphenoidal electrodes interictal	VEEG with sphenoidal electrodes: ictal	VEEG with bilateral depth electrodes: Interictal	VEEG with bilateral depth electrodes: ictal	MRI	Side of ATL and AH. Surgery outcome
1	Bilateral	ND	Left	Bilateral (R> L)	Bilateral	Right	Right MTS*	Right; good
2	Bilateral	Left	Bilateral	Bilateral	Bilateral	Left	Left MTS	Left, good
3	Left	Undetermined	Left	Undetermine d	Bilateral	Left	Left MTS, Right hippocampal signal changes	Left; Good
4	Bilateral	ND	Bilateral	Bilateral (R>L)	Bilateral	Right	Normal	Right; Good
5	Left	Left	ND	ND	Right	Right	Right MTS.	Right. Good
6	Left	ND	Left	Left, undetermined	Bilateral	Right	Right MTS	Right: Good
7	Bilateral	ND	Bilateral	Bilateral (3 L, 1 R)	Bilateral	Right	Right MTS	Right; Good
8	Bilateral	Bilateral	ND	ND	Bilateral	Right	Right MTS*	Right Unfavorable
9	Bilateral	Left	Left	Bilateral	Bilateral	Right, uncertain (5:2)	Right MTS*	Right. unfavorable
10	Bilateral	Bilateral	ND	ND	Bilateral	Left, uncertain (8:3)	Normal	Left Unfavorable

*Mild neocortical volume loss, ND- not done.

Table 2: Characteristics of seizures recorded on depth electrode monitoring

Pt no	Seizures	Onset pattern*	Initial spread	Offset	IPT (secs)
1	9R, 5EG-R, 2L	Beta (2R), SWD (7R, 5EG, 2L)	Focal, (EG- 5) Opposite depth (11)	Ipsilateral (7R, 5EG), Contralateral (2R), Diffuse (2L)	34
2	3 L-SG, 7EG-L	Beta (3L, 7EG)	Focal (EG-5) Opposite depth (2, EG-3,)	Ipsilateral (3, 5EG), Contralateral (2EG)	35
3	8 L, 1EG-L	Beta (3L), Theta (1L), SWD (4L, 1EG)	Opposite depth (9, 1-EG)	Ipsilateral (6), Contralateral (1), Simultaneous (2)	30
4	6R	Alpha (5), SWD (1)	Focal (2), Opposite depth (4)	Ipsilateral (3), Contralateral (1)	35
5	1R-SG, 26EG-R	Beta (26EG), SWD (1R)	Focal (25EG), Opposite depth (1EG), Diffuse (1R)	Ipsilateral (25 EG), Contralateral (1-EG), Diffuse (1R).	40
6	3R	Beta (3R)	Opposite depth & temporal (3)	Left depth (3R)	25
7	5R, 4EG-R	Beta (4R, 4EG), SWD (1R)	Focal –(EG –3) Opposite depth & temporal (5)	Ipsilateral (4EG), Contralateral (5R)	18
8	4R, 2EG-R	Beta (4R), SWD (2EG)	Opposite depth (6)	Diffuse	11
9	5R, 2 U	Beta (5R)	Local (5)	Ipsilateral (5), Diffuse (2)	0
10	8R, 3U	Beta (8R)	LTD (8), Diffuse (3)	Ipsilateral (4R), Contralateral (4R)	6

R-right, L-left, U-undetermined, EG-electrographic seizures, SG-secondary generalization, AEDs-antiepileptic medications, SWD- spike wave discharges

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