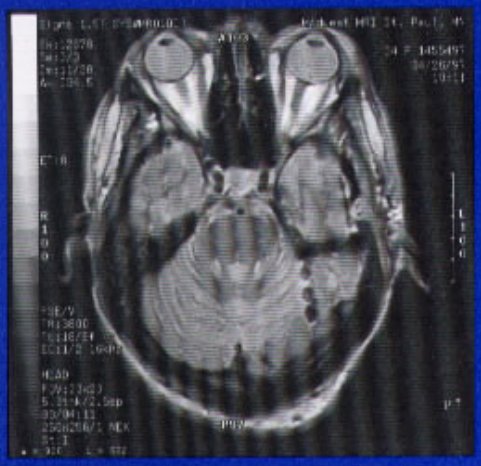
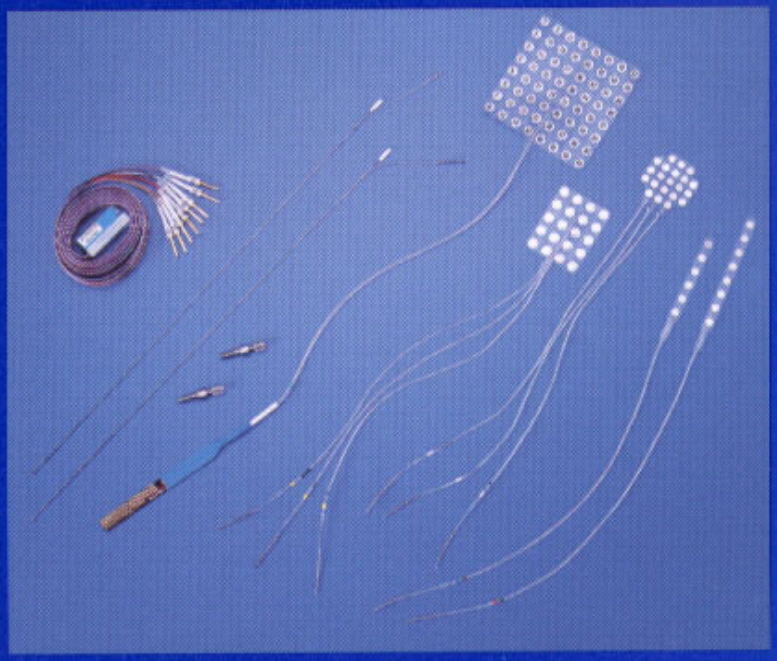
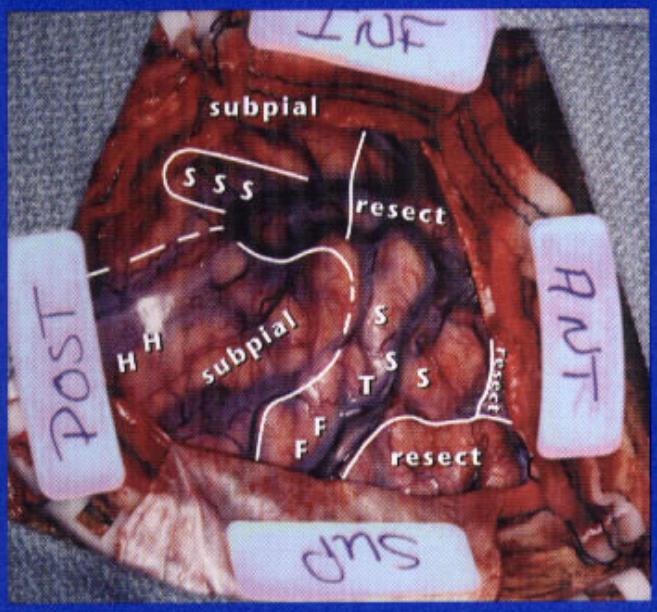
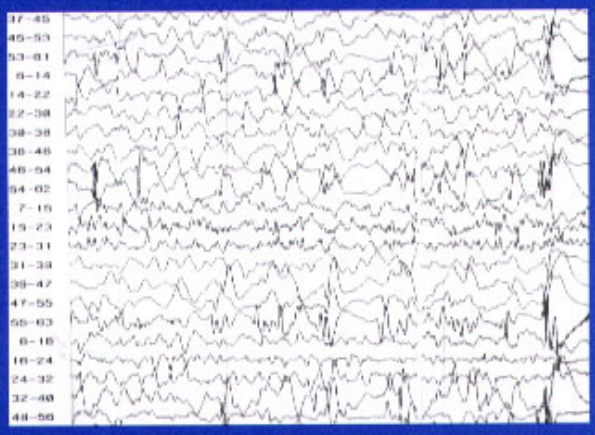
Procedure Technique Series

Presurgical Assessment and Surgical Treatment for Epilepsy









Monograph Editors

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1. Introduction

The advances in the surgical treatment of epilepsy have been dramatic in the last ten years with the advent of long-term monitoring for epilepsy[1] as well as advances in surgical technique. Technical resources are now available that allow surgical treatment for patients who even as late as the mid-1980's would not have been considered candidates for surgical intervention even at the most sophisticated epilepsy centers. Traditionally, surgical treatment has been the last court of appeal for patients who have exhausted all medical options. In the recommended guidelines from the National Association of Epilepsy Centers it was agreed by the initial group of ten major epilepsy centers in the country that if a patient did not come under control with two appropriately selected medicines alone and in combination within one year, a referral to an epilepsy center should be considered at that point, with surgery a definite option[2]. This is a departure from the previous perspective that patients had to exhaust all medical therapies in multiple combinations over several years. Clearly, the surgical option is more readily available as the techniques and the approaches, as further elaborated in the volume, have been refined.

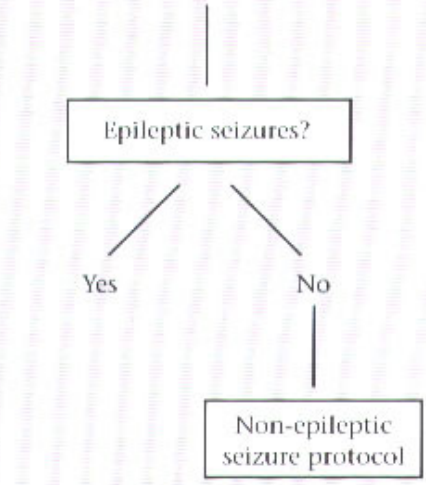
2. Background

Any surgical evaluation in the era of long-term monitoring requires the recording of the electroencephalogram with concomitant videotaping of the patient for examples of spontaneously occurring ictal events[3]. Interictal epileptiform activity is a component in the overall decision about the surgical candidacy. However, the epilepsy surgery centers are in general agreement that an interictal abnormality is insufficient in and of itself for a presurgical evaluation[2].

Certainly a very important reason for ictal recording is the existence in a significant proportion of patients at our referral epilepsy center (20% of admissions)[3] of nonepileptic (predominately psychogenic) seizures accounting for their intractable paroxysmal episodes. From previous studies[4] more than 50% of these patient also had epileptiform interictal abnormalities. Therefore, one must record the characteristic ictal events identified from the preadmission history as accounting for the patient's medically intractable events in order to identify whether the nonepileptic or the epileptic events are the reason for the medical refractoriness. A serious therapeutic error could result by relying on interictal data in these patients, no matter how convincing; surgery for a psychological disorder is clearly inappropriate.

Spontaneous seizures produced by the patient are sometimes too infrequent to allow recording of events in a reasonable time frame in the long-term inpatient monitoring environment. This ictal yield can be significantly enhanced by reducing the dosage or number of anticonvulsants the patient is taking[15]. This must be done with considerable caution and done only in an inpatient environment where one can immediately treat potential resultant status epilepticus. In our previous experience with the use of judicious reduction of medications, 85 out of 100 patients had seizures recorded on EEG within two weeks, and 100% of presurgical candidates had seizures recorded within one month[3].

FIGURE 1.



Initial decision point for entry into presurgical evaluation.

The average length of stay for surgical evaluation at the Minnesota Epilepsy Group of United and Children's Hospital in St. Paul Minnesota is now about 8 days to record a sufficient number of seizures to be confident as to the ictal location. Certainly difficulties with third party reimbursement for these somewhat long lengths of stay can be problematic, but generally can be appropriately handled with pre-admission approval and a prospective case management approach. The pharmacological induction of seizure with stimulant drugs is not a technique used at U.S. epilepsy centers because of the potential of unreliability of the localization of the induced events and the risk of inducing a non-localized tonic-clonic event.[16]

This monograph provides a decision algorithm for the evaluation of patients for epilepsy surgery that is currently followed by the Minnesota Epilepsy Group of United and Children's Hospital in St. Paul, Minnesota. The approach that is outlined is only one approach that continues to evolve as we learn more about this spectrum of disorders known as epilepsy.

3. Facility and Clinical Team Requirements

3.1 Clinical Team

As outlined in the National Association of Epilepsy Centers Recommended Guidelines, an appropriate team is required in order to perform these sophisticated presurgical and surgical assessments, as well as subsequent surgical interventions. As outlined in the guidelines, a board certified clinical neurophysiologist, neurologist, neurosurgeon, neuropsychologist, EEG technologist, unit nurses specializing in epilepsy management, nurse clinicians specializing in epilepsy management, social workers, psychologists knowledgeable in epilepsy issues and experienced with at least 25 epilepsy surgeries per year are required in order for this technology to be properly applied.

3.2 Facility

The facility should include an inpatient recording suite with access to full resuscitative capabilities; a dedicated unit with a nursing staff whose sole function is to care for individuals with epilepsy; a unit designed and furnished to minimize risk of injury to patients subject to seizures and falls; 24-hour medical coverage on site; and availability of the full-spectrum of imaging services.

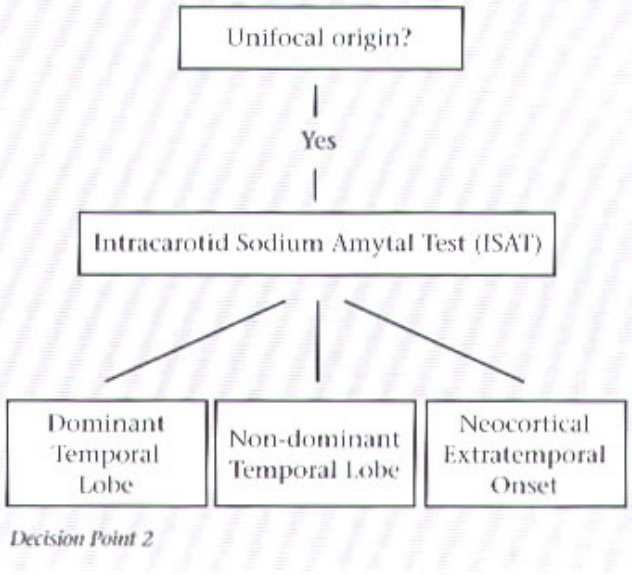
4. Decision Algorithm for Patient Evaluation

4.1 Decision Point One

To begin, ask the first vital question *(Figure 1)* : Are these events epileptic seizures? The number of recorded events required to determine whether a seizure type is epileptic can be quite variable. Generally this number is one to two of each characteristic event of concern that the patient describes upon admission. However, in some cases, especially for frontal lobe seizures, recording multiple events is generally quite easy as these patients often have ten or more events of this type per day[17]. An electrodecremental or epileptiform fast pattern can be hard to recognize under prominent muscle artifact bifrontally. The thread of stereotypy for these events, each event having a clearly defined commonality, often allows the distinction between psychogenic and nonepileptic events. Assistance can be further gained from post-ictal prolactin levels[18], staff interaction during the events, and a comprehensive neuropsychological, psychological, and social evaluation. Video recorded events should be shown to family or institutional personnel caring for the patient to confirm that the documented episodes are those that precipitated the evaluation for medically refractory seizures. Many patient and families provide home video recorded events that may be a source for comparison with the events recorded with concomitant EEG. Similarity, nursing staff and EEG technologists from the long-term monitoring facility can review the outside videotapes beforehand to more precisely document behavioral changes and interact more effectively with the patient when events are recorded.

Psychogenic events can be particularly problematic if they resemble partial epilepsy[19]. When psychogenic events resemble tonic-clonic seizures, video EEG and clinical observation can usually answer the question of organicity easily. For partial seizures, however, multiple events will need to be recorded to identify any thread of sterotypy or the considerable variation that usually occurs with psychogenic events as a point of distinction. A good rule of thumb is that no patient should advance to invasive intensive monitoring without having at least one surface/sphenoidal electrode recorded true epileptiform ictal event, even if only secondarily generalized. Similarly, no patient should advance to invasive monitoring with active psychogenic events. These should be dealt with through appropriate counseling. The reader is referred to *Nonepileptic Seizures*[18] edited by Rowan and Gates for more definite discussion of this particularly problematic disorder.

FIGURE 2.



Decision Point 2

4.2 Decision Point Two

Having excluded nonepileptic events (psychogenic seizures) from the diagnostic option, the primary question in the presurgical evaluation is: Are the epileptic seizures of unifocal origin as recorded using both surface and/or sphenoidal electrodes with X number of events obtained? "X" for this purpose can be difficult, but at least six events proves to be functionally quite reliable *(Figure 2)*. A recent statistical review[11] corroborates that six to eight is optimal and practical. It is vital to record a sufficient number to avoid a false unifocal localization in cases of multifocal origin or to decide if invasive techniques will eventually be required. Only the occasional patient will experience tonic-clonic status epilepticus under the paradigm, and this complication has always been readily treatable without any long-term morbidity or mortality in more than 15 years of treatment in more than 2000 medically refractory epilepsy patients.

The interictal localization should not be ignored and should be compared with the ictal localization. An insistently active interictal focus that does not localize to the ictal site of onset does dictate a careful review. It does raise the question: Are the seizures being recorded just one of several seizure types experienced by the patient with frequency of the different episodes possibly a function of medication levels? False localization by medication reduction is generally not problematic but must be considered. Once the necessary number of seizures are recorded by 16 or more channels[2] using the surface/sphenoidal electrode technique there are three potential answers to the unifocal origin question.

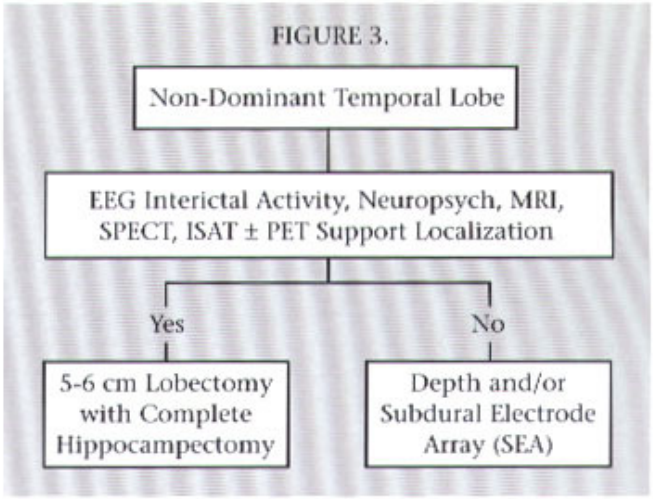
a. The unifocal origin is clearly established.
b. The unifocal origin is probable but not clearly established or the superimposition of eloquent functional cortex is a confounding variable.
c. A multifocal origin or primary generalized pattern is documented on the ictal recording.

4.2a. Unifocal Origin is Clearly Established by Surface Recording

The decision for resection based upon surface/sphenoidal EEG ictal and interictal localization is gaining popularity when utilized as part of a multifactorial localization approach. The basic concept underlying this approach is to use multiple sources of information to see if they converge on the same point within the brain.

As will be further elaborated in the section on temporal lobectomy, neurodiagnostic imagining, including magnetic resonance imaging (MRI), single photon emission computerized Tomography (SPECT) both ictally and interictally, and positron emission Tomography (PET) scans need to be reviewed carefully for localizing evidence that might be subtle and which correlate with localization by neuropsychological testing and interictal and ictal

FIGURE 3.



EEG. The intracarotid amobarbital test can often provide clarification regarding abnormalities in memory that correlate with the localization and clarify information about speech lateralization that could influence the extent of resection in the temporal lobe[12].

Previous studies have demonstrated a false localization rate by surface/sphenoidal recording from 10% to as high as 90%[13,14]. The Montreal Group probable defines the most likely scenario with a clear electrographic localization of seizure onset by extracranial electrodes in 22% to 40% of patients with the lower yield in those with frontal lobe origin, the higher in temporal lobe onset[7].

A review of 160 patients with temporal lobectomy followed for at least two years postoperatively revealed that with surface/sphenoidal selection, 76% of patients were seizure-free with and additional 20% having a greater than 90% reduction[14]. Such data would strongly suggest that surface/sphenoidal localization could reasonably localize onset with quite acceptable surgical results.

Additional characterization and localization of the epileptogenic focus can be done with sodium Pentothal injection (Lombroso - Erba Test)[15] or diazepam or pentobarbital suppression[16]. These are useful in cases likely to be of frontal origin with rapid secondary generalization. However, they rarely preclude subsequent invasive monitoring in our experience.

As will be further discussed in the section on temporal lobectomy, surgical intervention can generally proceed with surface/sphenoidal selection when all the information converges precisely to an area of the brain that is readily approachable and likely to be resected without causing significant deficit, for example, the non dominate temporal lobe *(Figure 3)*. The localization of the speech center in the dominate temporal lobe, however, has been observed to be as far anterior in approximately 5% of patients as 3 cm from the temporal tip[17,18]. Consequently, caution is often advised which paradoxically results in invasive recording for these patients in many cases. Simi-

FIGURE 4A.

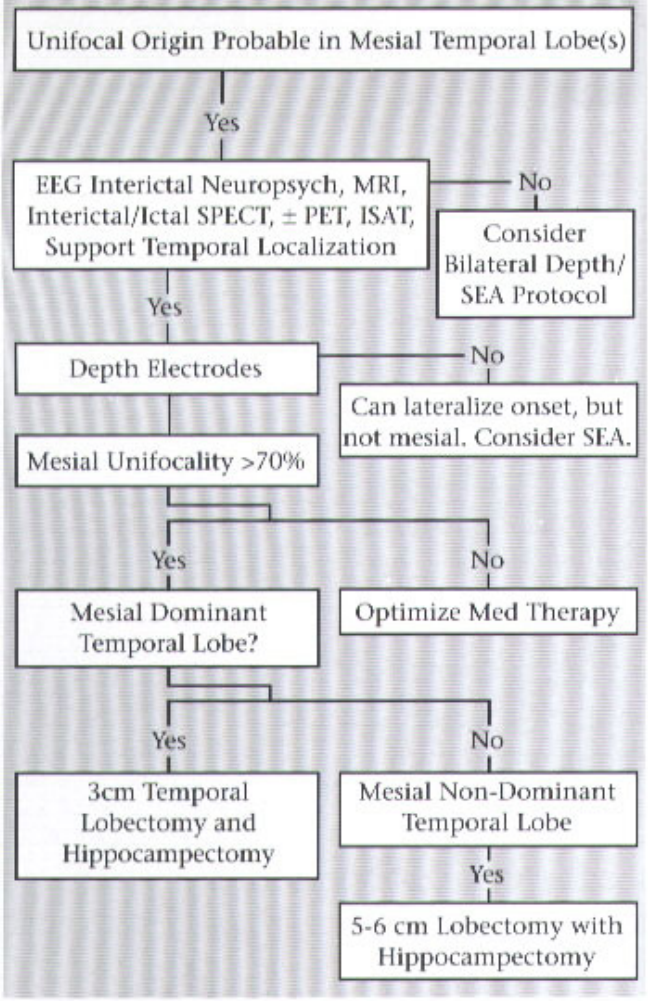
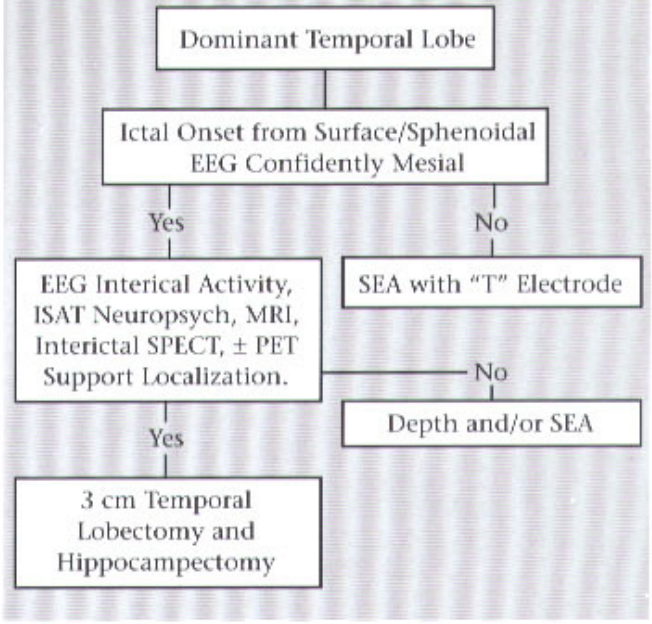


FIGURE 5.



larly, a body of literature is beginning to develop suggesting that resection of mesial structures in patients with preserved verbal memory function localized to the dominant hemisphere may result in significant memory compromise post surgery. How to approach these patients is problematic and is certainly undergoing assessment [19].

In patients with striking inconsistencies in the localization from the neurological examination, neuropsychological studies, structural assessment, or activation studies, the possibility of a false localization from surface/sphenoidal ictal in interictal recording should be seriously considered. At that point, depth electrode and subdural electrode array recording for a more precise epileptogenic localization is probably more appropriate.

Our depth electrode approach is summarized in Figures 4A and 4B. It is specifically designed to lateralize epileptogenesis in mesial temporal structures [20] when other evidence including interictal, neuropsychological testing, or MRI support lateralized onset, but supporting data is not congruent. The depth electrodes placed bifrontally are there to exclude a potential frontal onset but are not specifically designed to select a frontal resective site. Consequently our depth electrode technique without utilizing supplemental strip electrodes is specifically designed to lateralize mesial onset and to exclude a mesial frontal onset in appropriately selected patients [20].

FIGURE 4B.
Gates Dunn Depth Electrodes

Depth electrodes are placed using stereotaxis. The patient undergoes imaging using either the CRW frame or a frameless system to plan trajectories. The frontal electrodes are passed from an entry point 2 cm anterior to the coronal suture and 2 cm from midline through a small twist drill hole. The final position of the electrode is juxtaposed to the gyrus rectus approximately 1.5 cm anterior to the anterior clinoid. The temporal depth electrodes are passed through an entry point 8 cm superior to the inion and 4 cm off midline. The electrodes parallel the hippocampus so as to provide good recording both in the anterior aspect of the hippocampus as well as along the trajectory. These electrodes are flexible enough that a significant vascular structure will deflect the electrodes. This has been shown in our experience in over 500 depth electrode passages with only two small hematomas that did not require surgical treatment. The physicians and surgeons affiliated with the Minnesota Epilepsy Group have developed the technique of subdural electrode array (SEA) over 17 years. As with all technology, it has evolved significantly and identified new indications and applications as our comfort level with technique has improved. Specific applications will be discussed.

4.2b. The Unifocal Origin is Probable but Not Clearly Established or the Superimposition of the Eloquent Functional Cortex is a Confounding Variable.

Dominant Temporal Lobe Onset

A rationale for temporal lobectomy is provided in Figure 5. If surface/sphenoidal recordings cannot confidently identify the area of epileptogenesis within the Intracarotid Sodium Amytal Test (ISAT) confirmed dominant mesial temporal lobe (i.e., lateral cortical structures are likely to be involved), it is necessary to use a subdural array technique to definitively identify the area of epileptogenesis and to identify Wernicke's area within the temporal lobe. As the diagram demonstrates *(Figure 6A)* considerable variability can exist as to the location of Wernicke's area within the temporal lobe, but with appropriate speech mapping an aggressive dominant temporal lobectomy can still be effected *(Figure 6B)*.

Technique

Each patient is prepared with a standard dominant craniotomy utilizing, in most cases, a question mark incision extending from the frontal region through parietal and inferior to the temporal zygoma. The exposure allows visualization of the superior and middle temporal gyrus to within 3 cm from the temporal tip. The bone flap follows the skin incision and the dura is excised with a 1 cm margin. A T-electrode is passed into position under the dominant temporal lobe, although not easy to place, the T provides coverage of the hippocampus along its axis. The additional three contacts [8, 9, 10] assess activity from the para hippocampogyrus and inferior temporal gyrus. A 64-contact subdural array is placed 3.5 cm from the temporal tip, extending posteriorly and additional 8 cm *(Figure 7a, b, c)*. This usually provides coverage to confidently identify the speech area or to confirm it is beyond the area of the epileptogenesis within the temporal lobe *(Figure 7D)*. When coverage of the frontal structures is also needed a subfrontal and prefrontal 4 or 6 contact strip is generally utilized in this situation *(Figure 8A)*.

Stimulation studies are then carried out utilizing the standard Cleveland Clinic parameters [21] to obtain the functional anatomy of this area *(Figure 8A)*. The Ojemann Cortical Stimulator allows this mapping to be done safely *(Figure 8B)*. Detailed neuropsychological assistance is utilized to define the speech areas after an initial pass identifies speaking difficulties or mutism at appropriate electrodes. All studies are done below after-discharge threshold, if at all possible technically, which requires the patient to be maintained on significant antiepileptic medications for this period of study. Two stimulation passes are employed with at least the first and second pass done by two independent clinical neurophysiologists with the third corroborating the independent findings into a summary map *(Figure 8A)*.

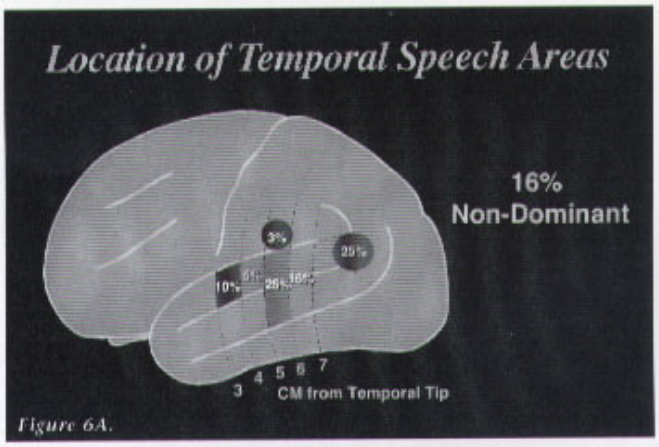


Figure 6A.

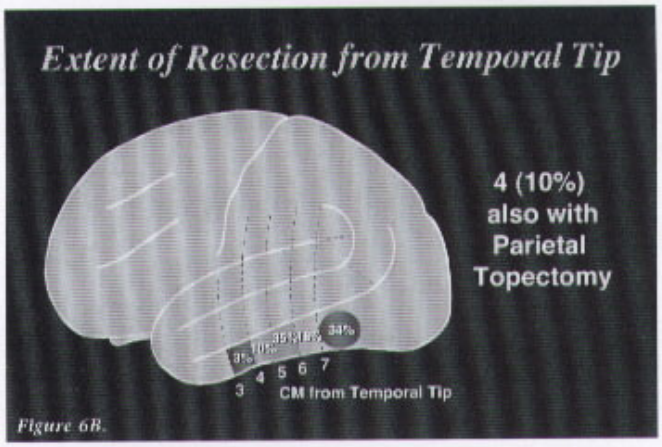


Figure 6B.

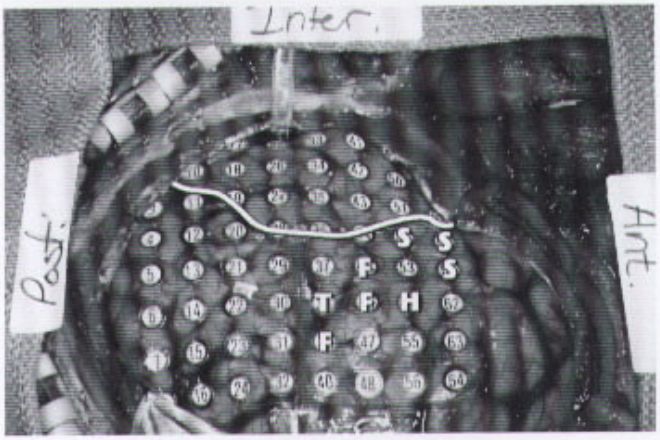


FIGURE 7A.

Dominant (left) hemisphere 8x8 grid exiting superiorly with subtemporal "T" electrode exiting inferiorly. Expressive speech was identified at electrodes 52, 60, 61. Receptive speech was confidently beyond the posterior margin of the electrode array. (S=Speech, T=Tongue, F=Face, H=Hand)

FIGURE 7B.
8x8 grid with connector.

FIGURE 7C.
"T" electrode.

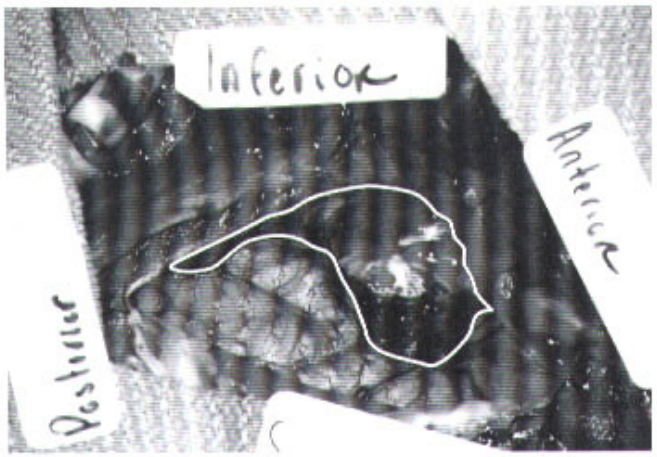


FIGURE 7D.

Aggressive resection allowed by this technique, 8.5 cm from temporal tip.

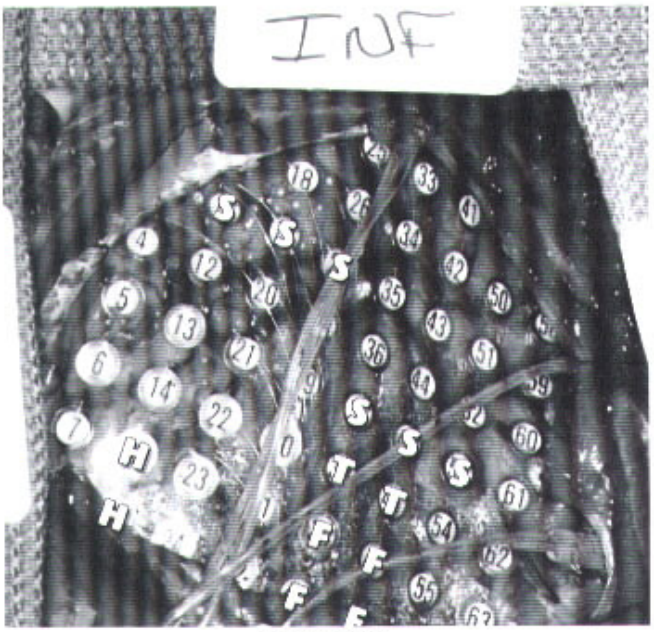


FIGURE 8A.

Coverage of frontal structures with strip and grid electrodes. An 8x8 grid covers dominant frontal and temporal lobes. (S=Speech, T=Tongue, F=Face, H=Hand)

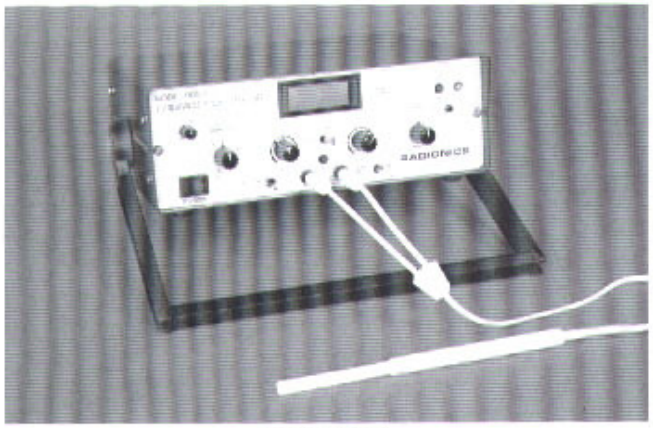


FIGURE 8B.

Ojemann Cortical Stimulator.

An epileptogenic map is then generated, identifying the area of most active interictal epileptogenesis, generally for the seven days of recording. An ictal map is also performed, having recorded the patient's characteristic clinical ictal events *(Figure 9 & 10)*. The three maps are then superimposed *(Figure 11)* and are cross-correlated with the functional MRI and PET scan, if available, in order to create the coordinates for resection. This clinical neurophysiological data is then cross-referenced to the vascular anatomical data to arrive at the definitive resection site *(Figure 11)*.

If epileptogenesis coexists with eloquent cortex, specifically motor and speech areas, a decision is made to extend the margins of the resection with a multiple subpial transection [22, 23]. We have found that multiple subpial transection (MST) in the area of Broca's and the motor area is well-tolerated, but some patients do not tolerate aggressive multiple subpial transection of Wernicke's area [22,23] *(Figure 11)*. With this technique, we have avoided damaging speech areas, including dominant temporal procedures and have been able to effect remarkable surgical outcomes in terms of the percentage seizure-free [22,23] avoiding functional deficit.

Neocortical Extratemporal Onset

Methods for diagnosis and treatment of neocortical extratemporal onset epilepsy are provided in Figure 12. When epileptogenesis appears to exist in cortical structures outside the temporal lobe, (i.e., frontal, parietal, or occipital) the technique of subdural electrode array in combination with depth electrodes and multiple subpial transection, offers a tremendous variety of potential approaches. For laterizerable/localizable areas of likely epileptogenesis, standard grid/strip placements [9] are used. *(Figure 8A)*

However, when unifocal origin is suspected in the frontal lobe, but definitive lateralization does not transpire from surface/sphenoidal recording as corroborated with the interictal EEG, neuropsychology, MRI and other functional imaging (PET, SPECT, fMRI), then the technique that we have somewhat whimsically termed the "Double Daisy" has utility *(Figure 13A and 13B)*.

Technique

The frontal montage involves initial imaging with either the CRW head frame or the frameless system to obtain the coordinates for calculation of trajectories. The trajectories are then calculated for both frontal and temporal depth electrodes as described previously. The patient then has the temporal depth electrodes passed into position followed by induction of general anesthesia and positioning for the frontal montage portion of the procedure. Midline exposure is accomplished 1 cm anterior to the coronal suture and extending approximately 5 cm to the

right and left of midline. Burr holes are placed over the sagittal sinus and as needed laterally to allow for a craniotomy of 8 X 4 cm. The dura is opened bilaterally with the flap hinge on the sagittal sinus. On the non-dominant hemisphere, there are four sentinel strips placed in a radiating pattern in the position of right anterior, lateral, posterior and interhemispheric bifaced 8-electrode sentinel *(Figures 13A, 13B, 14)*. These electrodes are passed in a blind fashion, however, these electrodes are designed in such a fashion that they become an extension of the finger. The electrodes slide into position with ease, but if resistance is met, then the electrode trajectory is passed with a small difference. On the dominant hemisphere as determined by preoperative ISAT, the radiating pattern is placed with the left anterior electrode followed by placement of the "pie" electrode as designed and demonstrated

FIGURE 9

Multifocal interictal discharges active subtemporally, sub and lateral frontally, and on the 64-contact grid.

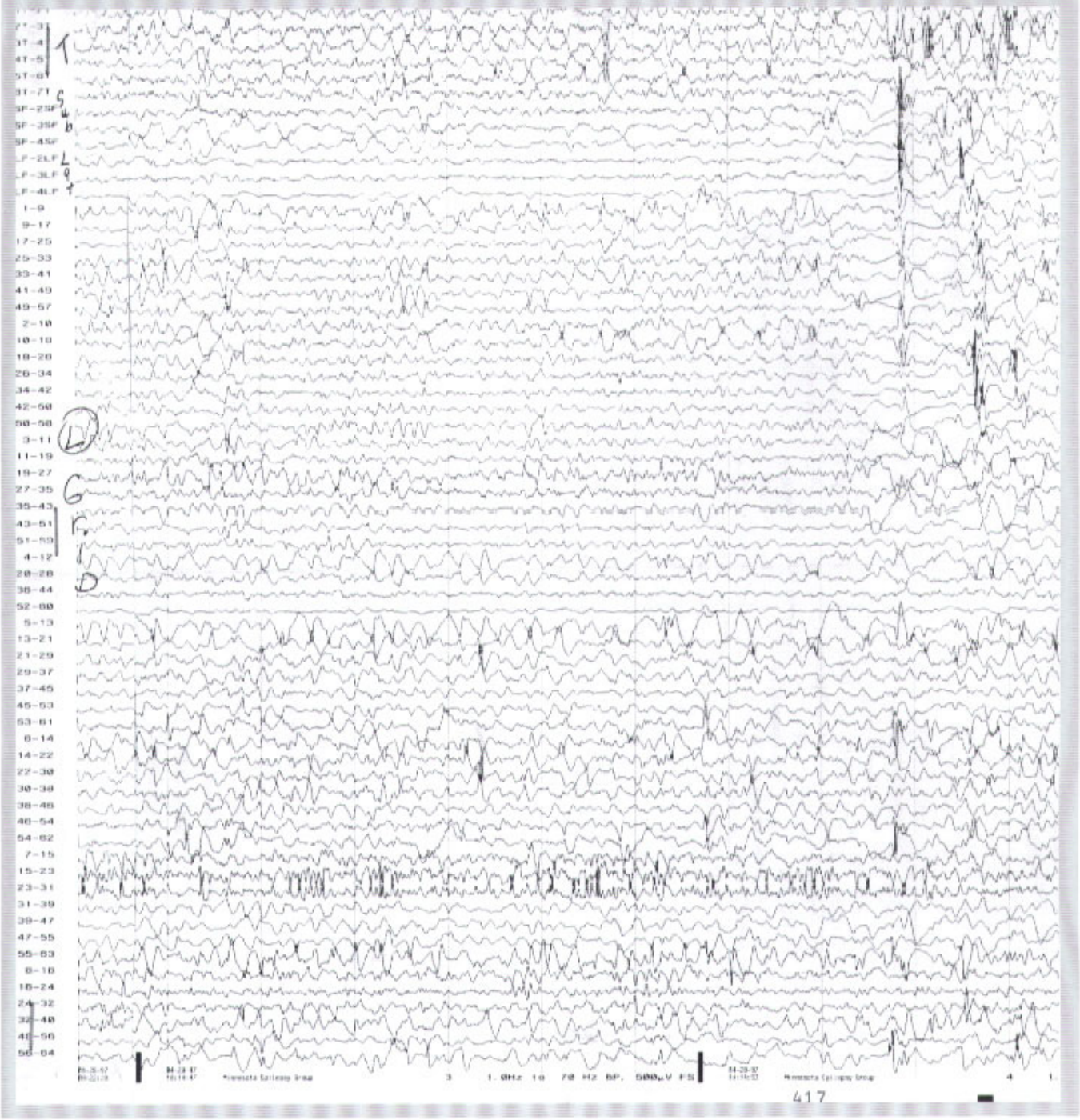
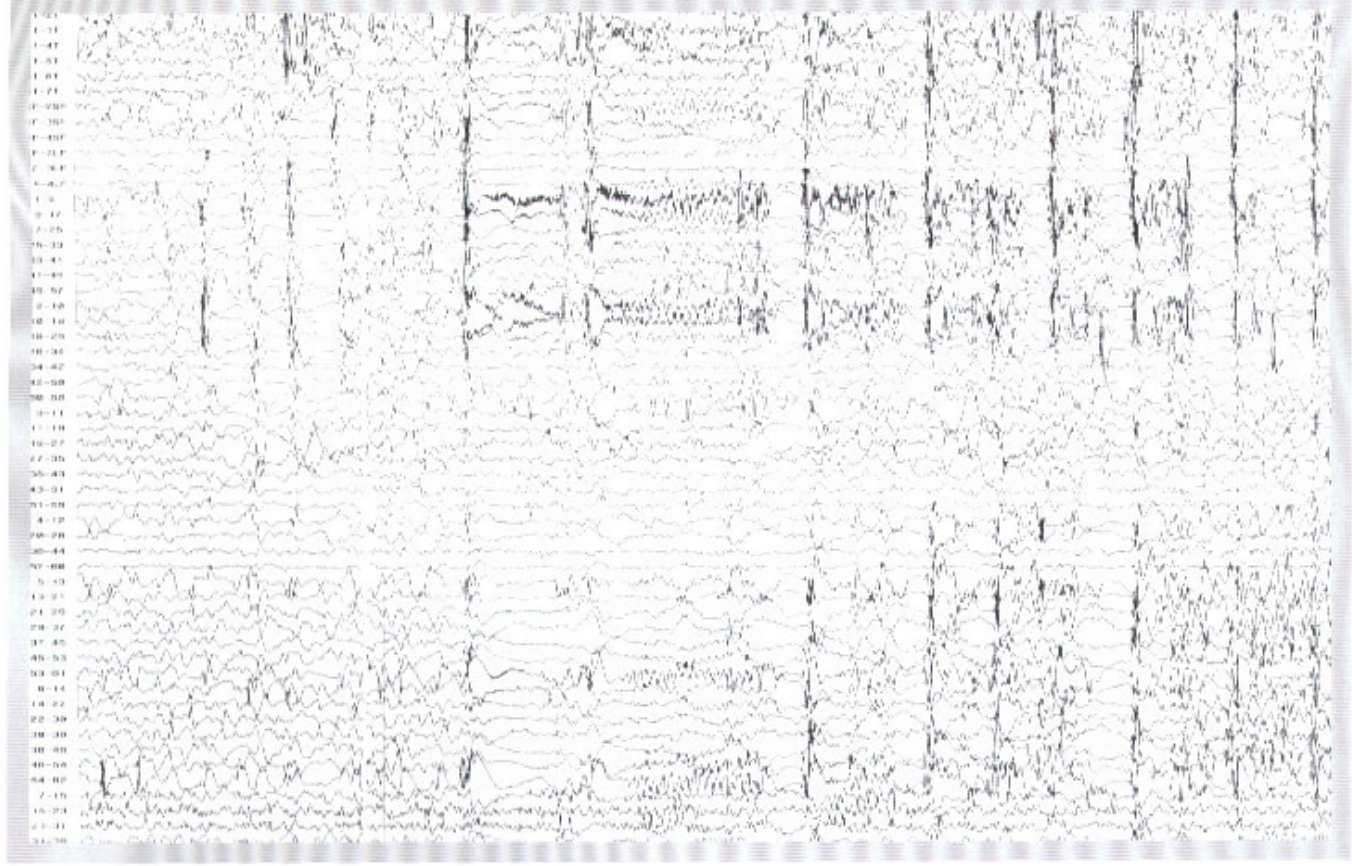


FIGURE 10.

Ictal onset of a typical complex partial seizure from the grid (electrodes 9, 17, 10, 18) with rapid spread.



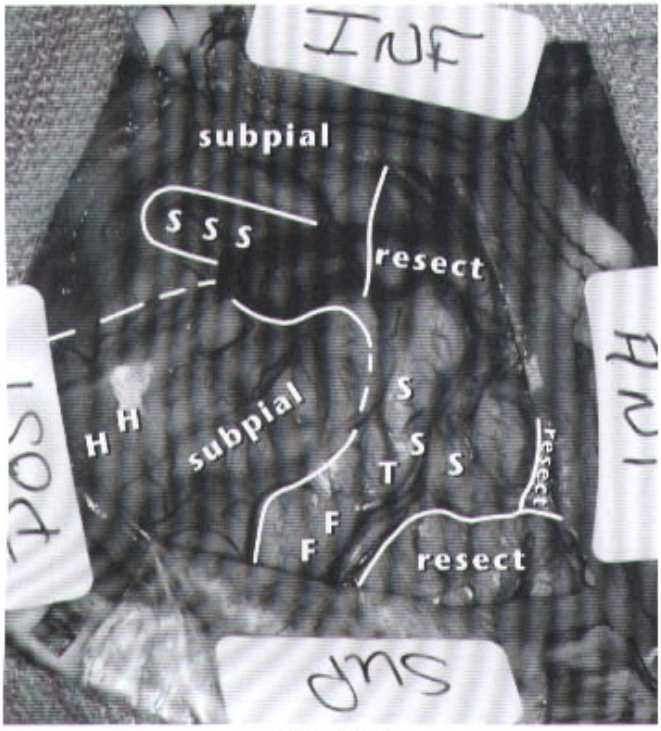
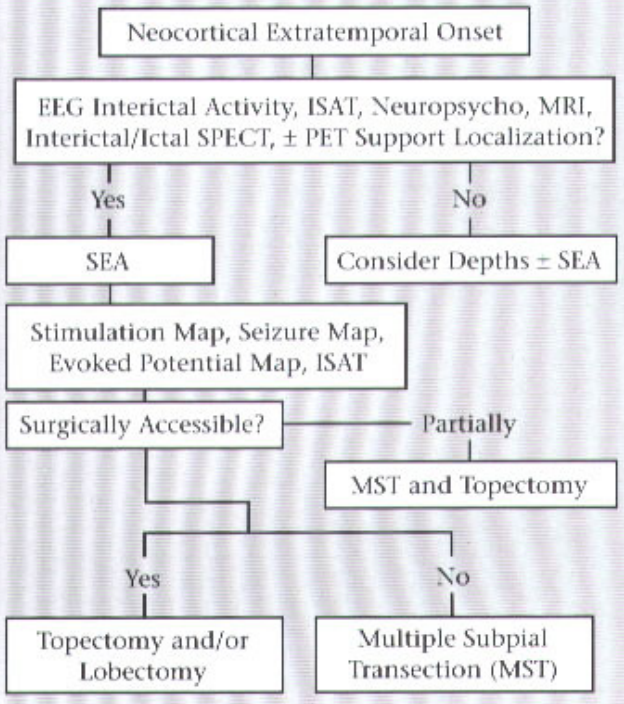


FIGURE 11

Patient summary map. (S=Speech, T=Tongue, F=Face, H=Hand)

FIGURE 12

Diagnosis and treatment of neocortical extratemporal onset epilepsy.



in this monograph *(Figure 15, 16)*. The pie electrode is used to map the language center. It provides higher resolution coverage of the language center than fanned multiple strips. In addition, the special shape allows it to slide beneath the skull and dura more easily than a rectangular grid by using a side-to-side motion. This pie grid does fit through a small opening and in no situations have we experienced hematoma formation or other complications from placement of the pie in over 90 patients. As the final portion of this procedure, the four contact depth electrodes are passed through the previously calculated trajectory into a standard frontal position as described previously. Dura closure is accomplished by the use of dura reconstruction or directly. The electrode leads are tunneled through a stab incision at a distance from the coronal incision.

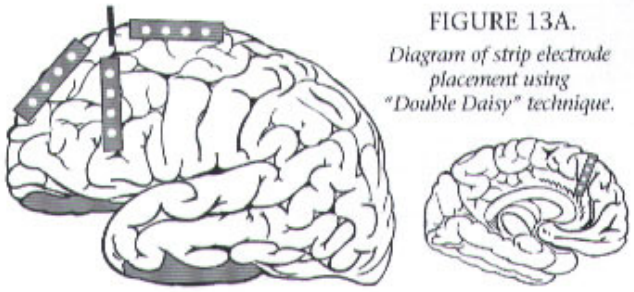


FIGURE 13A.

Diagram of strip electrode placement using "Double Daisy" technique.

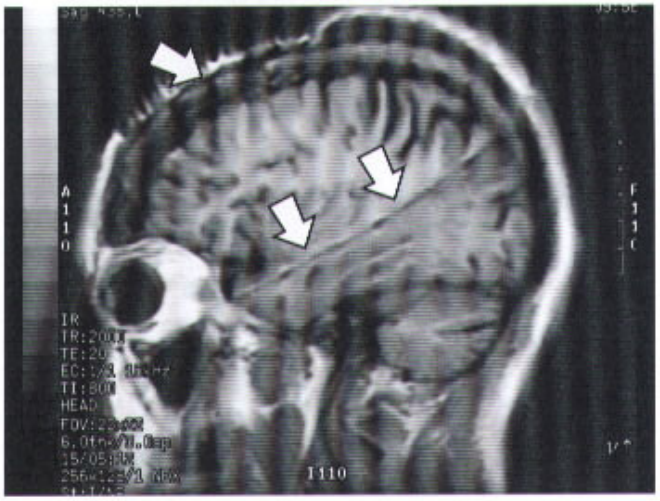


FIGURE 13B.

MRI of depth and strip electrodes. (See arrows for location.)

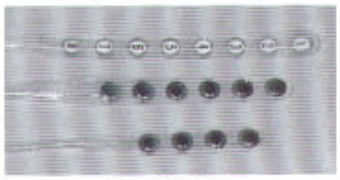


FIGURE 14.

Strip electrodes used in "Double Daisy" technique.

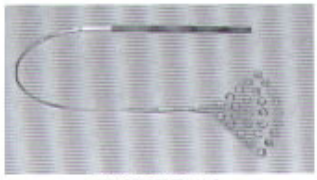


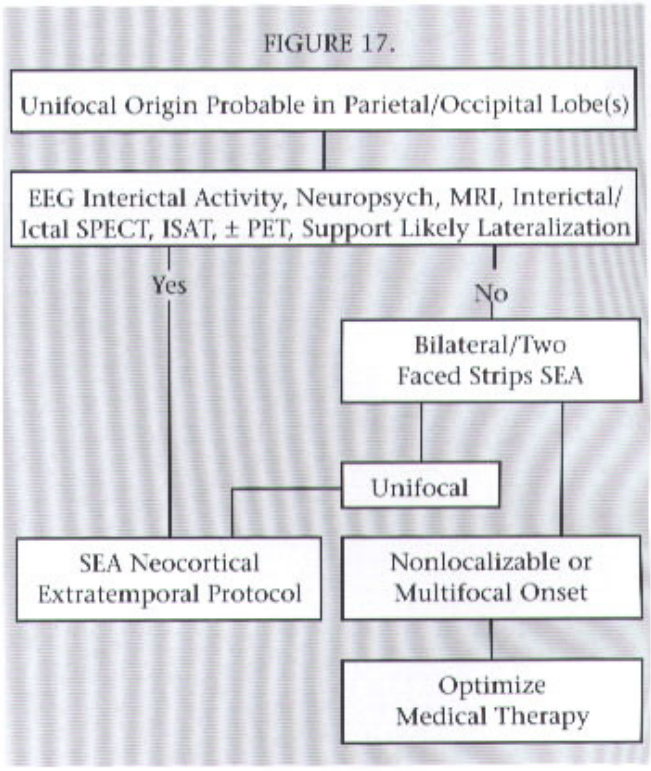
FIGURE 16.

Pie electrode.

When the parietal or occipital lobes are involved in epileptogenesis *(Figure 17)*, very customized subdural electrode arrays have to be utilized. Depth electrodes are generally not used in the occipital area because of the potential risk to vision, but a customized bifaced subdural strip can be used in the interhemispheric space, especially in the calcarine *(Figure 18, 19)*. This can be a remarkably deep space and if concern exists for potential deep-seated calcarine epileptogenesis, a 6-contact bifaced electrode may be needed. Otherwise, custom arrays can be placed over the occipital poles, though generally a 64-contact electrode array cannot be placed over the pole penetrating into calcarine cortex because of the sharp angulation of the occipital pole. However, subdural arrays of up to 64-electrodes have been placed within one centimeter of

FIGURE 15.

"Double Daisy" with pie electrode. (Arrow shows pie.)



the occipital pole with technically satisfactory results[25].

Exposure of the occipital polar involves a large U-shaped incision from just below the inion 2 cm opposite midline of the pole to be exposed. The lateral margin covers the posterior temporal region where it meets the occipital lobe. A craniotomy extends from the midline inferiorly at the torcula to just past the parietal occipital junction superiorly and laterally to the tentorium. The bone flap exposes the sagittal sinus from torcula inferiorly to the parietal occipital junction superiorly and laterally to the tentorium. Care is taken in opening the dura to preserve draining veins. The grid may be customized or trimmed to fit. Frequently, suboccipital 4 or 6 contact electrodes are passed as well as an interhemispheric 6-contact bifaced electrode so as to record from calcarine cortex.

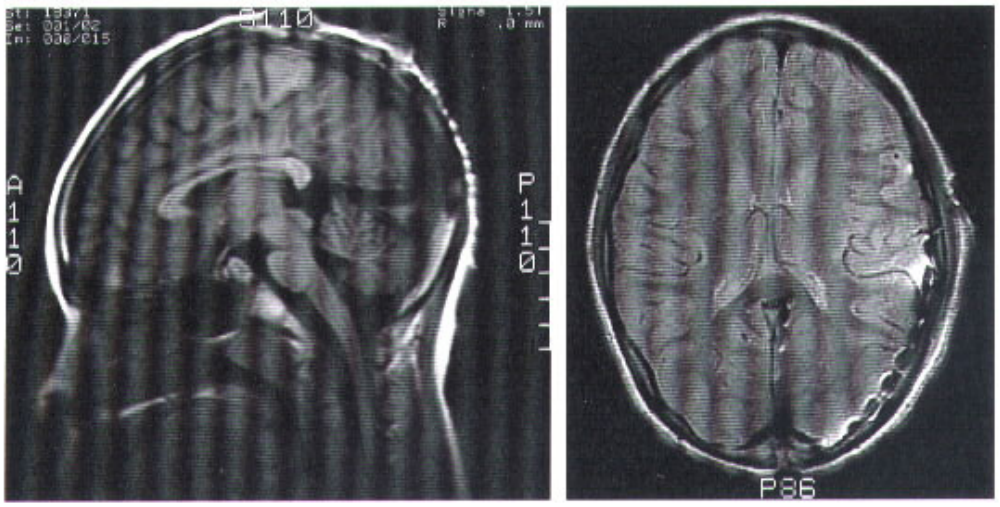


FIGURE 18.

Sagittal and axial views of calcarine interhemispherical strip electrode.

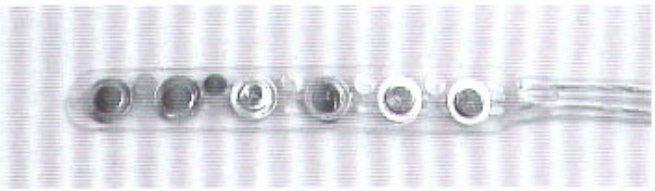


FIGURE 19.

Interhemispherical strip.

As in the other subdural electrode techniques, epileptogenic maps are produced and then based on standard anatomical considerations, the resection is then outlined. Multiple subpial transection has been utilized in the occipital pole with satisfactory functional outcome with minor disturbance of the visual fields, but without the production of blindness[23]. Doing functional mapping of the occipital area is difficult and standard functional concepts of occipital organization have to be utilized. It is generally undesirable to resect the occipital pole, or into the calcarine, as this will create a significant visual field defect. Similarly, a high parietal resection, whether dominant or nondominant, can often produce higher cortical function difficulties such as Gerstmann syndrome in the dominant parietal and a significant constructional dyspraxia, and/or neglect from the non-dominant parietal. In these areas, if it is know that this tissue is functional, it is prudent to utilize multiple subpial transection.[22,24]

An expanding application for the subdural electrode array technique had been done in patients who not only have medically refractory epilepsy without a clearly identifiable lesion, or the suggestion of a lesion without definitive epileptogenic margins, but also in those cases in which tumors, usually primary neocortical tumors, coexist with epileptogenesis. We have demonstrated exceptional seizure outcomes with lack of deficit apparent in these patients[26,27].

The development of this family of subdural electrode array electrodes has allowed the Minnesota Epilepsy Group to offer new hope to patients with medically refractory

FIGURE 20. EPILEPSY PRESURGICAL EVALUATION

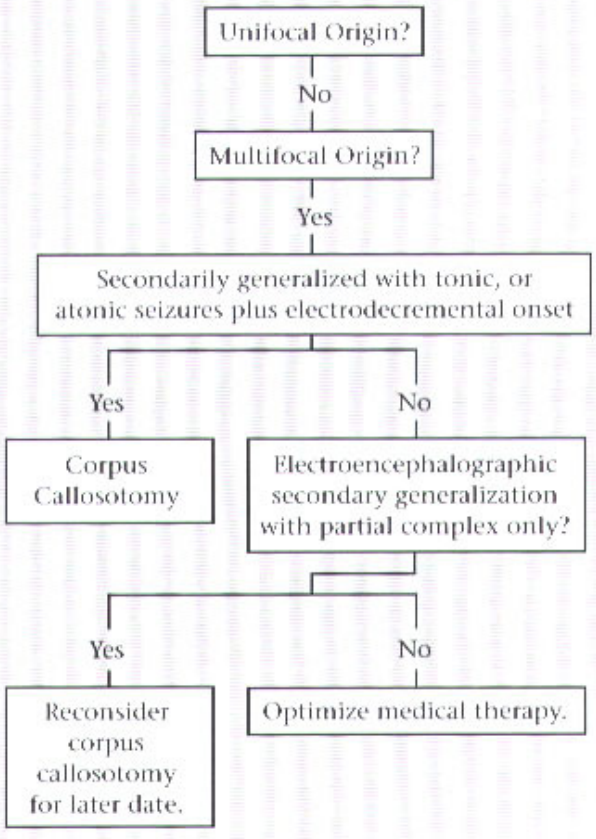


FIGURE 21. VAGAL NERVE STIMULATOR OPTION

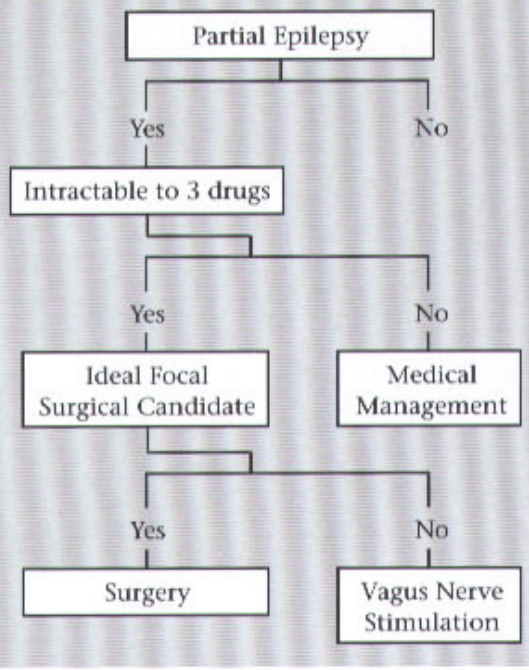
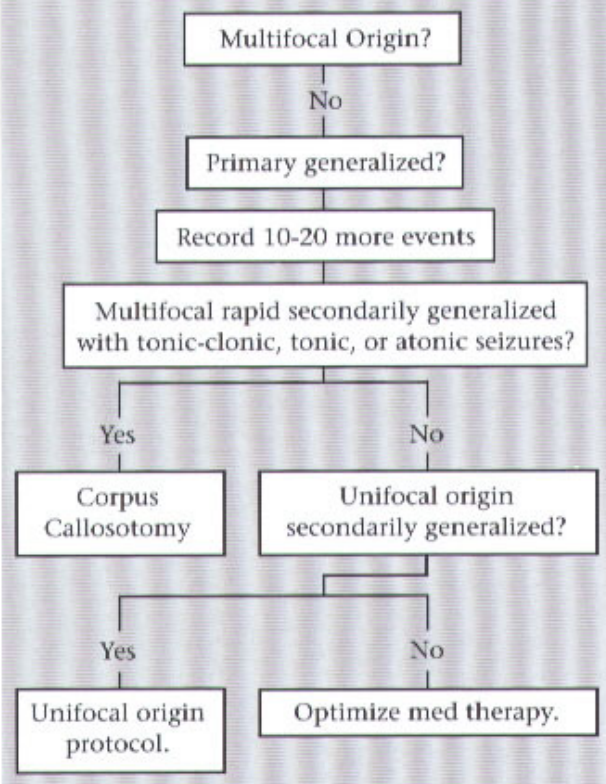


FIGURE 22. INTENSIVE NEURODIAGNOSTIC MONITORING



Often, when a primary generalized pattern is suggested, the recording of 10 to 20 more ictal events can establish unifocality or multifocality.

epilepsy, including those with primary brain tumors, who simply could not be safely approached before. This technique affords the clinical neurophysiologist and neurosurgeon to work together in manner that is marvelously collaborative, and a tremendous example of the application of team expertise to effect remarkable clinical outcomes.

4.2c Documentation Of Multifocal Origin Or A Primary Generalized Ictal Pattern.

Corpus callosum division is another surgical option available to a significant sub-group of patients intractable to medication *(Figure 20)*. In 1940[28] Van Wagenen and Herren from Rochester, New York, introduced corpus callostomy "In an effort to limit the spread of a convulsive wave to one-half of the cerebrum." They believed that consciousness would not be lost and the falls caused by apparently secondarily generalized seizures could be avoided.

Over the year, various combinations of sections of interhemispheric fiber tracts (corpus callosum, fornix, massa intermedia, anterior commissura, and hippocampal commissure) have been performed with mixed results both in terms of increased seizure control and complications of surgery[28, 29, 30, 31, 32, 33, 34, 35, 36]. Several centers have reevaluated this technique in recent years[37-42].

With the advent of the Vagal Nerve Stimulator as a surgical option for patients with medically refractory/partial epilepsy, modification of the surgical decision tree has to transpire. We would modify our existing decision trees to include Vagal Nerve Stimulator as an option for the patient who is not the ideal focal resective surgical candidate *(Figure 21)*. This would include predominantly non-dominant temporal lobectomy patients, individuals with dominant resection confidently mesial who do not have intact verbal memory function or patients having a lesion with clearly localized epileptogenesis in other neocortical structures that is not proximal to vital eloquent cortex. Finally, in patients for whom the corpus callosum division is indicated, there is a body of evidence[43] to suggest that the Vagal Nerve Stimulator may be an effective alternative associated with a lessor morbidity.

At the Minnesota Epilepsy Group we use a technique of anterior callostomy based upon a previous experience with over 300 cases. Our approach is outlined in the multifocal origin protocol *(Figure 20)*. An anterior two-thirds corpus callostomy is recommended[41] if secondarily generalized falling seizures of multifocal origin or unifocal origin from a surgically unapproachable epileptogenic lesion are demonstrated from multiple surface/sphenoidal ictal recording of long-term monitoring of epilepsy, and if comprehensive supplemental structural activation, and neuropsychological studies support this localization. The results of this procedure in recent patients are summarized in Table 1. For the drop seizures (tonic or atonic

episodes), we have found the procedure to be quite successful, with an acceptable morbidity.

Other centers use different selection criteria for the procedure [37, 38]. A clear consensus had not evolved as to the indications for callostomy. We found that the devastating atonic and tonic falling seizures intractable to anticonvulsants are significantly improved by this procedure, with a dramatic decrease in broken bones. A clear response group is identified, for patients with electrodecremental epileptiform fast tonic events, especially over the age of ten. [41, 42]

As indicated in Figure 22, what appears to be intractable primary generalized epilepsy, especially in the adult population, may prove to be more intensive recording of ictal events. If an area can be identified in potentially surgically approachable region, one must take a step back to a unifocal origin point in the presurgical evaluation decision tree. Alternatively, a corpus callostomy may be considered for those patients who are multi focal or unifocal, but surgically unapproachable, whose secondarily generalized events are tonic, atonic, or tonic-clonic seizures.

5. Conclusion

Dramatic advances have been made in the surgical treatment of epilepsy in recent years. Through the improvements in long-term monitoring for epilepsy and in the surgical procedures, which include invasive intracerebral recording techniques, physicians caring for those with medically intractable epilepsy now have diagnostic and therapeutic options that simply were not available a few years ago.

Table 1 – Response to Corpus Callosotomy of Multiple Seizure Types[a]

Patient No.	Extent of Callosotomy on MRI	Months of Followup	Partial Complex Preop/Postop		Simple Partial Preop/Postop		Tonic-Clonic Preop/Postop		Tonic or Atonic Preop/Postop	
1		67	21	6	21	0	21	0	16	2
2		51	34	50[b]			17	0	56	0
3	Complete	51	40	0	0	4[b]	40	0	20	0
4	Complete	71	40	0			40	0	20	0
5	Genu intact	52	50	0	0	30[f]	4	0	4	0
6		56	80	120			80	0	56	56
7[c]	Complete	43	12	12			12	1	28	4
8	Splenium intact	48	20	30[b]			20	3	20	0.5
9	Splenium intact	39	40	16					28	2
10		37	450	50			12	0	600	60[d]
11	Complete	34	20	0	0	30b	12	0	14	0
12		34	30	0					11	0
13	Splenium intact	32	900	120[b]					30	1[d]
14	Complete	30	10	60[b]			30	2	60	6[d]
15		25	30	6					11	0
16	Splenium intact	23			2		1	315	120[e]	
17		22	90	30[f]			2	0	70	2
18		22	4	8[b]					17	5
19	Splenium intact	21	60	10[f]			60	0	30	3
20	Splenium intact	19							70	30
21	Splenium intact	19					20	0	50	3
22		17	60	0					12	0
23	Splenium intact	15	0	2[c]			20	0.5	12	0.5
25		15	30	30			0.5	0	10	5
	Average	35.1	20 Patients p<0.02				17 Patients p<0.01		24 Patients p<0.01	

[a]Seizure numbers reflect average number of seizures per month for the 12 months from August 1984 to July 1985.

[b]Many of these seizures appear to be aborted tonic or atonic seizures status post-surgery.

[c]This patient was operated on twice, after having been found to have an incomplete callosotomy with persistent (12 months) atonic seizures after the first surgical procedure (11/5/81). Consequently, his callosotomy was completed in a second procedure on 3/9/84.

[d]Though still technically generalized atonic or tonic seizures, these episodes are less severe with more of a slump than an abrupt change in position of the body. Consequently, injuries are much less frequent from the resultant falls.

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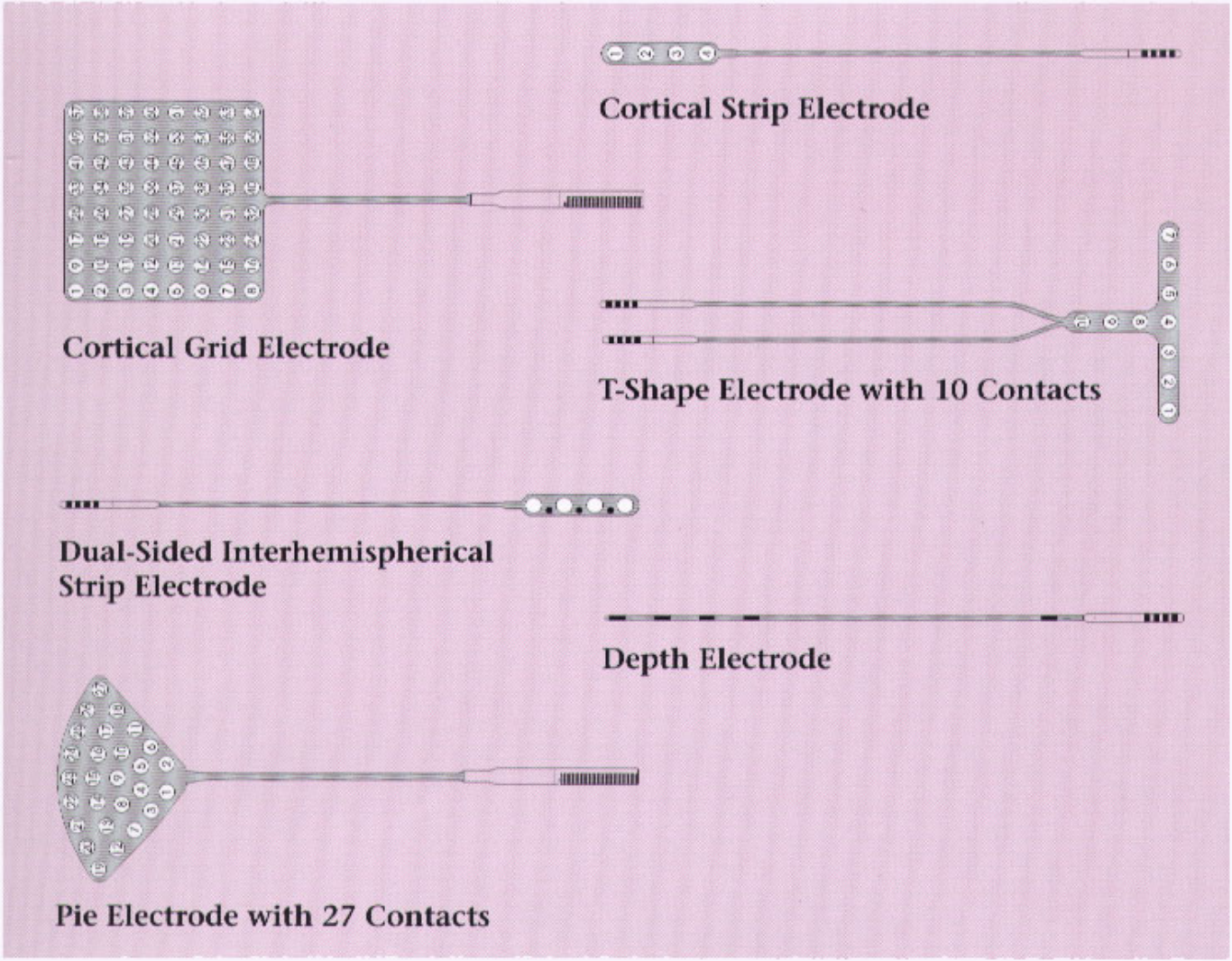

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