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Original Article

Resective epilepsy surgery in a limited-resource settings: A cohort from a multi-disciplinary epilepsy team in a developing country

Hussein Hamdi[1], Nirmeen Kishk[2], Reham Shamloul[2], Mona K. Moawad[2], Micheal Baghdadi[3], Mina Rizkallah[3], Amani Nawito[4], Mohammad Edrees Mohammad[2], Hatem Nazmi[5], Yasser Mohamed Nasr[5], Salwa Hassan Waly[5], Mo'men Elshahat[6], Rehab Magdy[2], Alshimaa S. Othman[2], Hesham Nafea[4], Amro M Fouad[2], Ismail Elantably[6], Haytham Rizk[2], Enas Elsayyad[2], Ahmed A. Morsy[6]

[1]Department of Neurosurgery, Faculty of Medicine, Tanta University, Tanta, [2]Department of Neurology, Faculty of Medicine, Cairo University, [3]Department of Radiology, Ministry of Health, [4]Department of Clinical Neurophysiology, Faculty of Medicine, Cairo University, Cairo, [5]Department of Anesthesia, Surgical Intensive Care and Pain Management, [6]Department of Neurosurgery, Faculty of Medicine, Zagazig University, Zagazig, Egypt.

E-mail: *Hussein Hamdi - hussein.m.hamdi@gmail.com; Nirmeen Kishk - nirmeenkishk@kasralainy.edu.eg; Reham Shamloul - rehamneuro2@gmail.com; Mona K. Moawad - mona.k.abdelfattah@kasralainy.edu.eg; Micheal Baghdadi - dr.michaelbaghdadi@gmail.com; Mina Rizkallah - dr.minafakhry@live.com; Amani Nawito - amani.nawito@kasralainy.edu.eg; Mohammad Edrees Mohammad - mohammad_edrees@hotmail.com; Hatem Nazmi - hatem.nazmi@yahoo.com; Yasser Mohamed Nasr - yasser_nasre@yahoo.com; Salwa Hassan Waly - salwa.waly@yahoo.com; Mo'men Elshahat - momenelshahat0@gmail.com; Rehab Magdy - rehab.m.hassan@kasralainy.edu.eg; Alshimaa S. Othman - alshimaa.s.othman@kasralainy.edu.eg; Hesham Nafea - drhesham101@gmail.com; Amro M Fouad - amro.fouad@kasralainy.edu.eg; Ismail Elantably - dr.antably.85@gmail.com; Haytham Rizk - dr.hithm@gmail.com; Enas Elsayyad - enas.alsayyad@kasralainy.edu.eg; Ahmed A. Morsy - dr.ahmed.ali.morsy@gmail.com

***Corresponding author:**
Hussein Hamdi,
Department of Neurosurgery,
Faculty of Medicine, Tanta University, Tanta, Egypt.
hussein.m.hamdi@gmail.com

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ABSTRACT

Background: Multidisciplinary pre-surgical evaluation is vital for epilepsy surgery decision and outcomes. Resective epilepsy surgery with assisted monitoring is currently a standard treatment for focal drug resistant epilepsy (DRE). In resource-limited countries, lack of epilepsy surgery center is a huge challenge. We presented and illustrated how to create a multidisciplinary protocol with resource-limited settings in a developing country and epilepsy surgery outcome using brain mapping and monitoring techniques for ensuring satisfactory resection.

Methods: We created multicentric incomplete but complementary units covering all epilepsy-related sub-specialties and covering a wide geographical area in our country. Then, we conducted a prospective and multicentric study with low resource settings on patients with focal DRE, who underwent resective epilepsy surgery and were followed up for at least 12 months and were evaluated for postoperative seizure outcome and complications if present. Preoperative comprehensive clinical, neurophysiological, neuropsychological, and radiological evaluations were performed by multidisciplinary epilepsy team. Intraoperative brain mapping including awake craniotomy and direct stimulation techniques, neurophysiological monitoring, and electrocorticography was carried out during surgical resection.

Results: The study included 47 patients (18 females and 29 males) with mean age 20.4 ± 10.02 years. Twenty-two (46.8%) patients were temporal epilepsy while 25 (53.2%) were extra-temporal epilepsy. The epilepsy surgery outcome at the last follow up was Engel Class I (seizure free) in 35 (74.5%), Class II (almost seizure free) in 8 (17%), Class III (worthwhile improvement) in 3 (6.4%), and Class IV (no worthwhile improvement) in 1 patient (2.1%).

Conclusion: With low resource settings and lack of single fully equipped epilepsy center, favorable outcomes after resective surgery in patients with focal DRE could be achieved using careful presurgical multidisciplinary selection, especially with using intraoperative brain mapping and electrocorticography techniques.

Keywords: Developing country, ECoG, Epilepsy, Resective, Surgery

INTRODUCTION

Seizure freedom is the ultimate final goal of any management strategy for epilepsy patients. Delayed proper treatment or failure of seizure control will be associated with progressive decline of several cognitive and psychiatric aspects with critical impact on the quality of life.[9,23] Antiseizure medications (ASMs) are the primary management for epilepsy either using monotherapy or poly-therapy protocols. However, one-third of the patients with focal DRE continue to have uncontrolled seizures despite adequate and appropriate medical treatment.[6]

Recently, several surgical techniques and approaches have been proposed for this group of patients suffering intractable epilepsy.[9] Successful resective epilepsy surgery should be aimed to seizure freedom outcome through optimum tailored resection of the epileptic zone and/or the epileptic lesion while sparing the critical brain areas around.[22] Such surgery could carry a significant risk of several potential surgical and neurological complications which impair the already disabled epileptic patients. Different strategies could be applied to optimize epilepsy surgery and its safety and efficacy including preoperative extensive workup and intraoperative assisted neurophysiological monitoring techniques. The benefits of these assisted surgeries outweigh the associated risks in achieving seizure freedom, improving quality of life, and reducing mortality.[17]

On the other hand, the usual cost of such complicated techniques could obstacle these procedures in the developing countries. Adaptation and selection among such expensive surgical techniques should be carefully discussed and applied with special attention to efficacy and available resources at the same time in a wide geographical area.

We present our multicentric prospective cohort in a developing country with special focus on surgical and resource-limited techniques utilized to optimize epilepsy surgery outcome in intractable focal epilepsy.

MATERIALS AND METHODS

Study design

We conducted a prospective study analysis in three tertiary hospitals and referral centers in our country to cover a wider geographical area between January 2018 and May 2021 [Figure 1]. Selection criteria included all patients with focal drug resistant epilepsy (DRE) with localized epileptogenic zone (EZ) and with concordance between clinical semiology, video ictal electroencephalography (EEG), and neuroimaging studies according to our epilepsy surgery algorithm which had been approved by the society of neurology, psychiatry, and neurosurgery as shown in the flowchart [Figure 1]. Patients were fit and accepting the resective epilepsy surgery. Primary outcome to be measured was the epilepsy surgery efficacy and safety at 1 year at least. Secondary outcome was the cognitive and psychological aspects. Exclusion criteria included patients with focal epilepsy but unconcordant between imaging, clinical, and neurophysiology and were advised to perform further invasive monitoring, patients who refused to perform resective epilepsy surgery, and those with multifocal, hemispheric, and generalized epilepsy and had palliative surgery according to our protocol [Figure 1]. Ethical committee approved the prospective design. The Strengthening the Reporting of Observational studies in Epidemiology guidelines were carefully considered during reporting present study. Informed consents were obtained from all participants (or parents if not applicable) after introducing verbal information and explanation of all expected benefits and risks of the surgery. All included subjects were carefully inspected and analyzed by a multidisciplinary team specialized in epilepsy through online and real meetings when possible. Seizure frequency before surgery was calculated as the average of the seizure frequency in the past 3 months before surgery using seizure diary logbook filled by the patients and families. Seizure descriptive analysis was according to the international league against epilepsy (ILAE) classification 2017.

Different variables were analyzed to be correlated with the clinical Engel class outcome such as gender, age of onset of the disease, duration, age at surgery, handedness, ASMs load, and seizure frequency per month, location in the hemisphere, dominant hemisphere, and pathology of the lesion.

Epilepsy center and multidisciplinary team

Lack of resources and trained staff in a single center was the main obstacle toward starting a specialized epilepsy surgery program. It was also extremely difficult to establish all resources required in a single center. A multidisciplinary board from different universities was formed after cooperation between several Neurology and Neurosurgery departments, and Specialized Neuroradiology team. The team included trained highly specialized epileptologists, neurophysiology experts, epilepsy neuroradiologists, nuclear medicine specialists, neuropsychologists, epilepsy neurosurgeons with anesthesiologist, and neurophysiology specialist who is expert in intraoperative brain mapping techniques and electrocorticography (ECOG) recordings. The team members joined a weekly real or on-line video conference meeting to discuss all candidate cases with focal DRE regarding the clinical, imaging, and electrophysiological data. The team was in contact with three international leading experts in epilepsy. Surgical decision was always discussed through the multidisciplinary board considering all benefits and risks to be explained to the patient before surgery and during the informed consent.

The surgical theaters in all different hospitals were equipped with all standard surgical instruments and devices required. Portable machines such as intraoperative navigation machine and

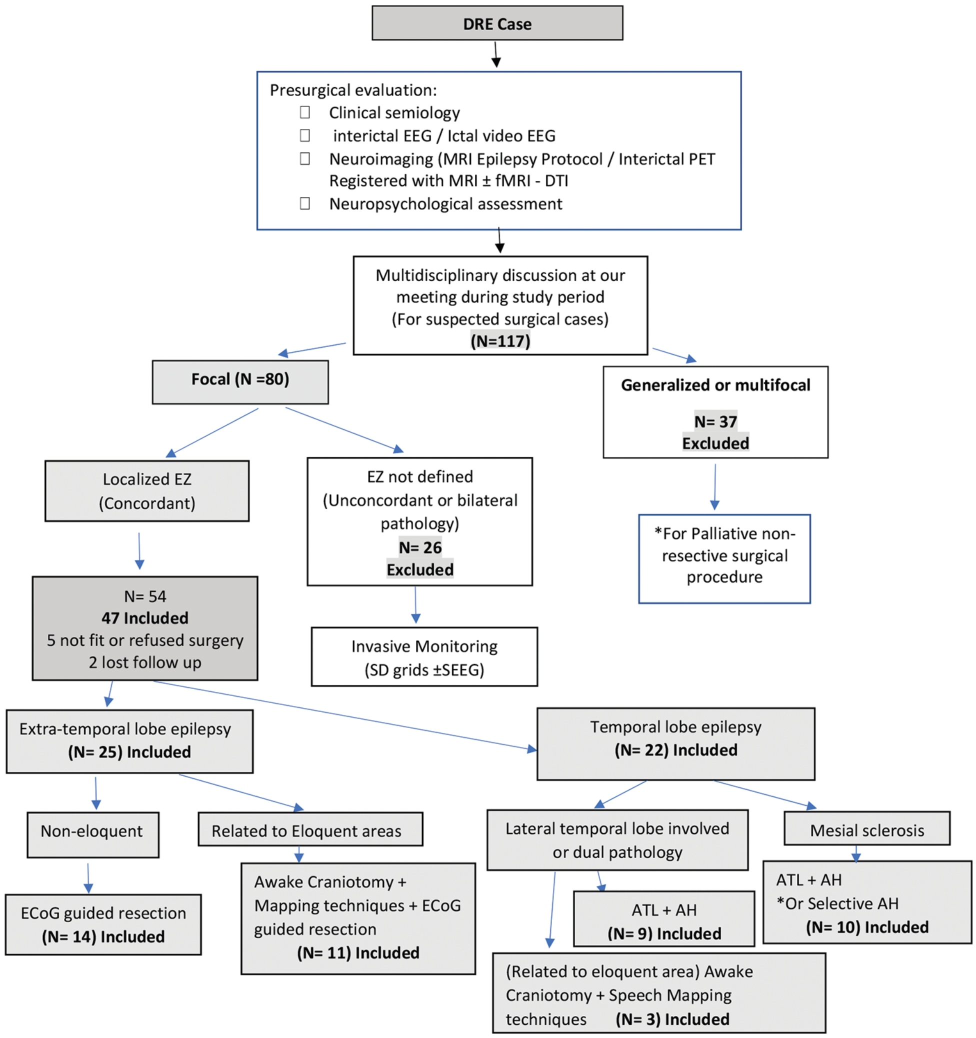

Figure 1: Flowchart shows patients inclusion for resective epilepsy surgery. DRE: Drug-resistent epilepsy, EEG: Electro-encephalography, PET: Positive emission tomogrpahy, MRI: Magnetic resonance image, DTI: Diffusion tensor imaging, N: Number of patients, SD: Subdural, SEEG: Stereotactic encephalography, ATL: Anterior temporal lobectomy, AH: Amygdalohippocampectomy, ECoG: Electro-enephalography, EZ: Epilepstic zone. *According to each case.

neurophysiological monitoring device for mapping and ECoG recording were always carried and used in our different centers.

Preoperative workup

All patients were subjected to the following

Detailed history

Demographics and clinical data were documented that included age, gender, age of onset, duration of epilepsy, and ASMs regimen. Seizure semiology was classified according to the new ILAE classification.[20] It was described by a reliable witness or home video record of the seizures or seizures recorded in the epilepsy unit. In addition, detailed neurological examination was done.

Video EEG

All recruited patients were scheduled for ictal video EEG recording with the help of a well-trained EEG technician. Arrangement ASMs withdrawal before ictal recording was done based on seizure frequency, type, and dose of ASMs. Rapid ASMs withdrawal up to 30% of daily dose with sleep deprivation before EEG recording to shorten the duration to first seizure.[14] Electrode placement was done according to the international 10–20 system; and additional electrodes at T1/T2 positions and for ECG recording were applied.[21] The occurrence of seizures during the recording was documented for detailed semiology analysis. An expert clinical neurophysiologist assessed all recordings for interictal epileptiform discharge, localization, and lateralization of seizure onset during ictal recording [Figure 2].

Neuropsychological assessment[1]

Patients were screened for depression and anxiety by Beck depression inventory questionnaire – Arabic version[7] and Beck anxiety inventory[5] – Arabic translate,[3] Wechsler Adult Intelligence Scale-Version IV (WAIS-IV)[11] was done by trained and specialized psychologist. Attention, verbal and visual memory, executive function, language, and social cognition were assessed by an Arabic battery [Table 1, Figure 3] that was constructed and selected according to ILAE 2015 recommendations.[25]

Neuroimaging techniques

We installed a neuroimaging protocol for epilepsy patients with acquisition specifications to catch various epileptic lesions and relevant pathology. Within four referral radiology centers, we launched the imaging protocol to cover wider geographical areas in our country. These centers were in several major cities. Epileptologists in different hospitals were announced about this protocol to follow it before referring patients to our team.

Magnetic resonance imaging (MRI) brain (epilepsy protocol)

All subjects were scanned on a 1.5 Tesla GESIGNA closed-configuration whole body scanner using a standard quadrature head coil. We acquired isotropic Sagittal 3D T1-weighted spoiled gradient, sagittal Cube T2 FLAIR, 2D Axial T2, Coronal T2 perpendicular to the long axis of the hippocampus, diffusion-weighted imaging, and susceptibility-weighted scan. In addition, we added complementary T1 MRI with gadolinium and/or thin cuts coronal T2 (2 mm) covering the temporal pole and sphenoid bones if needed.

Imaging postprocessing

FreeSurfer software package version 6.0 (https://surfer.nmr.mgh.harvard.edu/) was used for the volumetric analysis. Every patient was provided with an individualized report that detailed the volume and percentile of each segmented region compared to age-matched normative database. 3D slicer version 4.11 was used to generate brain surface 3D models to guide the surgeon intraoperatively according to brain surface anatomical curvatures [Figure 4].

Positron emission tomography (PET)/computed tomography (CT)

Fluorodeoxyglucose (FDG) brain PET/CT imaging protocol is well described in Society of Nuclear Medicine and European Association of Nuclear Medicine guidelines.[24] A low dose (10–30 mAs) CT attenuation correction (AC) images are obtained then static PET acquisition typically begins 30–60 min after FDG injection and lasts for 10 min. Visual inspection without semiquantitative analysis is the standard method of interpretation.

PET/MRI co-registration

PET images were registered to the magnetic resonance (MR) images using FSL version 5.0.11 (using FLIRT toolbox).

Anesthesia and surgical techniques

Type of anesthesia, either awake or general anesthesia (GA), was depending on proximity of EZ to an eloquent area according to our protocol [Figure 1]. Furthermore, age, neuropsychological assessment, and patient's fitness and acceptance for awake craniotomy were considered. Intraoperative ECoG was performed in all our patients with extra-temporal lobe epilepsy with its anesthetic considerations for accurate recording, whatever patient was awake or under GA. For awake craniotomy, circumferential scalp block and monitored conscious sedation protocol was used with continuous monitoring of Bi-spectral index to

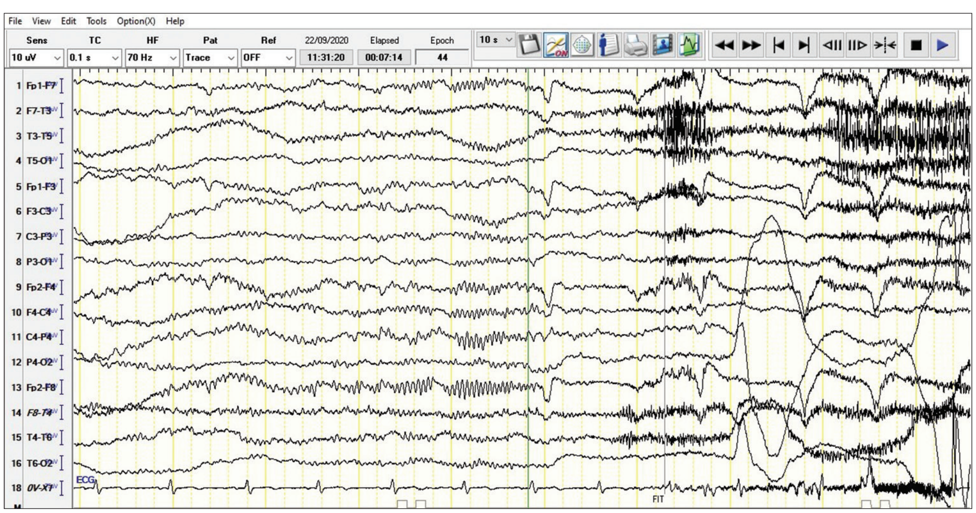

Figure 2: EEG trace of the patient mentioned in Figure 4 showing an ictal EEG onset in the right frontal derivation.

Table 1: Cognitive assessment before and after resective epilepsy surgery.

Intelligence quotient: (WAIS-IV)				
Domain	**Test/Index/Subset**	**Preoperative**	**Postoperative**	**Conclusion**
WAIS-IV	Verbal comprehension	113		
	Perceptual reasoning	91		
	Working memory	83		
	Processing speed	83		
	Full scale IQ	94		
Neuropsychological assessment: Patient showed improvement in performance in nearly all the assessed cognitive function				
Attention	Digit forward	7	8	Improved
	Digit backward	4	6	Improved
Verbal memory	PAT	15.5	18	Improved
Visual memory	Benton VRT	5	6	Improved
Language	Figurative interpretation	22	24	Improved *Stationary*
	Judgment on sentence	51	51	
Executive function	COWAT	20	24	Improved
Executive function	TMT	32	30	Improved
Social cognition	Ekman test Fear recognition	0	2	Improved
Depression and anxiety: Screening for depression and anxiety showed improvement of scores in screening inventories.				
Depression and anxiety	Beck depression inventory	16	7	Improved
	Beck anxiety inventory	8	3	Improved

PAT: Phonological awareness test, VRT: Visual retention test, COWAT: Controlled oral word associate test, TMT: Trail making test, WAIS-IV: Wechsler adult intelligence scale-version IV, IQ: Intelligence quotient

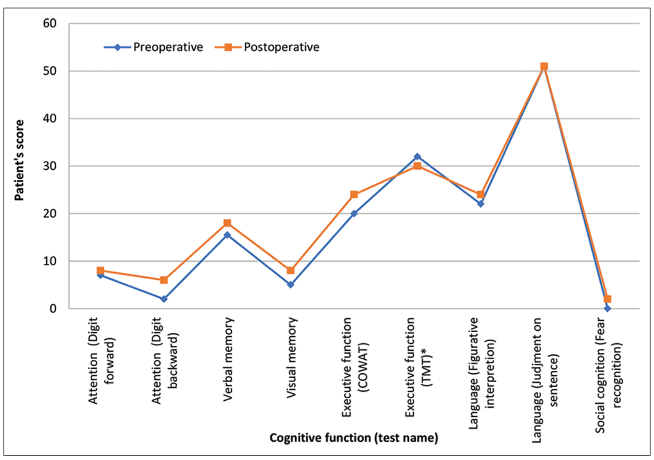

Figure 3: Comparison of Patient's performance (showed in Figure 4) in preoperative and postoperative neuropsychological assessment that showed improvement of the scores in postoperative performance. Unlike the rest of tests, the lower the score is better; however, preoperative and postoperative score was within normal range. COWAT: The Controlled Oral Word Association Test. TMT: The Trail Making Test. * TMT-A uses all numbers, TMT-B alternates numbers and letters, in consecutive order.

detect level of consciousness as previously reported by our team.[18] For patients who underwent surgery under GA, total intravenous anesthesia protocol was performed with avoidance of halogenated inhaled agents, which can increase the latency and decrease the amplitude of evoked potentials. In addition, if motor mapping is indicated, chemical muscle relaxants must be avoided.

Intraoperative ECoG was performed in all our patients using portable 64-channel intraoperative neurophysiological monitoring device, either (ISIS, IOM system, INOMED, Inc.) or (NIM Eclipse, Medtronic, Minneapolis, Minnesota). Different strip and grid electrodes were used to cover suspected epileptogenic area. Pre and post resection ECOG recordings were done by single experienced neurophysiologist

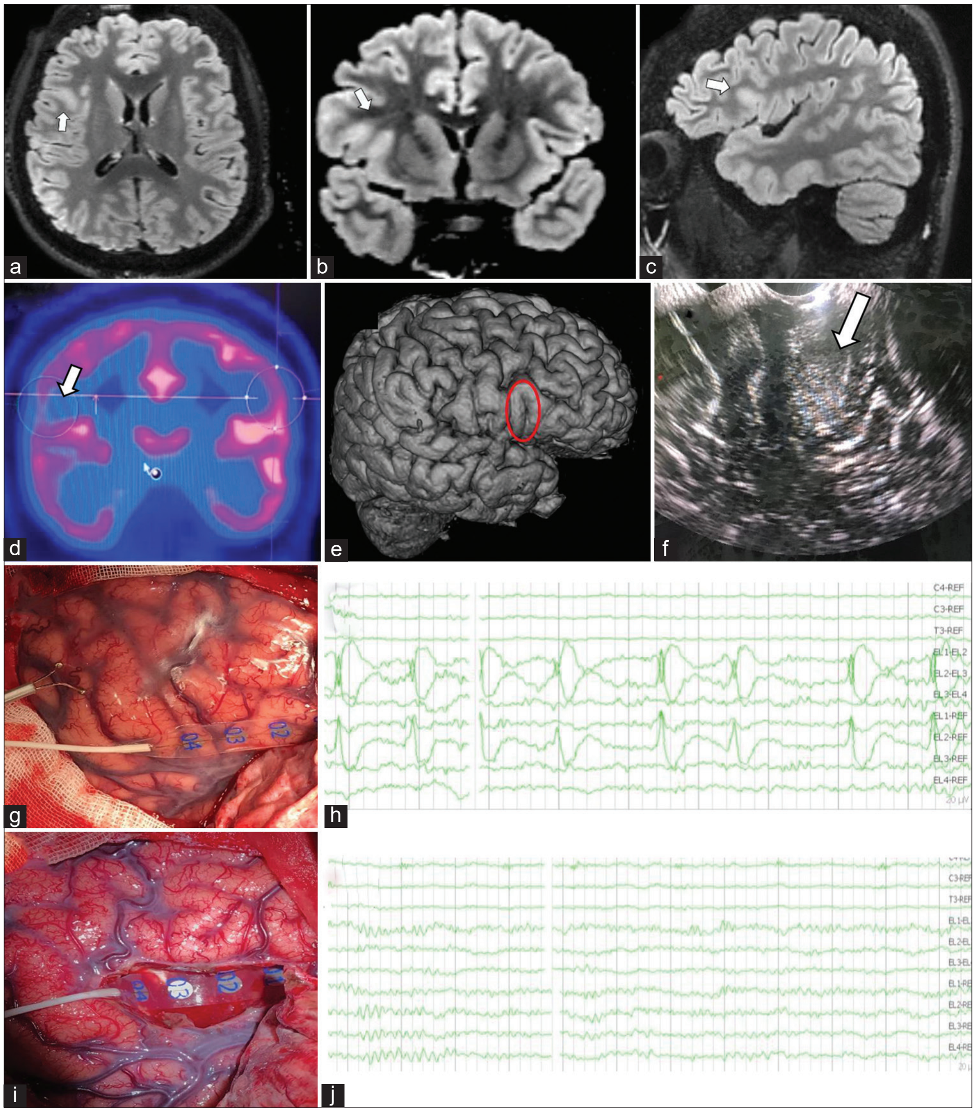

Figure 4: A 20-years-old male patient with focal drug resistant epilepsy. Patient was enrolled to our proposed presurgical evaluation protocol. Seizure Semiology was focal aware motor seizures in the form of palpitation, sense of fear followed by left-sided tonic posture with vocalization rarely with or Focal to bilateral tonic clonic seizure, with an ictal EEG onset in right frontal derivation. This was concordant with neuroimaging which revealed right inferior frontal focal cortical dysplasia. Patient underwent resective surgery using intraoperative mapping techniques and electrocorticography (ECoG), with Engel Class I outcome. Comparison of Patient's performance in preoperative and postoperative neuropsychological assessment showed improvement of the scores in postoperative performance.(Supplementary Data) (a,-c): Axial, coronal, and sagittal magnetic resonance (MR) neuroimaging shows right inferior frontal focal cortical dysplasia in the form of cortical thickening and blurring of grey-white matter junction with transmantle sign (highlighted by arrow). (d) Positron emission tomography image shows the interictal hypometabolism hypo-metabolism area (arrow) corresponding to the location of the focal cortical dysplasia. (e) Preoperative 3-dimentional illustration planning planning model shows the lesion (circle). (f) Intraoperative ultrasonography image shows thickened and hyper-echoic dysplasia (highlighted by arrow). (g and h) Intraoperative photograph shows preresection ECoG strip over the surgical target, and recording screenshot shows corresponding rhythmic sharp waves. (i and j) Intraoperative photograph shows postresection image with ECoG strip over the insula in the depth of resection cavity, and recording screenshot shows postresection ECoG recording shows normal electroencephalography findings.

and blinded from the location of electrode during surgery to properly define EZ and confirm satisfactory resection [Figure 4]. According to any proximity to eloquent area such as motor, speech and visual areas, direct cortical and sub-cortical stimulation techniques associated with motor evoked potentials, SSEP, and VEP modalities were used to locate the eloquent area of interest and plan the tailored resection.

Standard microsurgical resection techniques were performed either for awake or GA cases. Intraoperative ultrasonography (EUB-405 plus ultrasound scanner, HITACHI) and intraoperative navigation technique (Brainlab, Germany) were used in all cases for locating lesions and previously defined EZ with evaluating the extent of resection.

Follow-up

All patients were planned to be assessed immediately postoperatively with clinical and neurological evaluation with CT/MR follow up to role out any immediate surgical complications. Discharge from hospital was usually in the 3rd postoperative day. The follow-up was scheduled to be within 2 weeks in the neurosurgical clinic, 1 month with the multidisciplinary clinic, then with the epileptologist at the 3rd month to assess the outcome and ASMs modifications and withdrawal, then 6 months and 1 year after surgery then yearly. Engel classification for epilepsy surgery outcome was the standard method to evaluate our patients in the last clinical visit with at least 1-year follow-up.

Statistical analysis

All the statistical and descriptive analysis were performed by SPSS version 19 (IBM, USA). The normality distribution was tested by Kolmogorov–Smirnov test of normality. Because of the non-normality distribution of some data, we used Kendall's tau_b correlation one-sided test. Categorical variables were tested using Chi-square test. Benferroni correction was performed to limit the Type II error during multiple hypothesis testing.

RESULTS

Patients' characteristics

We included 54 patients with focal lesioned epilepsy, five refused surgical management, and we lost two cases for postsurgical follow-up then finally the study included 47 (18 females and 29 males) while seven patients were either refusing surgery, not fit for surgery, or lost during the follow up [Figure 1]. The mean age was 20.4 ± 10.02 years with range between 5 and 45 years and all of them were right-handed except two patients. Majority of them were people with highly functioning intellectual level, 21 (44.7%) were active attending students, 5 (10.6%) pre-school, 8 (17%) hard workers, and three scientists. During the last quarter of the prospective study, we received a referral request to operate on patients from five nearby developing counties which did not have an epilepsy multidisciplinary facility. The mean age of onset of first epileptic attack was 10.05 ± 9.3. The mean duration of the disease since age of the onset (delay of surgery) was 10 ± 9.2 years with range between a year and 29 years. The average seizure frequency was 44.4 ± 65.5/month. Seizures occurred daily in 19 (40.4%) patients, weekly in 16 (34%) patients, and monthly in 12 (25.6%) patients. According to ILAE 2017 classification, 19 patients had focal non-motor seizures, while focal motor seizures were present in 17 patients and 11 patients had focal to bilateral tonic clonic seizures. Patients' demographics and characteristics are mentioned in Table 2.

EZ

According to the laterality of the epileptic lesion, there were 18 (38.3%) on the left side, 27 (57.4%) on the right side, and bilateral in two lesions (4.3%). The location of the lesion was temporal in 22 (46.8%), extra-temporal in 25 (53.2%); 19 (40.4%) lobar, and multilobar in 6 (12.8%). The nature of the epileptic tissue was highly variable in our cohort as mentioned in Table 2.

Surgical outcome

The epilepsy surgery outcome at the last follow-up (12–51 months) was Engel Class I (seizure free) in 35 (74.5%), Class II (almost seizure free) in 8 (17%), Class III (worthwhile improvement) in 3 (6.4%), and Class IV (no worthwhile improvement) in 1 patient (2.1%). Surgical outcome and complications are mentioned in Table 3.

Different variables were analyzed to be correlated with the clinical Engel class outcome. The presence of the epileptic lesion

Table 2: Demographic data, seizure and epileptogenic lesion characteristics of 47 focal DRE patients who underwent resective epilepsy surgery.

Demographic data	
Gender	18 (38.3%) Female, 29 (61.7%) Male
Age (years)	Mean 20.4±10.02
Age at onset (years)	Mean 10.05±9.3
Handedness	45 (95.7%) Right-handed, 2 (4.2%) Left-handed
Comorbidity	2 (4.3%) Perinatal insult 1 (2.1%) Delayed milestones 5 (10.6%) Head trauma 1 (2.1%) CNS infection 2 (4.3%) Hypertension 1 (2.1%) Diabetes mellitus 1 (2.1%) Asthma/COPD 1 (2.1%) Ischemic heart disease

(*Contd...*)

Table 2: (*Continued*).

Seizure characteristics	
Seizure frequency (per month)	Mean 44.4±65.5
Seizure type	19 (40.4%) Focal non-motor 17 (36.2%) Focal motor 11 (23.4%) Focal to bilateral tonic-clonic
ASMs	26 (55.3%) 3 or less ASMs 21 (44.7%) more than 3 ASMs
Delay of surgery (years)	Mean 10±9.2
Epileptogenic lesion characteristics	
Sidedness of lesion	18 (38.3%) left, 27 (57.4%) right, 2 (4.3%) bilateral
Lesion location	22 (46.8%) Temporal 25 (53.2%) Extra-temporal 19 (40.4%) Lobar 12 (25.5%) Frontal 1 (2.1%) Occipital 4 (8.5%) Parietal 2 (4.3%) Insular 6 (12.8%) Multi-lobar 2 (4.3%) Bi-frontal*** 1 (2.1%) Fronto-temporal 2 (4.3%) Fronto-parietal 1 (2.1%) Pareito-Occipital
Lesion/Pathology	14 (29.8%) (FCD) 7 (14.9%) (MTS) 5 (10.6%) Gliosis/ Encephalomalacia 11 (23.4%) Tumors 1 (2.1%) Ganglioglioma 6 (12.8%) Low grade astrocytoma 3 (6.4%) (DNET) 1 (2.1%) Oligodendroglioma 2 (4.2%) Vascular lesions 1 (2.1%) AVM 1 (2.1%) Cavernoma 8 (17%) Dual pathology 5 (10.6%) FCD+MTS 1 (2.1%) Ganglioglioma+MTS 1 (2.1%) FCD+DNET 1 (2.1%) Low grade astrocytoma+MTS

***Bi-frontal lobe epilepsy (2 cases) was treated by "ECOG guided resection of bi fontal encepahalomalacia." CNS: Central nervous system, COPD: Chronic obstructive pulmonary disease, ASMs: Antiseizure medications, DNET: Dysembryoblastic neuroepithelial tumor, MTS: Mesial temporal sclerosis, FCD: Focal cortical displasia, AVM: Arteriovenous malformation

in the non-dominant hemisphere and late-onset disease was the main factors giving us better Engel outcome in our study [Figure 5]. Dominant hemisphere was identified according to handedness. The presence of the lesion into the dominant hemisphere affected the Engel outcome as 86% of lesion resected form the non-dominant hemisphere became Engel Class I versus 57% of lesion in the dominant hemisphere, p = 0.015, coefficient +0.31, after converting into numerical data. Age at onset of the disease affected the Engel outcome as median and mean age was 7–10 years in Engel class I + II group versus 4 and 3.25 years in Engel III + IV group, p = 0.04, coefficient −0.2. Pathology diagnosis (p = 0.39), age at time of surgery (p = 0.2), seizure frequency (p = 0.4), ASMs load (p = 0.36), and anatomical location (p = 0.47) did not affect Engel outcome.

DISCUSSION

Approximately one-third of epileptic patients have seizures that are refractory to ASM. Left untreated, patients are at risk of developing several comorbidities, and potentially death.[6] The success of resective epilepsy surgery depends on the accurate localization and complete removal of the EZ. Patient selection for epilepsy surgery is a two-step strategy that first aims to identify potential surgical candidates who could benefit from a presurgical multidisciplinary assessment, and then to determine in each assessed individual whether the risk-benefit ratio for surgery is acceptable.[10,22]

Non-invasive video-EEG monitor and cranial MRI are highly conclusive regarding resective surgery throughout a larger proportion of patients (~ 60%), invasive exploration plays a pivotal role for the remainder [Figure 2].[1] If ictal onset is not clear and difficult to be surgically localized, or if bilateral location or eloquent area ictal onset is suspected, the patients move on to have invasive monitoring technique. Additional cost should be considered and kept in mind during decision-making to do surgery with such monitoring techniques. Before thinking about advanced technology that improves the surgical outcome, health-care providers should consider how to establish an epilepsy center with all necessary neurophysiological and surgical equipment. Such fully equipped institute could be initially impossible to be established in a developing country due to resource-limited circumstances and undirected fund. Several helpful and different equipments could be scattered in different hospitals and institutes for other different purposes. Furthermore, the human resources and personnels having specific knowledge helpful for epilepsy surgery team could be also working in different places. The cost, limited technical resources, and scattered units specialized in epilepsy were the main challenges during thinking about epilepsy center establishment. We overcome these limitations by creating a network and multidisciplinary team from different units all over the country through five institutes.

The technique of ECoG, the intraoperative recording of cortical potentials was pioneered by Penfield and Jasper in the early 1950s to map focal interictal spiking and to determine the extent of the resection.[15] In a developing country, the introduction of such technologies in health systems with resource constraints requires a local evaluation of the value for money. The invasive EEG monitoring regarding refractory patients with epilepsy throughout the country is currently not available in either private or public hospitals, largely due to its enormous cost associated with the implantation of electrodes and monitoring. We replaced this challenge by using intraoperative ECoG recordings during resective surgeries in our concordant cases, and we are in the process of establishing an invasive monitoring unit for the nonconcordant focal DRE cases, whom EZ could not be defined by our standard presurgical protocol.

Table 3: Surgical outcomes and postoperative complications.

Epilepsy surgery outcomes	
Seizure outcome (according to Engel classification)	35 (74.5%) Engel I=Seizure free • 15/22 (68%) Temporal • 20/25 (80%) Extra-temporal 8 (17%) Engel II=Rare seizures • 5/22 (22%) Temporal • 3/25 (12%) Extra-temporal 3 (6.4%) Engel III=Worthwhile improvement • 2/22 (9%) Temporal • 1/25 (4%) Extra-temporal 1 (2.1%) Engel IV=No improvement • 4% Extra-temporal
Post-operative complications	
General and Regional complications	Conservative: 6 (12.8%) total 2 (4.3%) Superficial wound infection 3 (6.4%) Hematoma 1 (2.1%) Cerebrospinal fluid leak Surgical: 1 (2.1%) Subdural hemorrhage
Neurological complications	7 (14.9%) Transient 3 (6.4%) Transient psychiatric disorder (*Temporal*) 1 (2.1%) Transient third nerve palsy (*Temporal*) 2 (4.3%) Transient motor deficit (Extra-temporal) 1 (2.1%) Transient speech deficit (*Temporal*) 1 (2.1%) Permanant 1 (2.1%) Permanent dysphasia (*Extra-temporal*)

The advantages of the ECoG are the flexible placement of electrodes, performed before and after each stage of resection, and direct electrical stimulation of the regions involved in functions to be spared by the resection can be delineated with a high degree of confidence. The limitations are the limited sampling time, spontaneous epileptiform activity consists exclusively of interictal spikes and sharp waves, and seizures are rarely recorded, it is impossible to distinguish primary epileptiform discharges from secondarily propagated discharges arising at a distant epileptogenic site, both the background activity and epileptiform discharges may be altered by the anesthetics and by the surgery itself.[15]

Furthermore, our statistical model succeeded to find some preoperative factors associated with favorable outcome. In current study, late age of onset of epilepsy was a favorable factor to achieve better Engel outcome class which was clearly showed in some other epilepsy studies.[12] We observed that during surgical resection of the epileptic lesion in the nondominant hemisphere, we could resect more pathological tissue safely. We have assumed that it is a favorable factor to have an epileptic lesion within the non-dominant hemisphere. Our statistical analysis proved that as the patients having lesion in the non-dominant hemisphere, they have more probability toward better Engel outcome. The effect of presence of epilepsy in dominant hemisphere was also clearly studied in temporal lobe epilepsy.[19] We defined the dominant hemisphere in our cohort according to handedness.

We reviewed the publications[2,4,8,13,16] of resective epilepsy surgery in the developing countries [Table 4]. All these publications were published recently since 2012 and the resource-limited settings did not obstacle the idea in other developing countries. Our study is unique in its situation since we did not have a single specialized epilepsy center to date. We overcame this problem by distributing such incomplete but complementary units through a wide geographical area with availability of portable devices with specialized team. Our follow-up period is longer in comparison to some others which is a critical factor in assessment of epilepsy surgery study. Studies with shorter follow-up showed higher rate of being seizure

Table 4: Review of the developing countries epilepsy surgery reports.

Author	Year	Country	Period	No. Patients	Age/years	Follow up/months	Seizure free (%)	Monitoring
Habibabadi *et al.*[8]	2021	Iran	2014–2019	148	30.45±9.23	26.7±14.9	86	ECoG
Arifin *et al.*[4]	2021	Indonesia	1999–2017	589	23.1	60	80	ECoG
Jukkarwala *et al.*[13]	2019	India	2012–2015	125	24.3±11.6	24±14	92	ECoG
Mikati *et al.*[16]	2012	Lebanon	1996–2006	93	23	58	70	ECoG
Alsemari *et al.*[2]	2013	Saudi	1998–2012	502	25	60	79	ECoG
Current	2022	Our country	2018–2021	47	20±10	12–51	74	ECoG

ECoG: Electrocorticography

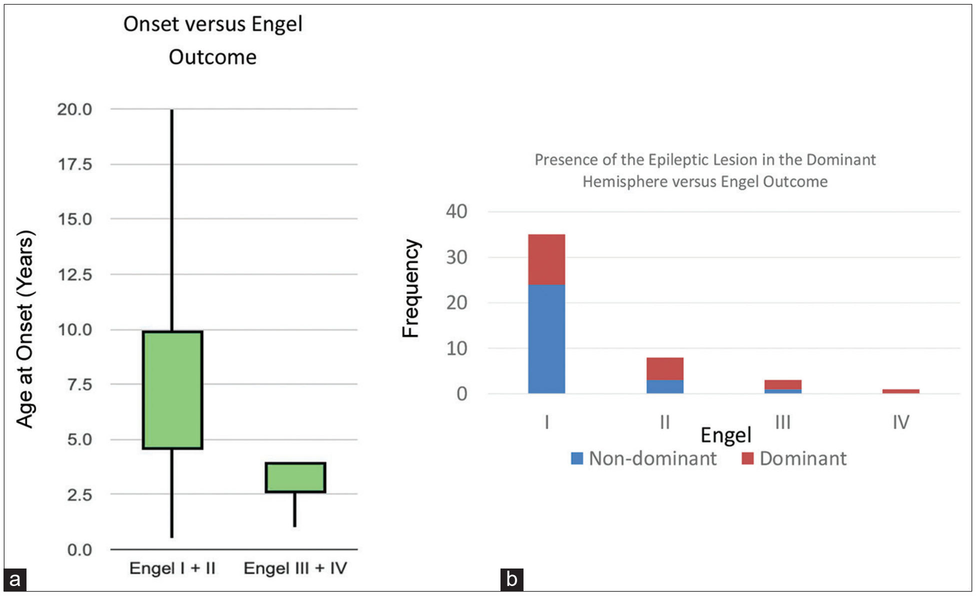

Figure 5: Statistical graphs; The left boxplot shows that late onset of the disease (a) and the right bar-chart shows presence of the epileptic lesion in the nondominant hemisphere (b) are the main predictors for favorable Engel outcome.

free postoperatively while studies with longer follow-up period have slightly less rate of being seizure free because recurrence of residual seizures in some cases. ECoG technique was always used in all studies showing high rate of efficacy and safety. More invasive techniques such as SEEG were required in some patients because of failure of epileptic zone localization by our protocol and ECoG survey. Our next step is to apply the SEEG technique in the more complicated lesion before decision-making and resective epilepsy surgery.

CONCLUSION

Resective surgery and satisfactory outcome in focal epilepsy could be achieved using presurgical multidisciplinary selection, especially with intraoperative neurophysiological and electrocorticography techniques. It is a major treatment option, even with low resources settings and should be encouraged in developing countries.

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Ethical consideration

The authors have nothing to declare regarding any kind of conflicts of interest or financial issue.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

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