Technical and Clinical Aspects of Topographic Brain Mapping

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Key Words
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INTRODUCTION

Topographic brain mapping (TBM) is a sensitive test which elucidates subtle abnormalities related to cerebral function. However, it may exaggerate some of the artifactual aspects of the conventional EEG recording if proper technical standards are not applied. With the advent of more advanced TBM technology and implementation of improved technique[1-5] one can obtain a TBM of higher quality which is marred with fewer artifacts.

To study different recording parameters for a proper TBM, a comparison of control versus patient population was done. Clinical aspects of TBM are detailed from our material mainly on neurologic and neuropsychiatric outpatients.

MATERIAL AND METHOD

TBM recordings were obtained from 100 volunteers without CNS disease and 400 consecutive outpatients.

While studying the 100 volunteers, the different parameters of recording were purposefully changed to observe the effects on the technical quality of the recording. For example, the brain mapping was averaged at 2.5, 10, 20, 40, 50, 100, 120, 180, and 200 seconds to study the averaging effect on brain mapping (Figures A-D).

The frequency analysis was done on units of 2.5 second epochs. The EEG recording was converted into frequency bands of delta (0.1-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), beta I (13-16 Hz), and beta II (17-32 Hz). The recording was done simultaneously with standard EEG recording as well as color coded topographic map printing.

TBM was done on a continuous basis for each frequency without interruption for data interpolation or averaging. The period of recording for each frequency averaging was approximately 12 to 14 minutes. Different TBM instruments were tried at the beginning of the study. However, the investigators resorted to a machine that would have no lost time for tabulation. This was done to avoid loss of any raw data prior to averaging. For example, a 10 second recording should not be reduced to 8 seconds due to tabulation downtime by the machine.

Normal Population

One hundred volunteers were selected according to the following criteria: 80 volunteers were between ages 20 and 55, and 20 volunteers were between ages 8 and 18. There were 58 females and 42 males. The adult volunteers consisted of 16 office employees who had no history of neurologic illness as well as 64 patients who were referred for evaluation of entrapment neuropathies.

The 20 young volunteers were respondants to a newspaper advertisement, which specified the purpose of the research work, and each underwent the same workup as the rest of the volunteers. All were required to have a normal physical examination and normal blood pressure.

The results of TBM on the 100 volunteers were compared to the TBM results of 400 consecutive outpatients who were referred to our clinic from different sources (see II Clinical Aspects of Brain Mapping).

Montages

The same standard differential and referential montages were included in the brain mapping of each volunteer as well as each patient. In volunteers as well as all patients, routine standard paper recordings of EEGs were compared with the brain mapping result on screen and on the graphics obtained from the compu-

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ter. In regard to detection of artifact, clinical observation as well as EEG raw data were compared to the results of brain mapping. The comparison was made after editing and excluding the analog 2.5 second epochs which may have contained extraneous artifacts.

Artifact recognition was mainly on the basis of observation of the patient, as well as observation of simultaneously recorded EEGs. Both physiological and extraneous non-cerebral artifacts were observed. These were then correlated with averaged and edited brain mapping results.

RESULTS

I. TECHNICAL ASPECTS

Statistical Data

The standard deviation of the right and left hemispheric voltage range of the volunteer group between ages 20 and 55 as well as those between ages 8 and 18 was studied. The Z score deviation was measured. Because of the limited number of volunteers the Z score standard deviation was compared to that of the cooperative multi-center group originated by Neuroscience Laboratories. This cooperative group consisted of the data from U.C.L.A., New York University, and Miami Children's Hospital, obtained from normal individuals 10 to 79 years of age separated by each decade. Our Z score standard deviation results were quite similar to the multi-center studies, therefore, in the final evaluation of the patients, the multi-center standard deviation was used as the guideline. It was noted that a 2.5 or higher standard deviation was definitely abnormal. However, such abnormality does not necessarily rule out the possibility of an aritfactual source. The Z score standard deviation is an excellent guideline for questionable borderline abnormalities and we feel it should be included in every brain map recording, but it is not a substitute for final judgment in regard to clinical correlation.

Referential vs. Differential Montages

Invariably, in our studies, the comparison of differential and referential recordings demonstrated a bias towards false lateralization in the case of ear referential montages. The same was true with vertex referential montages, even though it was not as clear-cut a false localization as was the case with the ear referential montages. The false lateralization refers to lateralization of power spectrum towards the temporal regions adjacent to the ear reference being recorded. The same normal TBM on differential recording would show a higher amplitude temporal focus on the side of the ear reference when recording from the A1, A2 or (A1 + A2) as common references. This problem is solved if the common reference is at a distance - such as mid-clavicular referential recording. A nasal reference may serve the same purpose.

In the study of the control group of 100 volunteers, the differential parasagittal montages were compared to the differential bitemporal as well as ear referential (A1, A2) and (A1 + A2) montages. The temporal lobe false positive rate was (5/100) for the (A1 + A2) referential montage versus (2/100) for differential montages. There was no statistically significant false localization or lateralization when AP differential montages were compared with the left to right bitemporal differential montages.

Length of Recording

The length of averaging of each frequency is instrumental in accurate identification of abnormal vs. artifactual TMB results. Even though each epoch has a 2.5 second length, the recording is only accurate and excludes random occurrence of different frequencies if the averaging time for each frequency is prolonged to several seconds (Table 1). When the recording is shorter than 100 seconds amplitude fluctuation is quite evident. This results in random voltage asymmetries (Figures A-D).

After 120 to 180 seconds the results become more consistent. This problem is even more exaggerated with theta and delta frequencies (Figures A-D). The 120 seconds or longer averaging helps to minimize the problem of eye movement artifact. It does not exclude the need for proper technique, or the need for excluding the gross eye movement artifacts by editing 2.5 second epochs of artifacts before averaging.

As the length of the recording of each frequency is extended to a minimum of 180 seconds, and the abnormality is seen in more than one frequency band, the artifactual false positive result drops to 2% vs. 13% and 37% when the abnormality is seen in one frequency or in recordings as short as 20 seconds (Table 1).

At times the alpha or delta frequencies show asymmetries which are not related to electrode or physiological artifacts. In frontal lobe dysfunctions, the power spectrum of delta frequency may become less prominent on the abnormal side, and as a result it may mimic eye movement artifact (Figure 1). The same is true

Table 1

False positive tests in TBM of 100 controls
(Differential montages)

	Single Occurrence		In Combination (more than 1 frequency)	
	180 seconds*	20 seconds*	180 seconds*	20 seconds*
Alpha	1**	6***	1**	2***
Beta I	1**	8**	2**	5***
Beta II	1**	5**	2**	2**
Theta	2***	17***	2***	7***
Delta	1	13	0	4
	2%	37%	2%	13%

*Length of averaging time. The averaging was done after excluding the 2.5 second epochs of obvious artifact contamination.

**Beta frequency asymmetries occurred in the same individual.

***Alpha and theta asymmetries occurred in the same individual. The concurrence of multiple artifacts in the same individual resulted in a lower percentage in each group.

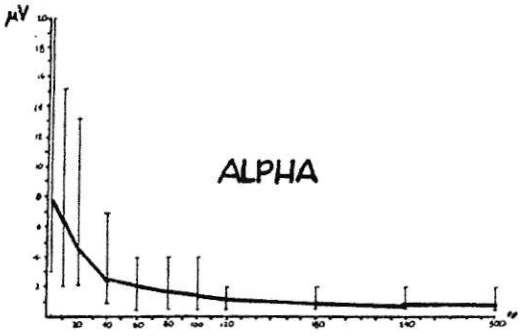

Figure A. Mean voltage differential (left minus right) occipital alpha frequency power spectrum is less variable when the averaging time is extended beyond 120 seconds. Ordinate is voltage range of occipital alpha power expectrum. Abscissa is the length of averaging time. An identical left and right hemispheric voltage is represented as zero microvolt (e.g., O_1 voltage 20 micro v. minus O_2 voltage 21 micro v. = 1 micro v.)

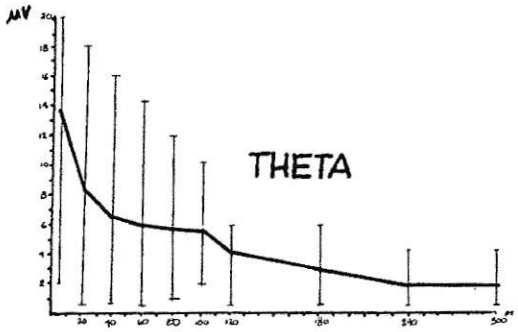

Figure B. The effect of averaging duration on mean voltage differential of frontal theta frequency power spectrum.

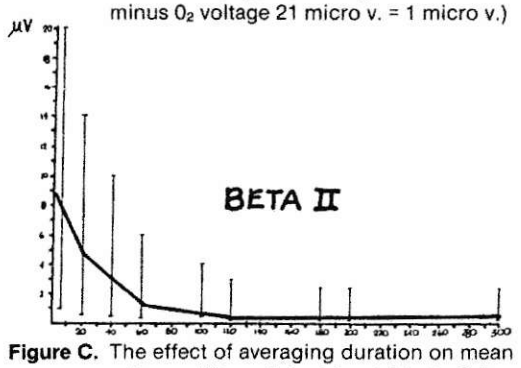

Figure C. The effect of averaging duration on mean voltage differential of frontal beta 2 frequency power spectrum.

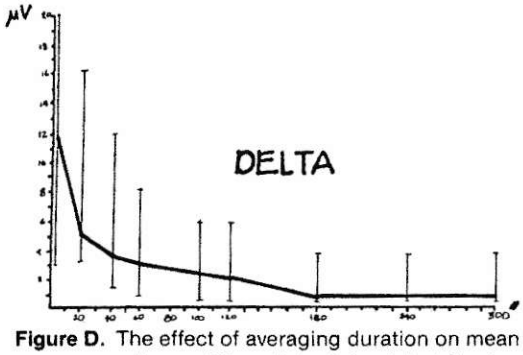

Figure D. The effect of averaging duration on mean voltage differential of frontal delta frequency power spectrum.

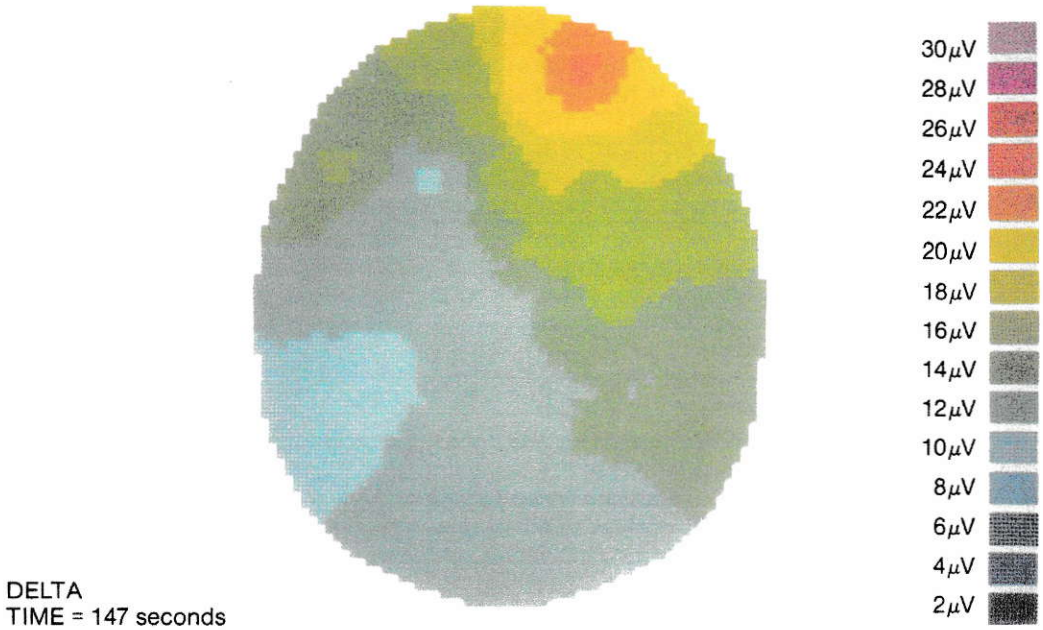

Figure 1. Delta asymmetry, due to head injury, resembling eye movement artifact.

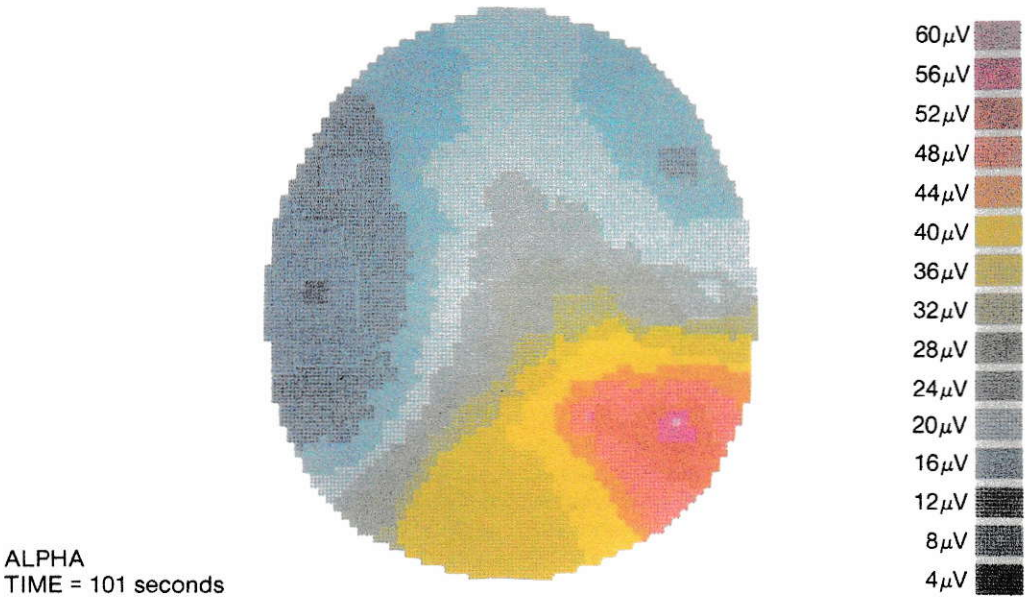

Figure 2. Alpha asymmetry secondary to head injury.

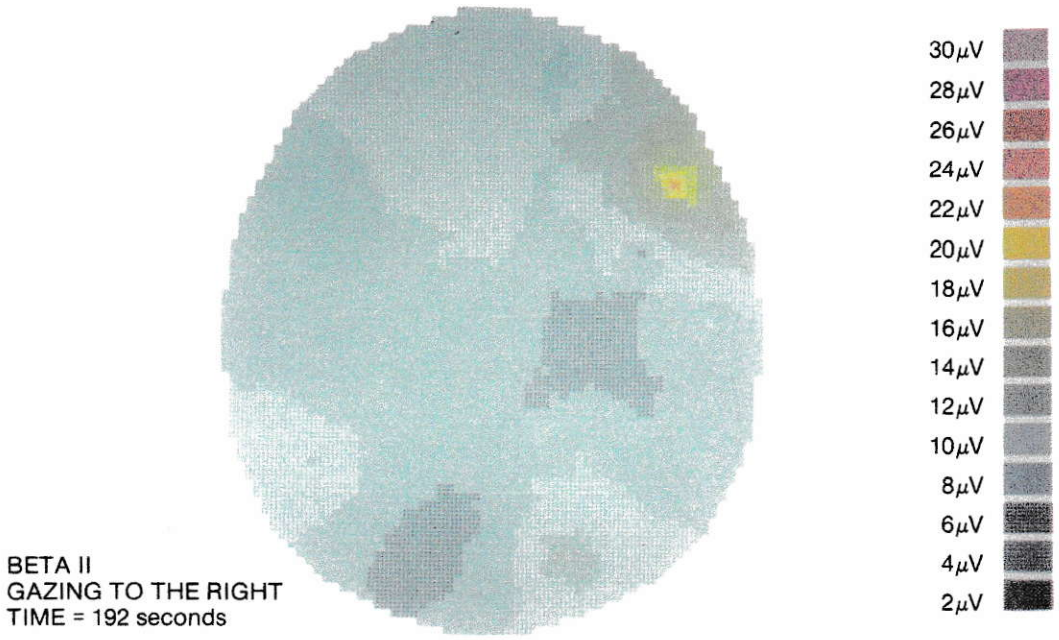

Figure 3. Dipole due to electrode artifact ("comet effect").

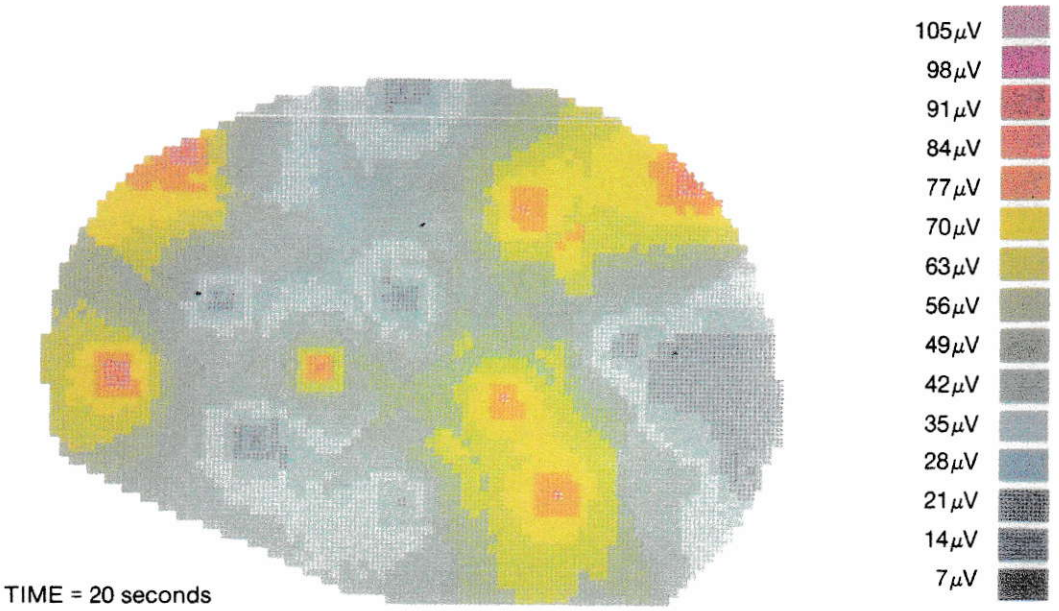

Figure 4. Geometric configuration of loose electrodes artifact.

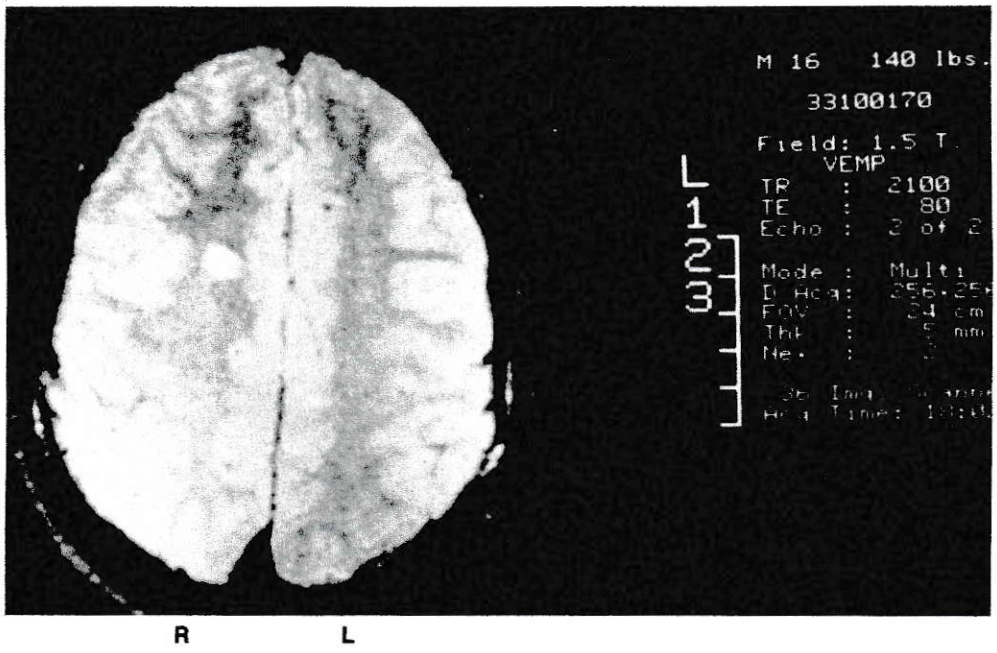

Figure 5A. Post-traumatic right frontal hematoma of chronic nature. EEG was normal. MRI was interpreted as metastatic tumor. (Patient had a malignant melanoma of the right thigh.)

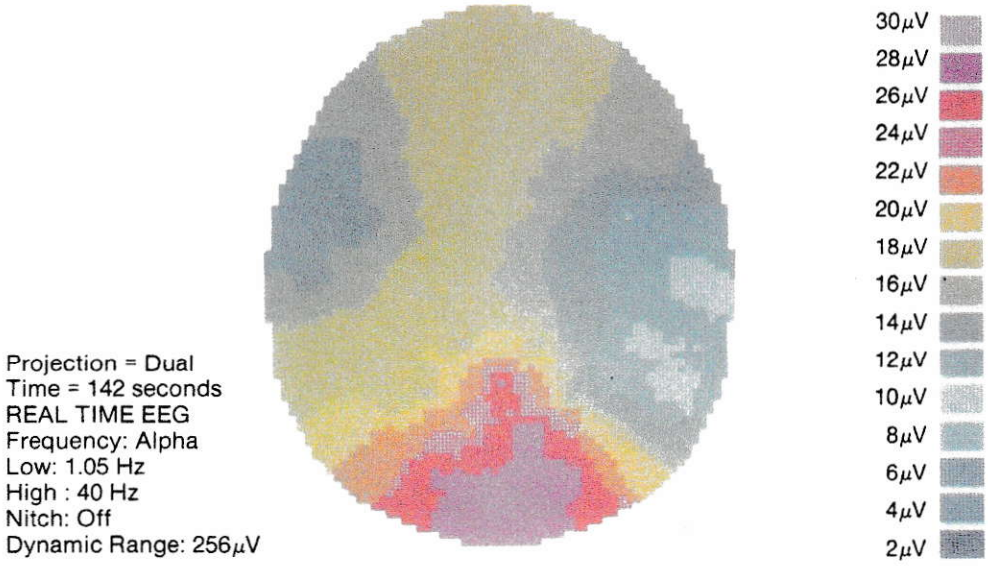

Figure 5B. Brain mapping of the same patient as Figure 5A shows right temporal lateralization of the frontal hematoma ("centrifugal effect").

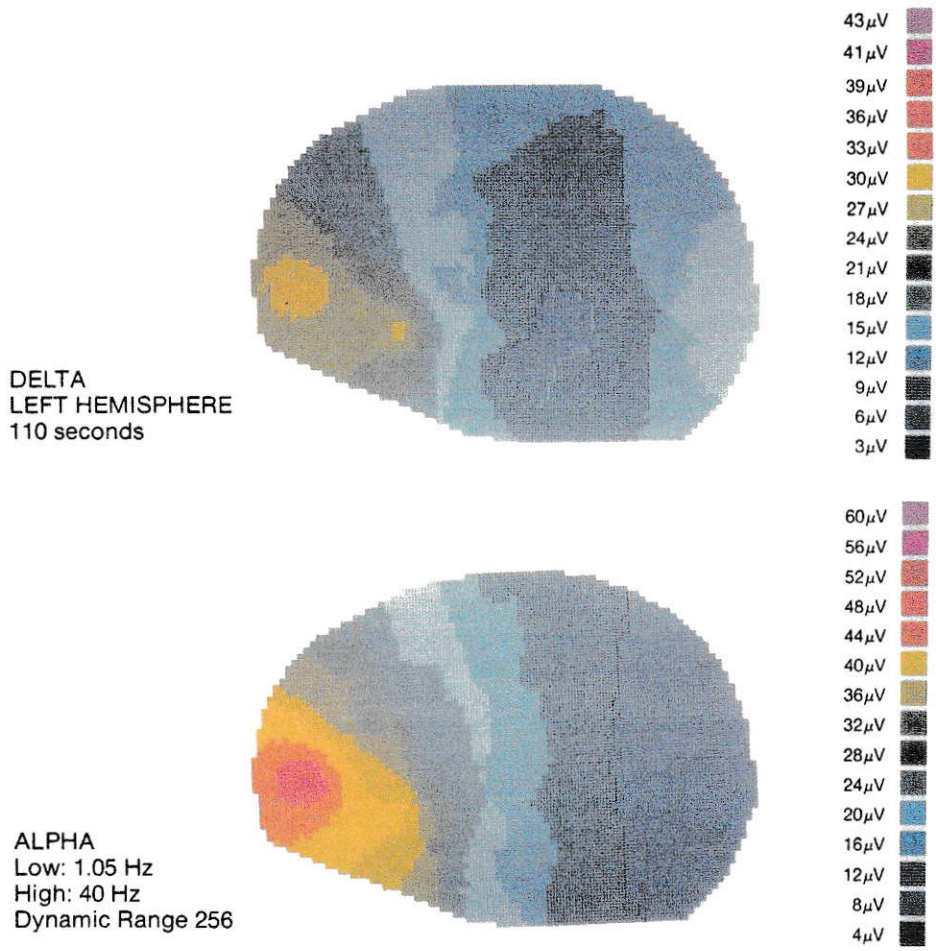

Figure 6. Alpha dislocation to frontal region, secondary to severe head injury, resembling delta localization.

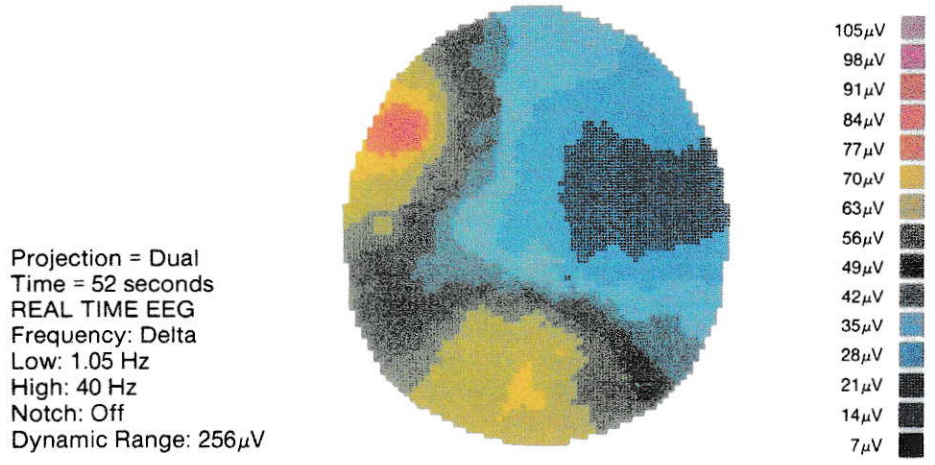

Figure 7. Right anterior head region delta suppression in Tourette syndrome.

with abnormal alpha frequency in posterior head regions (Figure 2).

Artifacts

A. PHYSIOLOGICAL

1. *Drowsiness:* The effect of drowsiness among the 100 volunteers was minimal in alpha and beta recordings. It was mainly a problem during theta recording, which showed variable and multifocal changes. However, the fact that it was limited to one frequency band (theta), made it easier to be identified as drowsiness "artifact." The contamination of the theta and delta frequency bands with drowsiness can be problematic, and requires an alert technician to arouse the patient during such recording. The activation of focal beta frequencies by drowsiness is not necessarily a normal variant, and should not be discarded as artifact. It may be the main feature of a seizure disorder or cerebrovascular disease.[6]

2. *Eye movement:* With proper editing, averaging, and montage application one can minimize the problem of eye movement artifacts. In our study, in trying to find out the influence of eye movement on the TBM recording, we were able to demonstrate significant eye movement artifact if the patient purposefully focused the eye movement in one position for more than 60 seconds at a time (Figure 3). In addition, both eye movement as well as electrode artifacts usually have a dipole pattern which is quite typical, showing the area of maximum voltage of power spectrum at the point of origination of the artifact. This area with warmer color is tailed by an area of decreased power spectrum ("comet effect") (Figure 3).

3. *Eye blinks, gritting* and *muscle artifacts* may be minimized by the same measures taken to reduce eye movement artifact (Table 2).

B. ELECTRODE ARTIFACTS

When the TBM shows multiple foci of independent power spectra on several areas of the head, the most likely cause is electrode artifacts. Usually the multiple foci are geometric and square shaped (Figure 4). More commonly, a single square or cross shaped area identifies a single electrode artifact. The artifacts from poor electrode contact are best recognized by continuous observation of the charted EEG, and on the imaging display screen.

DISCUSSION OF TECHNICAL ASPECTS

EEG Recording

Simultaneous EEG recording is an integral part of the TBM. Without such simultaneous recording, it becomes difficult to recognize artifacts. Moreover, EEG recording provides morphological data that cannot be obtained on brain mapping (e.g., periodic lateralized epileptiform discharges, projected delta, and small sharp spikes).

Activation Procedures

The TBM recording does not preclude the need for calibration as well as activation procedures. Such activation procedures, for example, hyperventilation and evoked potential stimulation, should be done routinely.

Localization

In addition to the proper length of averaging, in doubtful diagnostic situations, it may be helpful to use a subtraction technique (left minus right) to delineate the abnormalities to a more accurate area of the cerebral hemisphere.[7]

The TBM recording usually does not show midline vertex abnormalities. When an abnormality is close to the midline, it may be identified lateral to the original focus. The right and left parasagittal channel recordings are usually subtracted during the brain mapping procedures. As a result, the parasagittal difference of potentials appears smaller than the true abstract potentials. On the other hand, the comparison of the potentials of electrodes adjacent to Fz through Oz to more lateral electrode points on each side of the cerebral hemisphere, will have a tendency to show a more prominent potential gradient, hence, causing an exaggeration of the difference of potential at the areas away from the midline. As a result, the frequency asymmetries far from the midline become enhanced at the expense of attenuation of the midline electrode potentials (Figure 5, A and B). This "centrifugal effect" phenomenon[7] causes the main major localization problem that we have seen, comparing the anatomical (CT and MRI) and neurophysiological tests.[8]

Pre-Set Montages

It is traditional and not unusual for TBM manufacturers to include pre-set montages in their final products. A comparison of recording of pre-set vs. selected montages in our laboratory proved that the pre-set montages are not suitable for every patient and in every circumstance. Pre-set montages are fine for normal, or obviously abnormal recordings. However, when a question is raised regarding a borderline recording (for example, artifact vs. true

abnormality), the technician should be capable of changing the montage to map the area more precisely. If an ear reference causes fast frequency contamination or if a vertex reference causes vertex sharp wave contamination, it is best not to be locked into such artifact prone pre-set montages. In addition, pre-set montages may also limit the accuracy of the simultaneous EEG recording. These montages by and large use earlinks reference recording, which may at times contaminate wide areas of the head such as parietal and occipital regions with slower frequencies during the brain mapping with eye movement artifacts. Even after editing 2.5 second epochs of eye movement artifacts, subtle eye movement artifacts cannot always be totally eliminated. In addition, physiological slow waves (i.e. drowsiness) which are normally seen in temporofrontal regions have the same potential of contaminating posterior head regions with application of A1 + A2 montages. By avoidance of ear and vertex references along with the application of longer averaging times, in our experience, the above artifacts can be significantly reduced.

II. CLINICAL ASPECTS

Our experience with 400 consecutive patients has been mainly on neurologic and neuropsychiatric outpatients, including referrals from variable sources, primarily for a more definitive diagnosis in patients suffering from post-traumatic syndrome, neuropsychiatric problems, especially depression, difficult to diagnose seizure disorders, cerebral vascular disease, and behavioral disturbances such as seen with Gilles de la Tourette syndrome (Table 3). The 400 consecutive cases were studied to avoid any diagnostic bias, even though there have been several hundred more patients evaluated in our clinic. No instruction was made to withold any routine medication. The results of TBM were compared to MRI, CT scan and neuropsychiatric tests.

HEAD INJURIES

A study was made of 135 consecutive outpatients with mild to moderate head injury and complications 1 to 22 years after head injury (Table 3). The physiological tests, EEG and TBM were compared to anatomical tests, MRI and CT scan. All patients underwent Halstead-Reitan and other neuropsychological tests, as well as detailed neurologic examination. EEG abnormalities were seen in 40 patients consisting mainly of mild, nonspecific generalized slowing. No CT and MRI abnormalities were noted in 111 of 135 patients, 3 of whom had unrelated cerebral atrophy.

Of the 135 patients, 75 (56%) had abnormal TBMs. Six patients had bilateral abnormalities. In 37 patients the TBM was abnormal on the right side, and in 32 patients it was abnormal on the left side. The temporo-frontal regions were involved in 49 (65%) patients, the parieto-occipital regions in 7 (9%) patients and the temporo-occipital regions were involved in 19 (25%) patients.

The most common type of abnormality was absolute voltage asymmetry. However, in 2 patients with chronic head injury severe enough to cause several days of coma, the main abnormality was frontal alpha dislocation. These patients were mentally retarded secondary to the head injury. Even a few years after recovering from coma, the spectral power alpha frequency was located in the frontal regions similar to alpha coma patients (Figure 6).

The most common symptoms in patients with left hemispheric abnormalities on TBM were headache, depression, short term memory loss, and visual disturbances. They were associated with disturbances of verbal communication and neuropsychological function (history, English, learning disability, and verbal memory disturbance). The right hemispheric TBM abnormalities were most commonly associated with headache, auditory disturbances, and personality changes (schizoaffective tendency), and poor arithmetic performance.

Independent psychological and brain mapping interpretation showed over 96% lateralization accuracy. The problem with localization has already been discussed in the technical aspects of TBM.

SEIZURE DISORDERS

The TBM was done only on patients who did not show definite evidence of epileptiform discharges on standard EEGs. In the patients suffering from seizure disorder, the TBM was most helpful in the diagnosis of early development of post-traumatic seizure disorder in the form of complex partial seizures, and it was useful in cases with temporal lobe injuries who suffered from behavioral disturbances, not the sterotypical and classic forms of complex partial seizures. The TBM was very helpful in the diagnosis of early post-traumatic temporal lobe dysfunction, although only half such patients (20) developed a full blown clinical picture of complex

Table 2

Influence of averaging duration on artifacts

	Alpha		Beta I		Beta II		Theta		Delta	
Duration+	25"	180"	25"	180"	25"	180"	25"	180"	25"	180"
Eye Blinks	+2*	0	+2	0	+2	0	+3	0	+4	0
Gritting	+1	0	+1*	0	+2	+1	0	0	0	0
Eye Movement	+1	0	+2	+1	+2	+1	0	0	0	0

The averaging was done after excluding the 2.5 second epochs of obvious artifact contamination.
*Symmetrical changes have minimal effect in interpretation
+ = averaging duration
0 = less than 4 microvolts
+1 = 4 to 6 microvolts
+2 = 8 to 14 microvolts
+3 = 16 to 20 microvolts
+4 = over 20 microvolts

Table 3

Brain mapping in 400 consecutive outpatients

Diagnosis	Normal Map	Abnormal Map	Total Patients
Depression			145
Bipolar	18	0	
Menopausal	11	0	
Post-Traumatic	13	103	
Head Injury*			135
Mild to Moderate	60	75	
(Temporal lobe dysfunction)	(0	42)	
(with complex partial seizures)	(0	20)	
Attention Deficit			33
Ages 3 to 16			
"Hyperactive"	17	6	
Gilles de la Tourette	1	6	
"Childhood Schizophrenia"	0	3	
Cerebrovascular Disease			31
TIA	7	22	
Cerebral Infarct	0	2	
Pseudoseizures	16	0	16
Syncope	8	0	8
Miscellaneous+	3	29	32

*CT or MRI were abnormal in 24 (18%) of patients. EEG showed mild, non-specific abnormalities in 22 (16%) of patients. Halstead-Reitan Test was abnormal in 72 (53%) of head injury patients.
+Multiple sclerosis, metastatic tumor, Alzheimer's Disease, headaches.
Recordings were made with eyes open and closed routinely during mapping.

partial seizures (Table 3). The TBM findings included a combination of focal theta and beta asymmetries in 2 patients, as well as absolute power asymmetry in the frontal-temporal regions in the rest of the patients.

The TBM was limited in that it failed to show epileptiform discharges or other rhythmic activities such as periodic lateralized epileptiform discharges or frontal intermittent rhythmic delta activity (FIRDA), which were best recorded on the standard EEG.

The combination of TBM, measurement of serum prolactin, and recording of PSEUDOSEIZURES was found to be the most sensitive way to diagnose pseudoseizures vs. seizure disorder of hemispheric origin (Table 4). The adult patients with myoclonic or atonic seizures secondary to electrical injuries[9] had bilateral TBM abnormalities. Such abnormalities were asymmetrical, and could not be blamed on medication effect or other physiological factors (Table 4).

CEREBRAL VASCULAR DISEASE

In cerebral vascular disease, TBM was applied to the patients who were diagnostic problems. These were the patients who had a normal EEG and CAT scan or MRI in the face of what was suggestive of transient ischemic attacks or partial dissolving stroke. TBM was quite helpful, showing two main features. One was the presence of abnormality in the distribution of certain arteries, such as middle cerebral arteries or vertebral basilar artery; the second was concentric 3 to 4 halos of high voltage to low voltage abnormality in the distribution of the artery involved. This was in contrast to the circumscribed abnormalities noted in the head injury patients. The concentric halos were also seen in patients suffering from migraine vascular headaches.

NEUROPSYCHIATRIC PATIENTS

In the neuropsychiatric group of patients, the manic depressive patients had a normal TBM as did other patients with depression due to menopause or endocrine problems (Table 3). The normal value of TBM in such patients in contrast to post-traumatic or vascular depressions was quite helpful in the diagnosis and treatment of depression.

Brain mapping was consistently abnormal, showing focal abnormalities in the frontal temporal regions on one side or the other in 6 out of 7 patients with GILLES DE LA TOURETTE'S SYNDROME (Table 3 and Figure 7) and childhood schizophrenia (3 of 3 patients). In Tourette syndrome, the abnormalities were associated with abnormal psychological test results similar to the findings noted in the head injury group. The focal TBM findings suggest the probability of focal brain dysfunction in such patients (Table 3).* The patients with simple facial tics were not lumped in with the Tourette patients, and were excluded from this study.

MULTIPLE SCLEROSIS

Two patients suffering from headache, dizziness and memory loss had been diagnosed as multiple sclerosis due to multiple small lesions seen on MRI. One of these patients was a 28 year old man who had sustained head injury with total amnesia. After the head injury he developed the above symptoms. However, because of de novo development of the symptoms in a patient who could not remember his head injury, and because of the findings of MRI, the diagnosis of MS was made. The TBM on this patient showed marked voltage asymmetry and suppression of alpha, beta, and theta frequencies over the left temporal-frontal region. The large hemispheric abnormality noted on brain mapping prompted taking a more detailed history from the patient's colleagues at work which brought up the history of head injury at the onset of symptoms. The second patient was a 32 year old man who had a clear history of head injury followed by a half hour loss of consciousness and development of amnesia, headache and dizziness. The MRI again diagnosed MS, but the TBM showed a typical contrecoup abnormality involving right parietal-occipital and left temporal-frontal regions. TBM is not advocated as the test of choice for MS, but can clarify the confusing results of MRI in patients misdiagnosed as MS.

ALZHEIMER'S DISEASE

Six patients with the initial diagnosis of Alzheimer's disease underwent TBM. The results of TBM, as expected, were quite variable point-

*Since the beginning of this study through the end of 1988, there have been 15 patients referred to us with the diagnosis of Tourette syndrome. The Halstead-Reitan test, as well as TBM, demonstrated frontal-temporal dysfunction in 13 patients. Both tests were normal in 2 patients. Of the 13 patients with abnormal TBM findings, 9 had a marked improvement with treatment with carbamazepine. The other 4 patients had to continue taking pimozide or haloperidol. Two patients had classical features of fetal alcohol syndrome (FAS). These 2 patients were in the group which had to be kept on pimozide.

Table 4

Anatomical and physiological test results in seizure suspect patients
Sleep (half-hour intervals)

Seizures	No. of Pts.	EEG Results	BAER	Plasma* Prolactin Level	CT or MRI	Brain Mapping
A. Non-epileptic (controls)	12	Normal 12	Normal 12	3 - 9.3 ng/ml	Normal 12	Normal 12
B. Pseudoseizures	12	Normal 12	Normal 12	3.5 - 9.2 ng/ml	Normal 12	Normal 12
C. Electrical injury with atonic, myoclonic, or major motor seizures	9	Normal 4	Normal 0	9.8 - 17 ng/ml	Normal 10 Mild atrophy 2	Bihemispheric suppression 7 Right temporal suppression 4 Normal 1

*Nocturnal plasma prolactin levels of three samples during non-REM.

ing to the multiple causes of this syndrome. Two patients who mimicked Alzheimer were suffering from multiple infarcts due to hypertension and diabetes. These patients had bilateral hemispheric vascular type of involvement on TBM. Three patients suffered from alcohol cerebral atrophy resembling Alzheimer's disease. The TBM was abnormal, showing bifrontal temporal suppression of alpha, beta and theta frequencies in 2 patients, and right frontal-temporal suppression of the same frequencies in one. In one patient who had early onset dementia and was closest to the generic definition of Alzheimer's, all of the frequencies were suppressed in a generalized, but asymmetric fashion, resulting in a "blue" color mapping pointing to generalized low voltage electrical activity. In a review of patients referred to us with the diagnosis of Alzheimer's disease in the past 10 years, of 85 patients only 25 met the criteria of Alzheimer's disease. The rest suffered from alcohol cerebral atrophy (42 patients), chronic post-traumatic dementia (13), neurosyphilis (2), Jacob-Creutzfeldt (1), vitamin B12 deficiency (1), and post-encephalitic cerebral atrophy (1). In a recent study, Homer et al.[10] reported that only 6 of 13 patients clinically diagnosed as Alzheimer were confirmed at the time of autopsy. Realizing that some of the above conditions such as neurosyphilis and alcohol cerebral atrophy are treatable and potentially reversible, we feel there is a desperate need for more accurate diagnosis of "Alzheimer" disease.

DISCUSSION OF CLINICAL ASPECTS

TBM was instrumental in achieving a more accurate diagnosis in complex neuropsychiatric patients. A large number of the patients in this group were referred from a mental health hospital (see acknowledgment). With the help of TBM, the post-traumatic temporal lobe dysfunction patients were properly diagnosed. In such patients, similar to the complex partial seizures, carbamazepine resulted in practically immediate beneficial response to treatment, helping the patients to improve and to be discharged from the institution in a matter of a few days. Such patients with post-traumatic temporal lobe dysfunction do quite poorly with long term use of benzodiazepines, which tend to aggravate the patients' depression, and show excellent results with treatment with carbamazepine. Of the 42 patients in this category (Table 3), 38 were markedly improved with carbamazepine.

In Tourette syndrome, the TBM revealed the major role cerebral hemispheric dysfunction plays in this illness. Similar to Alzheimer's syndrome, the Tourette syndrome has been used as a liberal terminology to include a variety of behavioral disturbances accompanied by tic in children and teenagers. However, TBM helps differentiate between a benign tic and a Tourette syndrome. In our study, in 3 patients with benign tic, TBM was normal whereas in Tourette syndrome 6 out of 7 patients had abnormal TBM (Table 3). These patients showed a beneficial response to treatment with

anticonvulsants such as carbamazepine or phenytoin. Four of the 7 Tourette patients had marked improvement in their behavior and symptoms with treatment with carbamazepine.

TBM was also helpful in accurate diagnosis and management of post-traumatic syndrome, depression, and Alzheimer's syndrome.

SUMMARY AND CONCLUSION

TBM provides physiological and diagnostic information which is quite complementary to EEG, but does not replace the need for standard EEG recordings. For example, it does not show subtle morphologic abnormalities such as FIRDA, PLEDs or epileptiform discharges. Simultaneous EEG recording as well as impeccable technique are essential in proper recording of TBM, particularly as it can generate new forms of artifact. By prolonging the averaging time to over 180 seconds, and by application of flexible montages, a more accurate and cleaner record with less artifact can be obtained. Certain phenomena such as "centrifugal effect" and "comet effect" are examples of new problems generated by the advent of TBM. On the other hand, TBM can demonstrate subtle asymmetries, lateralization and localization effects more efficiently than a standard EEG.

TBM is quite helpful clinically, when recording is done properly from a technical standpoint, in the diagnosis of post-traumatic syndrome and post-traumatic seizure disorder. It demonstrates subtle focal and lateralized asymmetries in cerebral hemispheric frequency bands in such patients. This information helps differentiate neurologic complications from psychiatric disorders. TBM plays a useful role in the differentiation and management of various other disorders, including depression, behavioral disturbances and dementias.

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