

ELECTRO-CLINICAL PROFILE OF 117 DEEP CEREBRAL TUMORS

JOYCE GRAHAM SMALL, M.D.¹, B. K. BAGCHI, PH.D. AND KENNETH A. KOOI, M.D.

*The Neuropsychiatric Institute, University of Michigan, Ann Arbor, Mich. (U.S.A.)*²

(Received for publication: July 8, 1960)

Many studies report clinical and EEG findings in tumors of deep cerebral structures. It is contended in the main that clinical and radiological data are more useful for diagnosis and localization of such lesions than EEG findings. Workers largely agree on the character and localizing value of EEG in patients with tumors in or near the upper convexity of the brain but they report varied opinions in regard to the deep lesions.

One could cull several dozen cases of deep intra-cerebral tumors out of mixed reports in which EEG findings have been described as not outstanding or as not definitely outside normal limits (Broglia and Postir 1956a, b; Daly *et al.* 1953; Van der Drift 1957; Jus et Jus 1947; Klass and Bickford 1958; Lairy-Bounes et Dreyfus-Brisac 1950; Lam 1950; Londoño 1957; Longo *et al.* 1950; Magnus and Van der Drift 1957; McDonald and Korb 1940; Paillas *et al.* 1948; Parat 1948; Silverman and Graff 1957; Schlesinger and Strauss 1947; Tönnis *et al.* 1953; Walter and Dovey 1944; Williams 1939). Investigators have found what they consider diffuse and ill-defined EEG abnormalities in these lesions (Bagchi and Bassett 1943; Daly *et al.* 1953; Longo *et al.* 1950; Schlesinger and Strauss 1947; Williams and Gibbs 1939). Homolateral alpha depression (Bucy and Case 1940; Case 1940), bilateral alpha bursts (Cobb 1944), fast waves (Cordeau 1959), 14-6/sec positive spikes (Stephenson 1951) have been mentioned.

Some consider EEG localization unsatisfactory in such lesions (Cuneo and Rand 1950; Hoefler *et al.* 1946; Lairy-Bounes et Dreyfus-Brisac 1950; Schlesinger and Strauss 1947; Walter 1940). Non-specific value of EEG as affording a basis for further investigation has been conceded by others. Quite a few authors consider bilaterally synchronous theta or theta-delta bursts as being associated with deep lesions (Cobb 1944, 1957; Cuneo and Rand 1950; Daly *et al.* 1953; Van der Drift 1957; Inghirami et Capdevielle 1954; Jasper and Van Buren 1953; Jus et Jus 1947; Lairy-Bounes et Dreyfus-Brisac 1950; Londoño 1957; Longo *et al.* 1950; Paillas *et al.* 1948; Parat 1948; Silverman and Graff 1957; Stephenson 1951; Terzian and Cecotto 1954; Tönnis *et al.* 1953; Walter and Dovey 1944), and some of them have reported bilateral delta discharges as well (Bickford 1957; Broglia and Postir 1956 b; Cordeau 1959; Cuneo and Rand 1950; Daly *et al.* 1953; Van der Drift 1957; Inghirami et Capdevielle 1954; Jasper and Van Buren 1953; Jus et Jus 1947; Lairy-Bounes et Dreyfus-Brisac 1950; Laufer 1947; Longo *et al.* 1950; Paillas 1948; Silverman and Graff 1957; Terzian and Cecotto 1954; Walter 1937; Walter *et al.* 1939; Williams 1939). The so-called "distant rhythms" in deep lesions and their implications have been dealt with by several workers (Cobb 1957; Faure *et al.* 1951; Jasper and Von Buren 1953).

It is often not evident from the literature surveyed what amount of emphasis was placed by the authors upon their EEG findings in these deep tumors in order to guide the clinician and the surgeon. Neither is it always clear whether these EEG signs alone were regarded as sufficient to justify a diagnosis of a deep lesion. Nor is it clear whether some additional EEG factors on the one hand or some clinical findings limiting

¹ Present Address: Department of Psychiatry, University of Oregon Medical School, Portland, Oreg. (U.S.A.).

² Acknowledgement is due to the Departments of Neurology and Neurosurgery, University of Michigan Medical School. Appreciation for technical help is due to Miss Hazel Calhoun. Aided by a grant B-1805 from the National Institute of Neurological Diseases and Blindness, United States Public Health Service.

the application of EEG factors on the other were considered to guard against misleading information. Some passing mention has been made in this connection by others (Bickford 1957) since our earlier report (Bagchi *et al.* 1952).

The value of the EEG in such a situation can best be appraised on the basis of adequately gathered and treated data on a large series of cases. In our study of such lesions for over 15 years, certain EEG clues have emerged which have been structured and added to those found in the literature. These have been utilized in an attempt to rule out a focal superficial lesion of the upper convexity and to rule in a deep disturbance or lesion, without necessarily trying to identify the involved structures (Bagchi 1955a, b; Bagchi *et al.* 1952). This was done without any prejudice to the legitimate thinking that management, final diagnosis or disposition of a case will depend not on EEG findings alone, but on the integrated evaluation and proper weighting of all clinical and laboratory data.

The present study is an attempt (*a*) to discover any possible specificity of correlation between "distant EEG discharges" and clinico-anatomical data, and (*b*) to assess the degree of success or failure in the application of EEG clues to depth diagnosis.

MATERIALS AND METHODS

From 1941 to June of 1958, 117 patients were selected who had cerebral tumors situated at

least 2 cm and generally more in depth from the cortex. All patients had been extensively studied from a clinical point of view and had received an EEG examination prior to contrast studies and surgery. Patients with tumors in the cortex or primarily in the temporal lobe, or in infratentorial structures were not included. Within the context of our present purpose the first two groups were omitted in this study because many of these were reported by us elsewhere (Bagchi 1955 a, b; Bagchi and Bassett 1943, 1947) and because temporal tumors show, as a rule, relatively homogenous lateralizing EEG features. The infratentorial series is worked up in another study (Bagchi *et al.* 1961). Detailed information regarding 60 clinical and EEG variables were gathered in each case. 68 patients were males and 49 were females. Duration of symptoms ranged from under one month in 10 cases, one to twelve months in 60 cases, to more than one year in 47 cases. Contrast studies, *i.e.*, pneumoencephalography, arteriography and/or ventriculography, were done in 95 per cent of the cases. All tumors were verified by surgery and/or autopsy. Approximately one-third of the cases (41) came to postmortem.

The patients were judged to have increased intracranial pressure (IICP) if one or more of the following signs were present: papilledema, ventricular dilatation with or without asymmetry, increased cerebro-spinal fluid pressure, separation of sutures, and/or evidence of increased

TABLE I
EEG in deep tumors in relation to their histological types

Type	Total	Normal	Borderline	Mildly abnormal	Moderately abnormal	Markedly abnormal	Correct depth diagnosis by EEG
Glioblastoma	25	0	2	2	11	10	18
Astrocytoma	23	0	0	3	12	8	14
Craniopharyngioma and pituitary adenoma	20	1	2	4	8	5	14
Meningioma	18	0	0	2	4	12	16
Oligodendroglioma	8	0	0	1	4	3	6
Spongioblastoma polare	6	0	2	2	0	2	2
Pinealoma	5	0	0	0	2	3	5
Miscellaneous	12	0	2	2	6	2	10
TOTALS	117	1	8	16	47	45	85
Percentage	100	0.9	7.1	14	40	38	73

TABLE II
Some clinical and EEG findings in deep tumors in relation to their location

A	B	C	D	E	F	G	H	I	J	K	L	M
Tumor location	Number	Increased intra-cranial pressure	Seizures	Organic brain syndrome and/or mental changes	Biposterior theta or delta bursts	Bianterior theta or delta bursts	Background slowing	Delta or theta shift — anterior	Delta or theta shift — posterior	Both anterior and posterior bursts	Correct EEG lateralizing diagnosis of tumors with lateralization	Over-all EEG evaluation
I. <i>Olfactory groove meningioma</i>	14											
Sub-frontal	9	5	3	7	1	8	2	3	0	1		
Sub-frontal chiasm	5	2	1	2	2	5	1	1	1	2	8/9	000 ₃ 1 ₁
II. <i>Chiasmatic tumors</i>	32											
Chiasm	18	7	6	4	4	4	5	2	1	3		
C, IIIV, T	8	4	0	2	5	5	7	1	3	3	9/16	1 ₃ 10 ₁ 1 ₁₇
C, Adj. W. M.	3	0	1	0	1	1	1	0	0	1		
C, Adj. W. M., IIIV, T	3	2	1	3	3	1	3	1	2	1		
III. <i>Ventricular tumors</i>	31											
Post, IIIV, T	4	4	1	3	3	4	2	2	1	3		
L. V.	1	1	0	0	0	0	0	0	0	0	22/26	0 ₃ 5 ₁₅ 8
IIIIV, L.V., T	5	4	1	4	1	4	1	1	0	1		
V, Adj. W.M., T	21	10	12	11	5	7	6	4	1	6		
IV. <i>Basal ganglion tumors</i>	19											
B.G., V, T	6	4	4	1	3	3	2	0	0	1		
B.G., Adj. W.M.	2	2	1	2	1	1	1	0	0	1	17/18	0 ₁ 0 ₁ 1 ₁₇
B.G., W.M., V., T	11	9	4	5	5	6	4	1	1	4		
V. <i>Corpus callosum tumors</i>	13											
CC, Adj. W.M.	5	5	3	3	2	3	2	1	1	1		
CC, W.M., V, T	7	4	4	5	2	6	1	1	1	2	9/9	0 ₁ 0 ₆ 6
CC, W.M., B.G.	1	1	0	1	0	0	0	0	0	0		
VI. <i>Tumors of subcortical white matter alone</i>	8	5	6	7	4	5	2	1	0	4	8/8	0 ₀ 1 ₁ 6
<i>Total</i>	117	69	48	60	42	63	40	19	12	34	73/86	
<i>Percentage</i>	100	59	41	51	36	54	34	16	10	29	85	

C = Chiasm (with or without intrasellar involvement); V = Ventricle; T = Thalamus; L.V. = Lateral ventricle; W.M. = White matter; CC = Corpus callosum. Column M: Slanting figures = Total number of normal, borderline, mildly abnormal, moderately abnormal and markedly abnormal EEG's in each tumor location group.

pressure at operation. The exact location and extent of some deep tumors with sub-total removal and without postmortem presented a formidable problem. In such cases all the available clinical, roentgenological and surgical data were pooled to arrive at as close an estimate of the location as possible. Arbitrarily, areas of involvement were selected to comprise the major groups I to VI, with additional extension noted

under each (Table II). As all pituitary adenomas had chiasmatic involvement, they were put under group II, Table II, and one hypothalamic tumor with extension to chiasm, III ventricle, and thalamus was also put under the same group, subgroup II. Mental changes included organic brain syndrome and personality aberrations traceable to lesions.

19 cases were studied on a 3-channel and 11

cases on a 6-channel EEG instrument with incomplete technique by present day standards. The remainder (87) were examined on an 8-channel Grass instrument. In all but 5 cases, a detailed EEG study using 23 or more scalp electrodes in as many as 26 monopolar and bipolar, short and long distance, montages of 2 or more minutes each was performed. The technique has been elaborated elsewhere (Bagchi 1955 a, b). In about three-fourths of the cases, the elaborate technique was found to give independent or confirmatory information not obtainable from our routine 7 to 10 montages used in the first part of each record. The rationale for the prolonged work-up was to obtain longer samples to identify transient abnormal discharges and to utilize different reference leads in different epochs for the same scalp leads for manipulating (*a*) push-pull cancellation, (*b*) phase, and (*c*) inter-electrode distance factors. EEG's were interpreted on the basis of previously developed electro-clinical correlational matrices (Bagchi 1955 a, b; Bagchi *et al.* 1945).

The empirical EEG clues for depth diagnosis of a deep lesion included one or more of the following: synchronous bianterior (bimotor with or without biprefrontal) and/or biposterior delta, theta, or alpha bursts, inter-hemispheric shifting bursts between homologous regions anteriorly or posteriorly, biantero-posterior parasagittal burst variability and/or bi-parasagittal-lateral burst variability (asynchronous appearance of bursts), overall unihemispheric emphasis of episodes of voltage increase and/or wavelength decrease of bilateral synchronous or shifting bursts, widespread interareally variable bursts in the same hemisphere against a reasonably good background, and slow background (Bagchi 1955 a, b; Bagchi *et al.* 1952). Differential weighting of these clues was not done though the first few seemed to be more important. Sometimes it was difficult to distinguish burst activity from background activity. The bursts were considered minimal if they appeared 4-6 times of one or more sec each, moderate if 7-10 times, or marked if 11 or more times in a record. Our calculations are based on moderate and/or marked bursts only. Background EEG slowing and burst phenomena (over 50 per cent increase of background voltage in sudden epi-

sodes of any wave length) have been separately categorized. Homologous shifting bursts are sometimes called independent bursts in the literature but they should not be confused with random diffuse discharges.

On the basis of several thousand control cases as mentioned before (Bagchi *et al.* 1952) and additional cases studied later, some of the factors limiting depth diagnosis by EEG were considered to be "degeneration", damage, inflammation, hypertensive encephalopathy, post-traumatic states, advanced metabolic or extra-cerebral diseases and vascular conditions which may show some of the above-mentioned EEG signs. Epilepsy with bilateral, shifting or other EEG signs would not be considered as a truly limiting factor in deep cerebral diagnosis. Its presence (and as a matter of fact, the presence of the previously mentioned conditions) would, however, definitely complicate an EEG interpreter's choice between a diffuse abnormal condition with or without a focal emphasis, a deep patho-physiological trigger or triggers, and a deep macroscopic expanding lesion. If there was a doubt about the absence of any of the above-mentioned clinical limiting factors in a particular case, depth diagnosis by EEG alone was held in consequence rather uncertain or inapplicable.

RESULTS

Table I shows the degree of EEG abnormality and accuracy of depth diagnosis in relation to tumor types. Table II illustrates the location of tumors and relates this to some clinical and EEG findings. Table III relates age to some of these findings. Increased intracranial pressure (IICP) occurred in more than half of the cases (59%) (Table II, C). There is no single tumor site with a strong predilection for the development of increased intracranial pressure. On the contrary, there is a trend suggesting that some sites are less associated with IICP. For example, fewer chiasmatic tumors (13 out of 32, 41%) with or without involvement of neighboring locations (Table II, group II) tended to be associated with IICP than tumors in other locations (range 41-79%, median of six groups being 62%). Also a smaller number of chiasmatic tumors (56%) showed moderate to marked EEG abnormality than tumors situated elsewhere (range 56-100%,

TABLE III
Some clinical and EEG findings in deep tumors in relation to the age of patients

Age	Total number of tumors	Increased intracranial pressure	Seizures	Mental changes	Biposterior bursts	Bianterior bursts	Back-ground slowing	Correct depth diagnosis by EEG	
Under 10	13	Present	12	4	6	10	7	11	10
		Absent	1	1	0	0	0	0	0
10-25	16	Present	10	3	1	6	5	3	8
		Absent	6	1	2	3	5	3	5
26-55	66	Present	32	15	21	7	15	10	22
		Absent	34	17	14	10	18	5	24
Over 55	22	Present	15	5	13	5	11	5	11
		Absent	7	2	3	1	2	3	5
Totals	117	Present	69	27	41	28	38	29	51
		Absent	48	21	19	14	25	11	34
			117	48	60	42	63	40	85

median of six groups being 90%) (Table II, M). Further, these tumors in group II had the least association with seizures (8 out of 32) as compared with tumors in other locations. 41 percent of the total series had produced seizures of one type or another (Table II, D). However, this trend is reversed if only the chiasm subgroup is taken. Association in the group II with mental changes is lower (9 out of 32, 28%) than in other groups (range 28-87%, 60% being the median of the six groups) (Table II, E). On the other hand, the chiasmatic tumors display some localizing clinical and laboratory signs, seen less frequently in non-chiasmatic tumors. To illustrate, the figures for the two groups are: eye signs (atrophy, field defect)-73 vs. 30 per cent, endocrine signs - 41 vs. 18 per cent, and abnormal sella turcica in skull X-rays - 60 vs. 39 per cent (not shown on Table II). Background slowing (mixed theta-alphas, prominent thetas or deltas, not bursts) in chiasmatic tumors, with or without intrasellar involvement (not including thalamic and ventricular extension) is the same (5 out of 18, 28%) as the median of the six groups, (28%, range being 22-50%) (Table II, H). But when ventricular and thalamic extensions of chiasmatic tumors are included, background slowing becomes proportionally high (16 out of 32, 50%). This increase may be adventitious or it may be accounted for by the involvement of thalamic or

other neighboring regions. But when all cases with thalamic involvement are compared with those without, in relation to background slowing, there is no statistically significant correlation. This appears strange in view of the generally accepted association between alpha waves and the integrity of the antero-mesial thalamus. Only 22 per cent of chiasmatic tumors including pituitary adenomas but without neighborhood involvement show bianterior bursts (range of all groups 22-92%, median 52%). These tumors show about the same percentage of biposterior bursts (range 22-64%, median of all groups 31%).

Increased intracranial pressure appears to be present in children under 10 (12 out of 13) more than in older age groups (Table III). This relation between IICP and age (in our context downward age gradation) over the entire series is statistically significant ($X^2 = 9.66, P < 0.02$) as is the correlation between IICP and background slowing ($X^2 = 4.6, P 0.02-0.05$). After correcting for age norms, background slowing vs. age approaches significance ($X^2 = 8.99, df = 3, P 0.02-0.05$), so does the relation between IICP and mental changes ($X^2 = 4.5, P < 0.05$) for the total group.

47 of the patients had moderately abnormal and 45 profoundly abnormal EEG's. 16 had mildly abnormal and eight borderline EEG's (Table I). Only one patient had a normal EEG.

This was a patient with a craniopharyngioma near the midline. Of the 25 patients comprising the less disturbed EEG groups, 14 had chiasmatic tumors with or without extension else-

have increased intracranial pressure (Table II, group I, F). Chiasmatic tumors without subfrontal involvement do not usually show this picture of bifrontal deltas (Bagchi 1955 a, b);

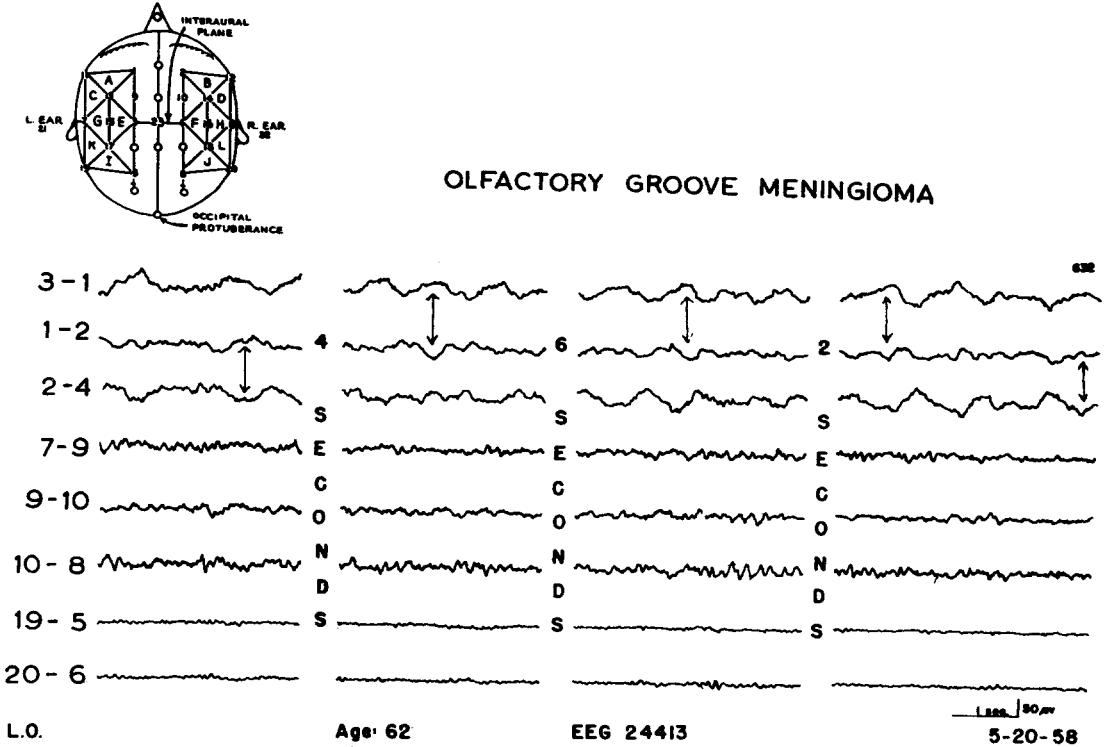


Fig. 1

Olfactory groove meningioma, midline, more on right than on left. Headache and organic brain syndrome for many years. Bilateral anosmia, constricted visual fields. No increased intracranial pressure. Ventriculogram abnormal without dilatation. Special transverse recording emphasizes shifting delta phase reversal between two prefrontal regions (see arrows). 11/1, 1/2, 2/12 linkages are also possible for transverse recording, although these may have certain disadvantages due to extraneous corneo-retinal field disturbances in leads 11 and 12. This type of shifting delta phase reversal in these special linkages involving prefrontal regions has been found empirically to suggest a deep lesion (especially subfrontal), and not an upper convexity anterior sagittal or parasagittal lesion. This discrimination of depth is not as secure when one has only biprefrontal delta bursts to go by in ordinary monopolar or antero-posterior parasagittal bipolar linkages.

Some uniprefrontal delta focal bursts on the right were also present in this case (not shown). There were no delta waves posterior to interaural line.

Time and voltage calibration in the right lower corner in this and other figures. True occipitals are empty circles in the head diagram posterior to leads 5 and 6 and are usually employed as such.

where. Moderately or markedly abnormal EEG's occurred in association with tumors in all locations, most prominently in olfactory groove meningiomas (100%) (Pavlovski 1958). These tumors pressing against the inferior surface of the frontal lobes occupied a special group showing marked bianterior deltas with posterior part of the brain free, except in 3 cases. These 3 cases with biposterior theta-delta bursts did not

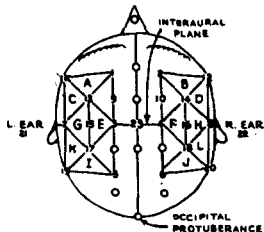
with subfrontal involvement they do (Fig. 2). There are exceptions. The following case illustrates that large pituitary and chiasmatic lesions may give rise to only minor EEG alterations:

C.G. - 49 year old white male. Failing vision, polyuria and polydypsia for five years. Blind O.S. and temporal field loss O.D. Skull X-ray revealed sellar erosion. Pneumoencephalogram outlined a suprasellar lesion. At operation a large

intrasellar chromophobe adenoma with some extension to the inferior frontal area and involving the chiasm and probably neighboring regions was subtotally resected. Preoperative EEG was borderline with slight alpha background suppression on the right.

involvement of the source of projection pathways in the involved side, differential edema, or obscuration of lateralizing signs by generalized signs may play variable roles in these false negative or undetected EEG lateralizations.

Moderate to marked inter-hemispheric shift



CRANIOPHARYNGIOMA
CHIASM, SUB-FRONTAL

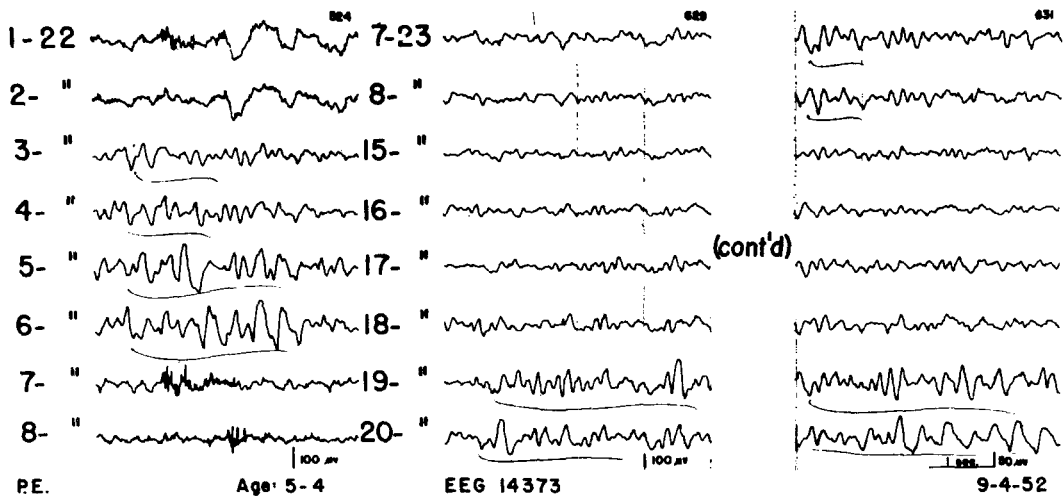


Fig. 2

Golf ball sized craniopharyngioma involving chiasm and third ventricle, midline with right sided extension. Papilledema, headache, nausea and vomiting. Visual fields untestable. EEG background slightly slow occasionally. Irregular theta-delta bursts are seen often and are chiefly in biposterior regions, a little more on the right (last lines, panel 3). In this case, the biprefrontal regions do not show bursts. There are some bimotor theta bursts (lines 3 and 4, panel 1).

Correct EEG lateralizing signs were found in 73 (85%) out of 86 deep tumors, purely lateral or midline with lateral extension (Table II, L). Of the remaining 13 EEG's, EEG lateralization was completely false in 3 and no lateralization was obtained in 10. Of those which were erroneously lateralized, one was in the chiasm, a second in the right lateral ventricle, thalamus and III ventricle, and the third in the left lateral ventricle and white matter. The reasons for these failures are obscure. Contralateral pressure, pathophysiological inter-hemispheric imbalance, expressed transiently in the uninvolved side, non-

of bursting thetas and deltas between homologous regions, either anterior or posterior, occurs (Table II, I, J) in approximately the same proportions (16% and 10%) in deep supra-as in 121 infratentorial lesions (Bagchi *et al.* 1961). However, if one includes mild shift phenomenon relating to all types of waves (not shown on Table II) supratentorial lesions show significantly less incidence of it than infratentorial lesions (shift between anterior homologous regions of the two hemispheres: 41 vs. 79 per cent, shift between posterior homologous regions of the two hemispheres: 24 vs.

48 per cent). In our experience inter-hemispheric shift phenomenon is not very common in cortical lesions. It may occur when these lesions are large enough to touch corpus callosum, roof of the III ventricle or other deeper sites.

Antero-posterior variability of waves of all

somewhat different, but not significantly so, from what is found in posterior fossa tumors (42 vs. 46%) (Bagchi *et al.* 1961). However, there is no statistically significant correlation between either location of bursts and IICP ($X^2 = 0.1$, P 0.70 - 0.80; $X^2 = 1.2$, P 0.20 -

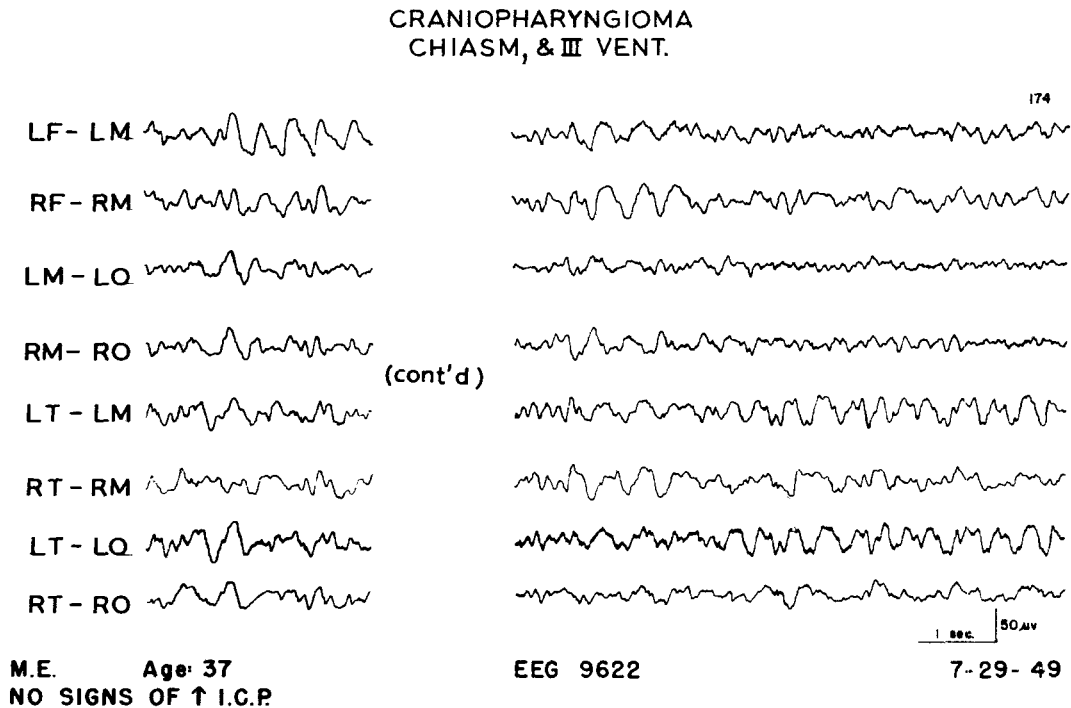


Fig. 3

Large cystic craniopharyngioma in chiasm mainly on the right. Grand mal seizures for one year. Left homonymous hemianopsia. No papilledema nor other signs of increased intracranial pressure. Ventriculogram abnormal without evidence of dilatation of ventricles. Marked bilateral delta bursts anteriorly and posteriorly with right sided emphasis (not shown), and some voltage and wave length and wave form shift between homologous regions (line 1, panel 1 vs. line 2, panel 2; lines 4 and 6 vs. lines 5 and 7, panel 2), which was considered preoperatively suggestive of a deep trigger or lesion (see p. 196).

degrees in 8 per cent of deep cerebral lesions (not shown in Table II) can also be contrasted with 45 per cent in infratentorial lesions (Bagchi *et al.* 1961). Outside of the degree of the shift and antero-posterior variability phenomena; just mentioned, most of the deep non-subfrontal cerebral lesions remain indistinguishable as a group from infratentorial lesions from the standpoint of EEG. This might be expected (Bagchi 1955 b; Van der Drift 1957).

Synchronous bianterior bursts appear to be present oftener than synchronous biposterior bursts (54 vs. 36%) in the total series, which is

0.30). So it may be maintained that probably IICP is not exclusively responsible for EEG burst phenomenon as is sometimes contended. But there is a significant correlation ($X^2 = 9.5$, $P < 0.01$) between burst phenomenon and background slowing. A combination of factors may account for this. Younger age may strike us as one of the factors in the burst phenomenon. Age is significantly correlated with biposterior bursts ($X^2 = 10.29$, $df = 3$, $P < 0.02$) but not with bianterior bursts. However, olfactory groove meningiomas in older age group with almost 100 per cent bianterior bursts may have

overloaded the correlation against age. Bianterior and biposterior bursts are, however, significantly correlated ($X^2 = 19.4, P < 0.01$). All these facts put together raise the suspicion that it is not the factor of IICP or the age alone, but these and particularly the strategic locations of lesions with

relation to other factors thus changing the direction and character of the unstable equilibrium of the entire system.

As mentioned earlier, it has been held by some workers that theta waves are usually associated with deep lesions but our material (not

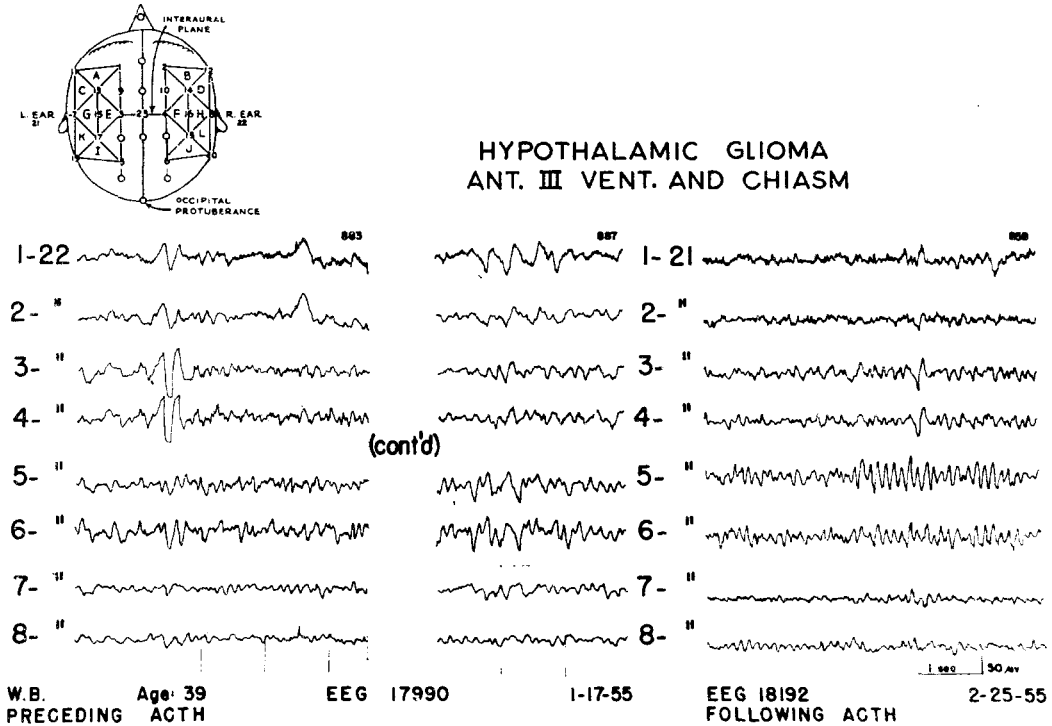


Fig. 4

Glioma of the hypothalamus and region of the optic chiasm and mammillary bodies. Headache, weight gain, polyuria and marked mental confusion for one year. No seizures, no signs of increased intracranial pressure. Spinal fluid protein exceeds 100 mg percent. Neurological examination, skull X-ray and arteriogram negative. Endocrine dysfunction according to biochemical studies. First EEG (left and middle panels, 1-17-55) moderately abnormal with many bianterior and also some biposterior theta-delta bursts. Bimotor bursts (lines 3 and 4, left panel) are not due to sleep. These are part of EEG depth signs (see p. 196). Patient's downhill course continued and she was placed on ACTH without clinical benefit. EEG (right panel, 2-25-55), two weeks later, was markedly improved. Patient died three weeks following and came to postmortem.

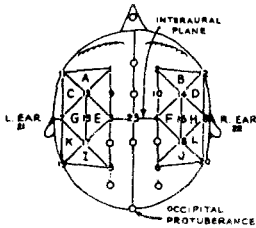
Note: This is the only case of EEG improvement with known brain tumor in this series. It may be speculated that ACTH might have reduced the edema around the lesion, causing recession of the abnormal EEG signs.

their attendant circulatory changes and preferential discharge arcs relaying the electrical counterpart of these changes that play the dominant role in the causation of EEG burst phenomenon at different locations and background slowing. Variations in EEG findings in particular cases would depend upon which important factor overplays or underplays at a particular time in

electronically analysed) does not support this view. Out of 71 cases showing moderate to marked burst phenomenon, 56 revealed primarily delta bursts and 15 theta bursts (not separated in Table II). And in the entire series, theta background slowing (dominant theta or significant theta components — not bursts) in all degrees was present in 68 cases and absent in 49. This

difference is, however, not large enough to permit any definitive conclusion exclusively in favor of thetas in deep cerebral lesions although many individual cases may show that type of background slowing. (The above figures are not

rior theta-delta bursts. Specifically, of all the 16 tumors invading the chiasm without extending to the anterior III ventricle and having field defect and/or atrophy without IICP, only 5 showed biposterior theta-delta bursts (not separated in



G.B.M.
CORPUS CALLOSUM, R. LAT. VENTRICLE
DEEP FRONTAL LOBES

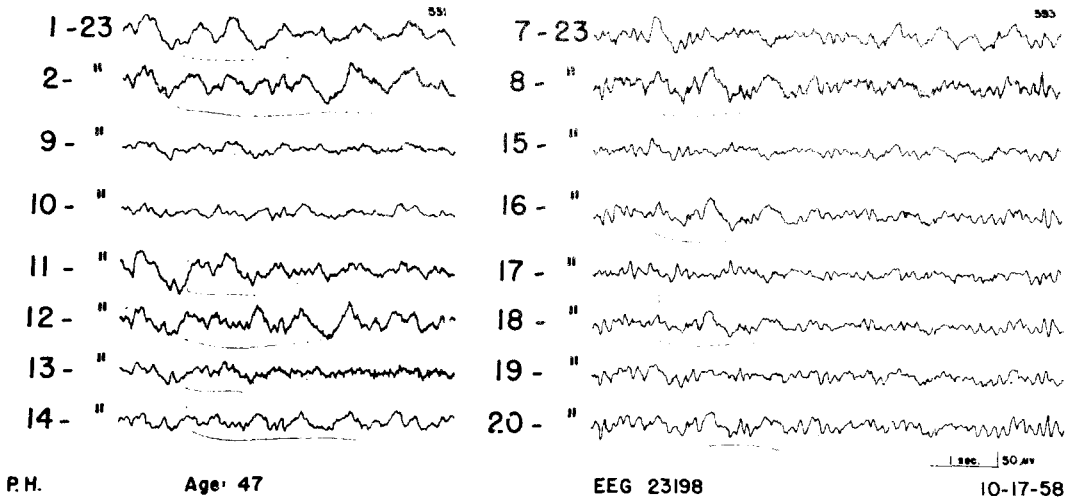


Fig. 5

Extensive glioblastoma multiforme involving the white matter of the right frontal lobe, corpus callosum, right caudate nucleus, and right lateral ventricle with some involvement of the left through the corpus callosum. Two grand mal seizures three months before admission, followed by personality change and confusion. Neurologic examination negative aside from mental change. Skull X-ray, arteriogram, and pneumoencephalogram negative. Moderate increase in cerebral spinal fluid pressure 190 to 210 mm of water.

EEG is profoundly abnormal with bilateral deltas with very slight right sided voltage and wave length emphasis (lines 2, 4, 8, underlined, right panel). Minimal shift is noted between interaural temporal areas (lines 1 and 2, right panel). These are part of EEG depth signs (see text p. 196).

Note: Here the EEG was the only definitive localizing and diagnostic indication of the focal lesion preoperatively.

limited to moderate to marked background slowing as in Table II, H and Table III). Only two cases showed medium to high voltage fast background.

No correlation was found between malignancy and degree of EEG abnormality in deep lesions though that probably is not the case with upper convexity lesions (Bagchi 1955 a,b). In the entire series the disturbance in the visual system could not be statistically correlated with biposte-

rior theta-delta bursts. Again excluding those tumors that had temporal lobe involvement, about half of all tumors (26) invading the chiasm and neighboring regions and producing field defect and/or atrophy had, regardless of the presence or absence of IICP, biposterior bursts and half did not.

DEPTH DIAGNOSIS

It was possible by using the empirical EEG clues mentioned before (p. 196) to suggest,

before operation or postmortem, that there was no evidence of a focal upper convexity lesion and that there was deep disturbance or a deep lesion, without any attempt at structure identification. 64 cases (55%) were considered as revealing such deep level indications preoperatively, and 21

present. These cases were, however, all correctly lateralized. Thus, a strong unilateral EEG focus tended in a few, but not in the majority of cases, to submerge EEG deep level signs either actually or in interpretation. These 18 tumors were distributed over different deep locations.

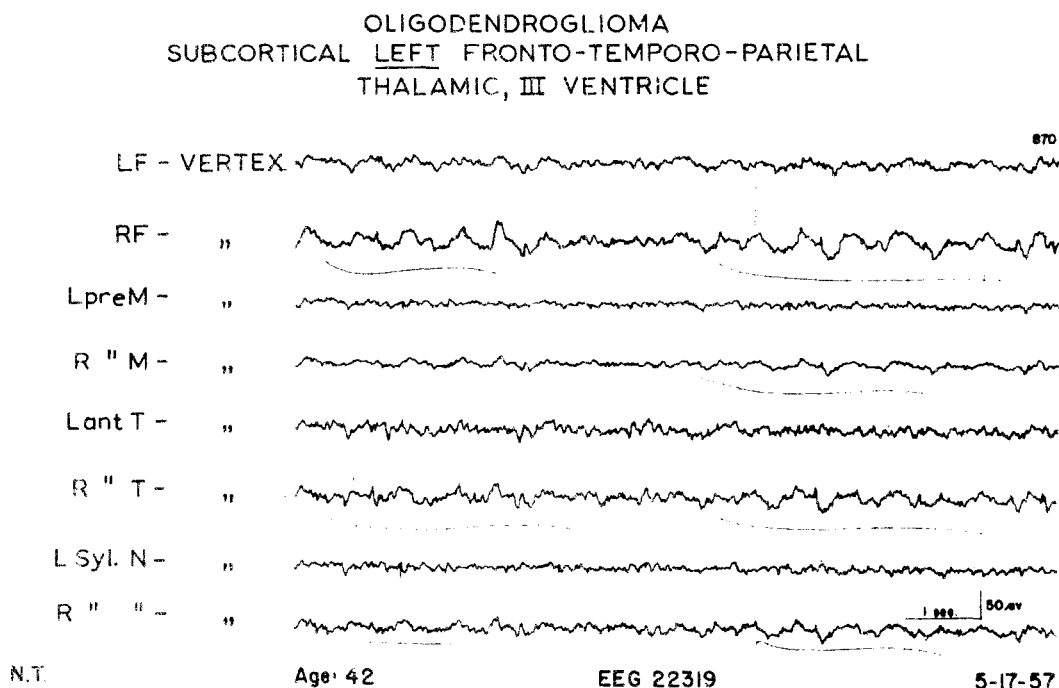


Fig. 6

Huge oligodendroglioma involving medial basilar area of left temporal lobe and hippocampal gyrus and compressing left thalamus. Postmortem verification. Two weeks' history of headache and vomiting. *Left* sided pyramidal tract signs. Skull X-ray negative. Arteriogram revealed a left sided lesion with shift of vessels to right. Early papilledema, OS.

Definite focal irregular deltas on the right side (lines 2, 4, 6 and 8) with little spread to the left. Preoperatively EEG localization was false.

Note: In one epoch only (not shown), with exclusive left ear lobe monopolar linkage, there was suggestive bilateral multilobar theta, probably due to contamination of left ear by the left temporal lesion. This was not considered in view of the strong right-sided focus. Marked compression effect deeply on the right might explain the deltas on that side but the absent EEG focus on the left is unexplained.

(18%) retrospectively (Tables I, III). In the remaining 32 cases (27%) deep pathology could not be suggested by EEG at any time, though EEG abnormality was present in most of them. In 15 of the last group, EEG's were done prior to 1948 and were, in many cases, inadequate by present standards. Also 18 of the cases not revealing EEG depth signs showed a strong unilateral EEG focus which led to the erroneous impression that a superficial cortical lesion was

DISCUSSION

It is clear that even when the cortical mantle is not structurally invaded by lesions lying deep in the brain, abnormal EEG signs are common. A multiplicity of mechanisms and factors are responsible for this. At least two fundamental mechanisms variably interlocked may be considered: (a) neuronal transmission to the cortex of potential changes of deep nuclear masses,

irritated directly or indirectly by a deep tumor, with attendant imbalance between functionally related regions (Bagchi 1955 a,b; Bickford 1957; Cobb 1957; Faure *et al.* 1951), and (b) direct functional derangement of the cortex from below by impairment of circulation to it with attendant edema due to the interposition of a deep tumor. There may be other secondary factors, such as tentorial herniation, IICP. Increased intracranial pressure is not invariably important, as 75 per cent of the 48 cases without IICP showed moderate to marked EEG abnormality. This lack of invariable association between IICP and EEG abnormality has been mentioned by others (Cobb 1944; Cuneo and Rand 1950; Jasper and Van Buren 1953; Williams 1939). The factor of age influences the EEG characteristics as shown before, as may the growth rate of the tumor. The latter could not be assessed. However, at least there is no statistical relationship between the duration of symptoms caused by these tumors and the degree of EEG abnormality in contrast to subtentorial tumors (Bagchi *et al.* 1961).

If the two above mentioned fundamental mechanisms (*i.e.*, neuronal transmission from below and between upper structures and cortical circulatory deficit) are not operative in the case of a deep tumor, theoretically EEG changes should be nil. It is known that the hypophysis is influenced by the hypothalamus releasing neuro-humoral substance in it but direct reverse neural (non-humoral) influence of the hypophysis on the hypothalamus or other deep structure is not known, whatever the delayed and indirect humoral effect may be. This may be pertinent to our, and others', observations that some pituitary tumors, cradled within the sella turcica with minimal involvement of the chiasm, produced no, or less, EEG change than tumors in other locations (Magnus and Van der Drift 1957). Olfactory groove meningiomas or other tumors compressing the inferior surface of the frontal lobe cause strong abnormal bifrontal or bianterior temporal bursts. Vertical fronto-orbital fibres, orbito-antero-temporal uncinat fasciculus, associational and callosal fibre systems must be involved in this cortical abnormality caused by these deep lesions (Dr. Elizabeth C. Crosby, personal communication). Why these tumors, even when they functionally impair the chiasm, do

not usually relay impulses of irritation to the occipital part of the brain over visual radiations and through the lateral geniculate body and pulvinar or over inferior fronto-occipital fasciculus is not clear. The first relay system may be too indirect. Rarely are there bi-aural temporal bursts from olfactory groove meningiomas. These discharges may, in part, be mediated by the involvement of inferior aspect of the inferior frontal occipital fasciculus, or may be directly due to compression effect on the medial surfaces of the temporal lobes. The third possibility is the limited transmission from the anterior to the interaural temporal region. Those chiasmatic tumors that substantially implicate neighboring regions do not show minimal changes.

The role of tentorial herniation in causing EEG changes can not be adequately evaluated because in over 40 per cent of the 41 patients who had autopsy the interval between EEG and date of autopsy was too long, one month to nine months, in 24 per cent, 11 to 30 days. This makes any attempt to relate herniation to the EEG findings of doubtful value. Of the remaining 36 per cent only one had herniation discovered at autopsy six days after the EEG, which incidentally showed marked changes. Another was found to have herniation 24 days after EEG which also showed some changes, and a few after a month or more following EEG. The preponderance of autopsied cases without herniation and with EEG done long before autopsy makes it improbable that tentorial herniation was by and large an important factor in the production of EEG changes in our series.

It is not surprising when III ventricle tumors and median thalamic tumors show EEG abnormality since, in these cases, disruption of activity within the diffuse thalamic projection system is likely to play its role in influencing the cortex. But it is surprising when EEG abnormality is not outstanding in the presence of a large thalamic tumor or III ventricle tumor invading or compressing the thalamus, as has been reported in the literature. It is difficult to ascertain whether such was the case due to the physical attenuation of deep potential changes by the intervening mass of conductive but inactive tissue, or whether the EEG changes were occasional and hence missed, due to short sampling or limited EEG technique,

or whether some other factors, such as differential irritation of the thalamus, are involved. The physical attenuation would not be a satisfactory explanation because it does not answer: why there would be most attenuation in one deep lesion and not in another located in about the same place. In our series, no thalamic tumor was associated with a normal EEG. The mechanism of so-called "distant rhythms" still needs further clarification.¹ Also, whether the phenomenon of shift and that of interareal variability are special variants of "distant rhythms" and not simply meaningless random events will, for the present, remain open questions. Biposterior theta-delta bursts in a few tumors invading the chiasm but not the III ventricle and not producing ICP will remain another unexplained problem, if one exonerates the visual radiation - lateral geniculate - occipital circuit, which we had to do in a large number of such cases (p. 204). One could implicate, for an explanation, the inferior fronto-occipital fasciculus but the negative cases would offer a deterrent from doing so.

It is of interest to the electroencephalographer, and definitely useful to the clinician, to be able to exclude, on the basis of EEG clues, existence of a superficial lesion and to suggest the presence of a deep disturbance, including a structural lesion deep in the brain. As mentioned under *Materials and methods*, different clinical conditions would restrict such a diagnosis. These conditions may give simulated depth signs Bagchi *et al.* 1952; Cordeau 1959). While it may be contended that depth diagnosis by EEG does not have the same clarity as the focal diagnosis by EEG of an upper convexity lesion, depth diagnosis ceases to be misleading if previously mentioned clinical reservations are observed, and a cautious evaluation made and reported on the basis of data adequately gathered. A false positive finding is as undesirable as, if not more than, a false negative finding. It should be kept in mind also that sometimes it is not possible to distinguish between a "surgical" EEG focus and "non-surgical" EEG focus or patho-physiological trigger, either deep or superficial, which appears for a time and disappears after a few months or years. So no mis-

leading EEG statement need be made which may disturb the expectation of a multidimensional approach to a final diagnosis.

SUMMARY AND CONCLUSION

117 patients with verified deep cerebral tumors were studied qualitatively and statistically in relation to 60 clinical and EEG variables. 92 patients had moderate to profound EEG abnormality. The need for adequacy of EEG technique was stressed. Some of the factors causing so-called "distant rhythms" were analyzed.

Statistically significant relationships were present between increased intracranial pressure on the one hand and mental changes, age (downward age gradation) or background theta-delta slowing on the other; between age on the one hand and background theta-delta EEG slowing or biposterior EEG theta-delta burst phenomenon on the other; between bianterior and biposterior burst phenomena. No statistical relationships existed between increased intracranial pressure, on the one hand, and location of tumors, bianterior bursts, biposterior bursts, or thalamic involvement on the other; between background theta-delta slowing and thalamic involvement or anterior or posterior burst phenomenon; between duration of symptoms and degree of EEG abnormality; between age and bianterior bursts. Implications of these correlations are discussed. Particular cases may behave contrary to expectations that these correlations suggest, and show unexplained aberrant signs. Though many factors are independently or cumulatively involved, the strategic location of deep tumors, not necessarily thalamic, is considered one of the most important in the disruption of electro-cortical activity.

Much larger proportion of olfactory groove meningiomas was shown to have bianterior EEG delta abnormality than intra-sellar or restricted chiasmatic tumors. There are various degrees, types and distributions of EEG abnormality in ventricular and white matter tumors. Deep lateral tumors which usually show EEG lateralization may mask EEG depth signs. These EEG depth signs have been empirically structured for aiding interpretation (p. 196). It is contended that within certain clinical reservations these

¹ These rhythms are distant only in the sense that the primary cause lies at a distance, but in reality they are cortico-subcortical manifestations.

EEG depth signs, though not having the same clarity as upper convexity focal signs, have been definitely helpful in ruling out a focal upper convexity lesion and ruling in a deep level disturbance or lesion without structure identification in about three-fourths of the proved cases.

REFERENCES

- BAGCHI, B. K. Pre-operative electroencephalographic localization of brain tumors. Chapter 18, in T. SHEDLOVSKY (Editor), *Electrochemistry in biology and medicine*. Wiley and Sons, New York, 1955a, pp. 331-351.
- BAGCHI, B. K. Electroencephalographic localization of intracranial tumors. Chapter 3 in E. A. KAHN, R. C. BASSETT, R. C. SCHNEIDER and E. C. CROSBY (Editors), *Correlative neurosurgery*. C. C. Thomas, Springfield, Ill., 1955b.
- BAGCHI, B. K. and BASSETT, R. C. The localization of intracranial lesions by EEG. *Univ. Mich. Hosp. Bull.*, 1943, 9: 86-87.
- BAGCHI, B. K. and BASSETT, R. C. Some additional EEG techniques for the localization of intracranial lesions. *J. Neurosurg.*, 1947, 4: 348-369.
- BAGCHI, B. K., HOWELL, R. W. and SCHMALE, H. R. The EEG and clinical effects of electrically induced convulsions in the treatment of mental disorders. Appendix. *Amer. J. Psychiat.*, 1945, 102: 49-61.
- BAGCHI, B. K., KOOL, K. A., SELVING, B. T. and CALHOUN, H. D. Posterior fossa lesions: An EEG study of 121 cases. *Electroenceph. clin. Neurophysiol.*, 1963, 13: 180-192.
- BAGCHI, B. K., LAM, R. L., KOOL, K. A. and BASSETT, R. C. EEG findings in posterior fossa tumors. *Electroenceph. clin. Neurophysiol.*, 1952, 4: 23-40.
- BICKFORD, R. G. EEG diagnosis of brain tumors. *Amer. J. Surg.*, 1957, 93: 946-951.
- BROGLIA, S. and POSTIR, A. Comparative EEG studies of subtentorial and third ventricle tumours. *Minerva Chir. (Torino)*, 1956a, 11: 457-460.
- BROGLIA, S. and POSTIR, A. EEG aspects of 100 tumors of the posterior fossa and 40 of the third ventricle. *Riv. Neurol.*, 1956b, 26: 29-50.
- BUCY, P. C. and CASE, T. J. An association between homonymous hemianopsia and unilateral absence of the alpha waves. *Trans. Amer. neurol. Ass.*, 1946, 66: 17-20.
- CASE, T. J. Association of homonymous hemianopsia and unilateral absence of alpha waves. *Arch. Neurol. Psychiat. (Chicago)*, 1940, 43: 1273-1274.
- COBB, W. A. The electroencephalographic localization of intracranial neoplasms. *J. Neurol. Neurosurg. Psychiat.*, 1944, 7: 96-102.
- COBB, W. A. Electroencephalographic abnormalities as signs of localized pathology. EEG abnormalities at a distance from the lesion. *Quatrième Congr. Intern. Electroenceph. Neurophysiol. clin. (Bruxelles)*, 1957, pp. 205-223.
- COBB, W. A. and MULLER, G. Parietal focal theta rhythm. *Electroenceph. clin. Neurophysiol.*, 1954, 6: 455-460.
- CORDEAU, J. P. Monorhythmic frontal delta activity in the human EEG: a study of 100 cases. *Electroenceph. clin. Neurophysiol.*, 1959, 11: 733-746.
- CUNEO, H. M. and RAND, C. W. Analysis of EEG findings in 40 cases of verified brain tumours. *Bull. Los Angeles neurol. Soc.*, 1950, 15: 22-36.
- DALY, D. D. and THOMAS, J. E. Sequential alterations in the EEG's of patients with brain tumours. *Electroenceph. clin. Neurophysiol.*, 1958, 10: 395-404.
- DALY, D., WHELAN, J. L., BICKFORD, R. G. and MCCARTY, C. S. The EEG in cases of tumours of the posterior fossa and third ventricle. *Electroenceph. clin. Neurophysiol.*, 1953, 5: 203-216.
- DRIFT, J. H. A. VAN DER. *The significance of electroencephalography for the diagnosis and localization of cerebral tumours*. H. E. Steniert Kroese. Leiden, 1957.
- FAURE, J., DROOGLEEVER-FORTUYN, J., GASTAUT, H., LARRAMENDI, L., MARTIN, P., PASSOUANT, P., REMOND, A., TITECA, J., et WALTER, W. G. De la genèse et de la signification des rythmes rectoëpis à distance dans les cas de tumeurs cérébrales. *Electroenceph. clin. Neurophysiol.*, 1951, 3: 429-434.
- FISCHGOLD, H., DREYFUS-BRISAC, C. et CANALI, G. La réaction d'arrêt dans les tumeurs occipitales, pariétales et temporales. *Rev. neurol.*, 1949, 81: 536-537.
- GREENSTEIN, L. and STRAUSS, H. Correlation between the EEG and the histological structure of gliogenous and metastatic brain tumors. *J. Mt. Sinai Hosp.*, 1945, 12: 874-877.
- HOFFER, P. F. A., SCHLESINGER, E. B. and PENNES, H. H. Clinical and EEG findings in a large series of verified brain tumors (Discussion on paper). *Trans. Amer. Neurol. Ass.*, 1946, 71: 52-57.
- JINGHIRAMI, J. et CAPDEVILLE, G. A. Notes sur l'EEG de quelques tumeurs thalamiques. *Rev. Neurol.*, 1954, 90: 320-321.
- JASPER, H. and VAN BUREN, J. Interrelationship between cortex and subcortical structures: (clinical) EEG studies. *Electroenceph. clin. Neurophysiol.*, 1953, Suppl. 4: 168-188.
- JUS, A. et JUS, C. Les lésions de la base du cerveau et leur expression électroencéphalographique. *Paris méd.*, 1947, 37: 593-595.
- KIRSTEIN, L. The occurrence of sharp waves, spikes, and fast activity in supratentorial tumours. *Electroenceph. clin. Neurophysiol.*, 1953, 5: 33-40.
- KLASS, D. W. and BICKFORD, R. G. The EEG in metastatic tumours of the brain. *Neurology (Minneapolis)*, 1958, 8: 333-337.
- LAIRY-BOUNES, G. C., et DREYFUS-BRISAC, C. EEG des tumeurs hémisphériques intra et sous ventriculaires. *Rev. neurol.*, 1950, 83: 613-618.
- LAM, R. L. An unusual electroencephalogram associated with thalamic tumor. *Electroenceph. clin. Neurophysiol.*, 1950, 2: 329-330.
- LAUFER, M. W. Some electroencephalographic findings in subcortical and hypothalamic lesions. *J. nerv. ment. Dis.*, 1947, 106: 527-536.
- LOEB, C. and POGGIO, G. F. Distribution and character-

- istics of the electrical rhythms of the brain in 100 cases of supratentorial tumors. *Riv. Neurol.*, **1953**, *23*: 481-486.
- LONDOÑO, R. EEG in adenomas of the hypophysis and in craniopharyngiomas. *Neurocirugia*, **1957**, *15*: 50-53.
- LONGO, P. W., PUPO, P. P., PAZZANESE, O. et PIMENTA, A. M. Résultats électroencéphalographiques dans 33 cas de tumeurs intra-craniennes chirurgicalement vérifiés. *Arch. Neuro-psiquiat. (S. Paulo)*, **1950**, *8*: 43-46.
- MAGNUS, O. and VAN DER DRIFT, J. H. A. The significance of the EEG for the diagnosis and localization of cerebral tumours. *Folia psychiat. neerl.*, **1957**, *60*: 118-125.
- MCDONALD, C. A. and KORB, M. Brain tumor with normal brain potentials. *R.I. med. J.*, **1940**, *23*: 111-113.
- PAILLAS, J. E., GASTAUT, H., TAMALET, J. et VERSPICK. Valeur de l'électroencéphalographie pour la diagnostic des tumeurs cérébrales. *Presse méd.*, **1948**, *56*: 851-853.
- PARAT, J. Valeur localisatrice de l'EEG dans les tumeurs de la fosse antérieure. *Rev. Neurol.*, **1948**, *80*: 627-628.
- PAVLOVSKI, Y. M. Some problems on the subject of diagnosis of tumors of the base of the frontal region. *Nevropat. i Psihiat.* **1958**, *58*: 521-525.
- SARKISOV, S. A. and PENZIK, A. S. The electroencephalogram in cases of cerebral tumors. *Acta med. URSS*, **1939**, *2*: 185-190.
- SCHLESINGER, B. and STRAUSS, H. Comparison of pneumoencephalography and electroencephalography in brain tumors. *J. Mt Sinai Hosp.* **1947**, *14*: 47-50.
- SILVERMAN, D. and GRAFF, R. A. Brain tumor depth determination by electrographic recordings during sleep. *Arch. Neurol. Psychiat. (Chicago)*, **1957**, *78*: 15-28.
- STEINMANN, H. W. und TÖNNIS, W. Das EEG bei intrakraniellen raumbeengenden Prozessen. *Zbl. Neurochir.* **1953**, *13*: 129-146.
- STEPHENSON, W. A. Intracranial neoplasm associated with 14 and 6 per second positive spikes. *Neurology (Minneapolis)*, **1951**, *1*: 372-376.
- TERZIAN, H. and CECOTTO, C. Electroencephalograms in tumors of the basal nuclei regions. *Riv. Neurol.*, **1954**, *24*: 752-759.
- TÖNNIS, W., STEINMANN, H. W. und KRENKEI, W. Elektroencephalographische Befunde bei 44 Tumoren der Sellagegend. *Acta neuroveg. (Wien)*, **1953**, *5*: 291-305.
- WALTER, W. G. The localization of cerebral tumors by EEG. *Lancet*, **1936**, *2*: 305-308.
- WALTER, W. G. The EEG in cases of cerebral tumors. *Proc. royal. Soc. Med.*, **1937**, *30*: 579-598.
- WALTER, W. G. Electroencephalography in the diagnosis of cerebral tumor and abscess. *Pract. oto-rhino-laryng. (Basel)*, **1940**, *3*: 17-26.
- WALTER, W. G. and DOVEY, V. J. Electroencephalography in cases of subcortical tumor. *J. Neurol. Neurosurg. Psychiat.*, **1944**, *7*: 57-65.
- WALTER, W. G., GRIFFITHS, G. M. and NEVIN, S. The electroencephalogram in a case of pathological sleep due to hypothalamic tumor. *Brit. med. J.* **1939**, *1*: 107.
- WILLIAMS, D. The abnormal cortical potentials associated with high intracranial pressure. *Brain*, **1939**, *62*: 321-334.
- WILLIAMS, D. and GIBBS, F. A. Localization of intracranial lesions by EEG. *Arch. Neurol. Psychiat. (Chicago)*, **1939**, *41*: 519-534.
- YEAGER, C. L. and LUSE, S. Electroencephalographic localization and differentiation of lesions of frontal lobes with pathological confirmation. *Arch. Neurol. Psychiat. (Chicago)*, **1945**, *54*: 197-201.

Reference: SMALL, J. G., BAGCHI, B. K. A. and KOOL, K. A. Electro-clinical profile of 117 deep cerebral tumors. *Electroenceph. clin. Neurophysiol.*, **1961**, *13*: 193-207.