CLINICO-ELECTROENCEPHALOGRAPHIC
STUDY OF 3200 HEAD INJURY CASES
—A COMPARATIVE WORK
BETWEEN AGED, ADULTS AND CHILDREN

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The modern civilization has made much to our welfare, but it has also brought various kinds of harms to our society. One of them is the traffic accidents which has become a serious social problem. The head injuries by the accidents have considerably increased as the automobiles have been popularized. It is necessary to know the kinds and degrees of the brain damages by the trauma to interpret the diagnosis of the head injuries and the convalescence. EEG is the most useful method to this and, though many techniques have been devised. With it, we can detect the degree of the head injury and the presence of the intracranial complication without giving any pains and physical burdens to the patients.

We followed up about 3,800 cases underwent EEG examinations of the head injured patients who visited out-patient clinic, Department of Surgery, Keio Univ. Hospital, until July, 1968, and investigated the relationship between the clinical and EEG findings by dividing them into three age groups; the children, the adults and the aged.

METHOD AND MATERIAL

Recording was performed by 12 and 13 channels EEG machine supplied by NIHON KOHDEN KOGYO CO., LTD. The electrode system was the silver disc type and 18 electrodes were set independently in frontal, pre-central, central,

Fig. 1.

parietal, occipital, anterior temporal, midtemporal, posterior temporal in bilateral hemispheres and both ear lobes (Fig. 1). The period of time of the total recording was amounted 22—24 mins altogether which composed of 8 mins monopolar recording from each ear lobe reference, 6 mins bipolar recording.

The recording was proceeded under 2-3 mins, photic stimulation and 3 mins hyperventilation activation period and the recording at least for additional 3 mins was taken after the withdrawal of the hyperventilation. Further, recording was carried out by adding necessary numbers of the electrodes on the appearance of the focal abnormality or asymmetry.

We followed up about 3,800 cases underwent EEG examinations to the patients of the head injuries for five years and six months, from Jan., 1963 to June, 1968. We crossed out the incomplete records of the clinical pictures and, then, 3,284 cases were finally investigated. Fifteen hundreds and eighty cases were classified as the children (0—15 yrs); 1,110 cases as the adults (20—49 yrs); and 594 cases as the aged (more than 50 yrs). When two or more EEG examinations were performed, the initial one was adapted as material to be checked.

RESULTS

The results are summarized in Fig. 2A. In the adults, 23.8% of the cases were evaluated abnormal, 8.3%, borderline; and 67.9%, normal. In the children, 49.2% were found abnormal; 14.6%, borderline; and 36.2%, normal. In the aged, 35.4% were abnormal; 12.1%, borderline; and 52.5%, normal. The abnormal tracing was found most frequently in the children group, and next to it was in the aged group.

We arranged the cases of the consciousness disturbances in seven classes according to the interval of the unconsciousness; 1) absence of the unconscious-

Table 1
Unconsciousness and EEG Abnormality

Interval of unconsciousness	Interval head injury to EEG	Abnormal			Border line			Normal		
		0~15	20~49	50~	0~15	20~49	50~	0~15	20~49	50~
None	1 W>	16	8	7	8	2	6	36	26	33
	2 W>	29	6	10	16	7	13	46	40	38
	1 M>	97	25	20	40	14	13	156	145	53
	3 M>	85	39	13	39	14	14	108	154	37
	6 M>	56	18	1	25	9	3	39	75	12
	6 M<	120	32	6	45	44	0	51	104	26
Within 10 min	1 W>	6	2	11	0	0	1	2	4	11
	2 W>	14	2	11	1	2	2	8	12	19
	1 M>	53	4	18	7	4	3	26	28	9
	3 M>	39	8	12	4	3	1	17	30	7
	6 M>	19	9	2	2	0	0	3	8	2
	6 M<	36	5	5	5	1	1	4	16	5
Within 1 hr	1 W>	1	0	3	1	0	0	0	0	1
	2 W>	3	1	4	0	1	1	2	5	1
	1 M>	28	5	3	6	1	2	7	11	5
	3 M>	23	11	4	2	1	0	2	14	1
	6 M>	8	3	1	1	0	0	0	7	3
	6 M<	10	1	3	3	1	1	3	5	4
Within 6 hrs	1 W>	0	0	3	0	0	0	0	1	1
	2 W>	1	0	2	1	0	0	3	0	0
	1 M>	8	1	6	0	3	0	3	1	1
	3 M>	6	5	1	2	2	1	3	10	3
	6 M>	6	0	1	1	1	0	0	5	3
	6 M<	6	3	4	2	1	1	1	6	3
Within 24 hrs	1 W>	1	0	0	0	0	1	0	1	1
	2 W>	2	0	0	0	0	0	1	0	0
	1 M>	7	4	1	0	0	0	4	1	0
	3 M>	3	1	1	1	2	0	1	3	2
	6 M>	4	1	1	1	0	0	0	0	1
	6 M<	2	4	2	0	0	0	2	1	0
Over 24 hrs	1 W>	1	0	1	0	0	0	0	0	1
	2 W>	3	2	2	2	0	0	1	1	0
	1 M>	7	1	4	0	1	1	3	12	2
	3 M>	10	11	4	1	1	0	2	7	0
	6 M>	8	12	3	0	1	0	2	3	3
	6 M<	16	16	8	2	3	2	1	5	3
Unknown	1 W>	3	0	2	0	1	0	2	0	1
	2 W>	7	0	2	2	1	1	4	3	2
	1 M>	11	0	12	6	0	1	14	8	10
	3 M>	8	2	6	4	0	1	9	8	5
	6 M>	7	1	7	1	2	0	7	3	1
	6 M<	5	8	6	5	3	0	2	0	1
Total		775	251	213	230	96	70	575	763	311

ness, 2) the interval within 10 mins, 3) the interval within 1 hr, 4) the interval within 6 hrs, 5) the interval within 24 hrs, 6) the interval more than 24 hrs, 7) Skeptic existence of the interval of the unconsciousness or the possible existence for the unknown period (Table 1). In the cases of the absence of the unconsciousness, the abnormal tracing was obtained in 19% of the adult group and the normal tracing was noted in 73% of the same group, and in the aged 18% were abnormal and 65% were normal; between both groups little differences were found. In the children group 40% showed abnormal and 43% were normal. The incidence of the abnormal EEG was higher in the children than in the adults and the aged and similar tendency was found in the case of slight trauma (Fig. 2B). Much the same rates of the appearance of the abnormal EEG were

Fig. 2.

observed through the case of absence of the unconsciousness and cases of the time interval of the unconsciousness less than 10 mins, in each age group. The incidence became increasingly higher when the interval exceeded 10 mins. The rate in the cases of the interval within one hour became twice as high as the cases of absence of the unconsciousness, both in the children and the aged, but

not in the adults in which they were found indifferent. The high incidence was noted in the cases of the unconsciousness more than one hour in each age group (Fig. 3).

Fig. 3.

The time interval between the EEG recording and the onset of the trauma is significant. The EEG examination was performed from 3 wks to 3 mths after the trauma when the clinical symptom was supposed to be settled. The correlation between the EEG abnormality and the unconsciousness was, then, investigated. The abnormality appeared in 39% of the children, 18% of adults, and 22% of the aged in the cases of the unconsciousness within 10 mins. If more than 10 mins, it appeared twice as frequently as the above; in 66% of the children, 38% of the adults, and 63% of the aged. The longer the time interval of the unconsciousness was, the higher the appearance rate of the abnormal tracing was. The correlation between these two elements are summarized in Fig. 4.

Unconsciousness & EEG abnormality

(EEG was taken between 2 weeks & 3 months after head injury)

Fig. 4.

Fig. 5.

In Fig. 5 (A), relationship between EEG and the skull fracture is shown separately according to the age group. The skull fractures were found in 4% of the adults and 4.5% of the aged, but in 12.8% of the children three times as much as the above two. In Fig. 5 (B), the incidence of the abnormal EEG of the patients who suffered the skull fractures showed separately according to the age group. Fifty two percent of the children and the aged, and 47% of the adults showed abnormal tracing, and little difference was found between the adults and the others. It may be presumed that abnormal EEG was found in half of the patients who suffered the skull fracture.

The detail analysis of 1,239 EEG pictures interpreted abnormal was summarized in Table 2. We omitted the EEG picture which were too few to be compared each other and which showed insignificant differences through the

Table 2
Details of Abnormal EEG

			child (775)	Adult(251)	Aged (213)
Asymmetry between homologous reginos			5.9 %	8.9 %	7.6 %
Burst or burst like activity	δ		6.6	2.6	13.5
	θ		33.6	12.4	20.6
	α		5.4	25.2	18.2
Shifting burst			1.3	3.5	17.1
Focus	δ		2.5	8.9	21.2
	θ		3.3	5.1	10.6
	α		0.2	2.2	11.2
Spike			4.6	0.9	0
Spike and wave			7.7	0.6	0
Sharp wave			10.7	8.9	6.5
Diffuse slow waves			3.3	2.9	9.4
Biposterior superimposed δ & θ			26.5	7.0	4.4
Diffuse low voltage fast activity			0.9	6.7	7.1
Anterior psoterior voltage equilibrium			0.4	4.8	5.9
Slowing of background activity			0.5	0.6	32.4
Hyperventilation	During H. V.	asymmetry or focus	1.0	4.4	8.2
		spike or spike and wave	0.2	0.6	0
		early builp up	5.1	0	0.5
	After H. V.	asymmetry or focus	3.0	11.2	5.3
		spike or spike and waves	2.1	1.3	0
		prolonged build up	18.4	10.2	8.8
Photic stimulation			2.3	1.3	0

age groups. The asymmetric tracing the homologous regions of the bilateral hemisphere was recorded in 5.9% of the children, 8.9% of the adults and 7.9% of the aged. It was mainly noted in temporal in the children and the adults, and in occipital in the aged.

The commonest manifestation of the post-traumatic EEG in our series was

Fig. 6.

burst appearance, and θ -burst appeared most frequently in 38.7% of whole cases (Fig. 6). Frequency band constituted burst were; in the children δ -wave occupied 6.6%, θ -wave, 33.6%, and α -wave, 5.4%. θ -wave was predominant in the group. In adults α -wave predominance was observed; δ -wave occupied 2.6%; θ -wave, 12.4%; and α -wave 25.2%. Burst appeared frequently as a whole in the aged and θ -wave was found most frequently; δ -wave occupied 13.5%; θ -wave, 20.6%; and α -wave, 18.2%. Characteristic was that δ -wave occupied larger segment in the aged than in the children and the adults. In Fig. 7,

Burst or Burstlike waves
(Incidence of δ , θ , & α band waves)

Fig. 7.

percentage of δ , θ and α burst is shown separately according to the age groups; the dominant θ -wave occupied 73.6% of burst in the children; α -wave, 62.2% in the adults; δ -wave, 23.0% in the aged which was considerably different with 14.4% of the children and 6.3% of the adults.

Shifting type of burst was noted in 11 cases (1.3%) in the children, 11 cases (3.5%) in the adults and 33 cases (17.1%) in the aged. It means it was frequently observed only in the aged.

Spike and spike and wave complex occupied 36 cases (4.6%) and 54 cases (7.7%) respectively in the children but only 3 cases (0.9%) and 2 cases (0.6%) respectively in the adults. They were not observed only in the aged (Fig. 8).

Fig. 8.

Sharp wave was noted in 114 cases (10.7%) in the children, 33 cases (8.9%) in the adults, and 16 cases (6.5%) in the aged. The incidence decreased as the age of group increased. The incidence of the focal abnormality, on the contrary, increased according to the order of the age as shown in Fig. 9. The tracing particularly observed in the aged; δ -wave focus was noted in 2.5% of the children cases, 21.2% of the aged, 8 times as high as the former, and 8.9% of the adults. θ -wave focus was observed in 3.3% of the children, 5.1% of the adults, and 10.6% of the aged. As to the location of focus, it appeared in 34 cases in the temporal and 29 cases in the frontal in the children, 37 cases in the temporal and 12 cases in the frontal in the adults, revealing 3:1 predominance to the temporal, and 81 cases in the temporal and only 4 cases in the frontal in the aged showing 20:1 predominance to the temporal.

The diffuse slow wave was observed in 3.3% of the children 2.9% of the adults, and relatively frequently 9.4% of the aged. The posterior random δ - θ

Fig. 9.

were recorded in 26.5% of the children, frequently 7% of the adults and 4.4% of the aged. The anterior random δ - θ were observed in 7% of the children and the adults, but not in the aged. The posterior slow wave was, on the contrary, rarely noted in 0.4% of the children, 0.6% of the adults, but characteristically high 32.4% of the aged. Anterior posterior amplitude equilibrium was recorded in 0.4% of the children and 4.8% of the adults, but 5.9% of the aged. Diffuse low voltage, diffuse mono-rhythmic α and anterior half amplitude emphasis were noted in the aged and less frequently in the children and adults, as to anterior half θ episode, central θ episode and such, the significant differences were not observed among the aged groups. As to the activation effects, the appearance of the abnormal tracing by the hyperventilation and the photic stimulation was frequently noted in the children cases (Table 2). The hyperventilation produced asymmetry in 1.0% of the children, 4.4% of the adults and 8.2% of the aged. The adults and the aged were more easily activated by hyperventilation than the children. Spike and wave complex was observed in 7.7% of the children and 0.6% of the adults, but not in the aged. The early appearance of build up was noted nothing in the adults, but in 5.1% of the children and 0.5% of the aged. The resting record after the hyperventilation revealed relatively frequent asymmetry or focal abnormality; in 3.0% of the children, 11.2% of the adults and 5.3% of the aged. And spike or spike and wave complex was found in 2.1% of the children and 1.3% of the adults, but not in the aged. The prolonged appearance of build up was seen in 18.4% of the children, in 10.2% of the adults and in 8.8% of the aged. The activated abnormality by the photic stimulation appeared in 2.3% of the children, 1.3% of the adults and the aged were not activated entirely.

DISCUSSION

Many reports of EEG recording of the head trauma have been made public, but they are notably different each other about the incidence of the abnormal tracing. In the adults, the rate was 52% by Gastaut,³ 31.6—39.5% by Frantzen,² 23% by Okumura,¹⁶ and 19% by ourselves. Among the reports in which the high rate was observed, Lechner¹² (within 8 days after the trauma) reported 96.8%; Mitsumune,¹³ 81% including borderline cases; Yoshii,²² 28.8% without consciousness disturbance, and 69% with unconsciousness for more than 24 hrs. In the cases of the children who suffered the head injuries, the appearance rate was 45.7% by Mizue,¹⁵ 29% of the very slight cases, 68% of the slight cases, 90% of the intermediate cases and 100% of the serious cases by Silverman;¹⁹ 69% (below 12 yrs old) by Gastaut;³ 83.3% (within a month after the trauma) by Kuromaru.¹⁰ For the rate of the appearance of the abnormal tracing varies according to the degree of trauma of the patient group to be examined, and as Kiloh⁹ pointed out the head trauma is a process which accompanies advance and retreat, and type and lapse of the trauma vary with the individual patient. Furthermore the secondary symptoms like the fluctuation of the consciousness and the intracranial pressure vary themselves, and of the patient is a factor which influences the degree of the abnormality. The recent knowledge of the EEG and the diffusion of EEG machine did much toward tendency of recording EEG even in the slightest case. Difference between the central part of the large city and the suburban district and between the univ. hospital and the private clinic must be counted. The above mentioned are the explanations why there have been disagreements among investigators about the rate of the appearance of the abnormal EEG.

Williams²⁰ considered the duration of post traumatic amnesia as an index to evaluate the degree of the head injury. We took the time interval of the unconsciousness as an index of the appearance rate of the EEG abnormality and observed that they were paralleled.

The most frequently observed EEG fluctuation after the trauma was a phenomenon which period of the basal rhythm became delayed or disturbed. According to Williams and Denny-Brown,²¹ a concussion of the brain given to animals caused a reduction or disappearance in amplitude of the electric activity on the whole cerebral cortex, slow wave, then, appeared as the consciousness recovered, and finally, the normal EEG reappeared. That is, the amplitude of EEG was decreased or, sometimes, completely suppressed immediately after the trauma. Such state continued for 10—80 secs, and then δ -wave appeared for

10—160 secs until normal EEG was restored.

Pampus *et al*¹⁸ examined the knocked out boxers and found an appearance of slow wave and a comparatively low voltage activity accompanied by an apparent decrease or disappearance of α -wave. Their EEG examination after 3 days disclosed a return of α -wave and still remaining slow wave. In less severe cases, frequency of a basal wave was 7-8 cycles and normal frequency was recovered within 2-3 days. The basal frequency decreased to 4-6 cycles in the case of the serious trauma. Kiloh⁹ reported that the time when such slowing activity took place was significant for interpreting the prognosis, and that if it took place within the first 48 hrs, after the trauma, the prognosis would be unfavorable, and if after 48 hrs favorable.

It was considered that the basal rhythm become gradually into the slow wave range under the secondary influence. Dawson¹ reported that EEG tracing which had the basal frequency of less than 4 cycles was rarely found and any electric activity would disappear in this degree. Katsura *et al*⁷ reported that a fast wave was the basal wave of EEG vicissitudes on the damaged part of the brain at the time of the head injury, and that a local slow wave of overlapped fact appeared when local damage of the brain was slight, and the slow wave was due to the cerebral edema or similar cause.

According to Hachiya,⁴ on the other hand, the slow wave of high voltage appeared from all regions and lasted for a long time in the severer cases, and local low voltage slow wave and frequent fast low voltage wave appeared in the slight traumatic cases. According to him, the degree of the trauma could be assumed by the quantity of slow waves appeared and their lasting time. In our results, a slow wave appeared most frequently especially in the aged; 48% of the children, 35% of the adults and 85% of the aged. Mitsumune¹³ and Okumura¹⁶ obtained 40% and 58% of the appearance rate respectively, and our average rate was close to them. Random slow wave in the posterior half of the brain appeared frequently in the children.

The appearance of focal abnormality indicated the existence of the local disorder like cerebral edema, hematoma and such but the focal abnormality was, occasionally transient and unsettled and supposed to be due to the edema and vascular disturbance of the brain. And, the focal abnormality become apparent in some instances as the diffuse abnormality disappeared. We observed that a slow wave focus, δ wave focus particularly in the aged, was frequently found.

Heppenstalle and Hill⁵ reported that the EEG abnormality which lacked any neurological symptom after the trauma was due to the brain damage by the trauma only when a local abnormality was noted, and that diffuse bilateral

symmetric abnormality was due to the constitutional abnormality rather than the brain damage by the trauma. We think that the age of a patient as a factor gives the considerable influence on his EEG at the time of trauma. A child is easily influenced by the internal or external stimulation because his brain is still growing. It can be inferred from the facts that he is easily seized up with convulsion by fever and the early convulsion by a slight trauma. Slow wave is readily activated by the slightly low level of blood sugars during hyperventilation in the children.

Lorenzoni¹¹ and Izumi⁶ pointed out that a child tended to show the violent fluctuation of EEG, but rapidly recover normality. Kellaway⁸ reported that the severe trauma often aroused unreversal EEG fluctuation in the children. According to him, 2-3 weeks were needed in adults and at least a month, sometimes several years needed in the children to reach to a state of EEG equilibrium. Generally speaking, however, the acute paroxysmal abnormal wave is due to the violent change of the brain and is transient.

We observed that spike, spike and wave complex and sharp wave frequently appeared in the children. Kuromaru recorded frequent sharp wave and spike and wave complex in the younger age group of less than 5-6 yrs. According to him they appeared in 58% of the children and 15-25% of the adults, but we found them in 4.6% of the children, 0.9% of the adults and nothing in the aged. The repeated appearance of spike and sharp wave coincides with the high occurrence rate of epilepsy after the trauma in the children. The trauma brought about spike and spike and wave complex, but it is not certain whether the trauma was a trigger of the abnormality or the abnormality already existed before the trauma. Since we have not recorded such high appearance rate of spike in examination EEG of the children other than the trauma, influence by the external force on the brain and spike would be, to some degree, closely associated. Though we have not recorded the appearance rate of epilepsy, according to Kuromaru, it appeared in 17.2% of the children. It less frequently appeared in the adults; 3.34% by Kuromaru¹⁷ and 7.9% by Miller.¹⁴

The focal abnormality of the aged was mainly δ -wave which was concentrated on temporal lobe. It was due to the transient circulatory interception of middle cerebral artery especially sylvian sulcus and its surrounding brain tissue rather than cerebral organic disturbance. The frequent change in the basin of middle cerebral artery reflected on the phenomenon that the intermittent focal slow wave were repeatedly found in the old man's high blood pressure and cerebral arterial sclerotic patient. To imagine such mechanism at the time of trauma helps to understand the EEG fluctuation. The appearance of temporal focal abnormality

which we repeatedly observed can be understood by considering that most of the cases of the brain system damage are found in anterior temporal region and frontal lobe. It is very important to know the degree of cerebral arterial sclerosis by the old age in examining EEG of the aged. In the above instance, θ -wave of the temporal region was mainly taken, however our research showed the high appearance rate of δ -wave. We think abnormal when θ -wave too often appeared comparing with the patient's age, and distinguish it from EEG fluctuation by cerebral sclerosis by ageing.

The hyperventilation was thought to be very effective to the head injuries in order to rule out the latent abnormality which otherwise manifested to be normal while keeping quiet. The frequent early appearance of build up was found with spike and spike and wave complex during the hyperventilation in the children. Asymmetry and focal abnormality were activated in the adults and the aged.

Prolonged build up appearance was frequently noted after the hyperventilation in the children. Asymmetry and focal abnormality appeared both in the adults and the aged, but no spike was found in the aged. Abnormal wave by the photic stimulation was activated only in the children and the adults. Therefore, the activated EEG is necessary particularly in the children.

ABSTRACT

Divided 3,284 patients of the head injuries into three age groups, the children, the adults, and the aged, and investigated the relationship of their clinical pictures, X-ray evidences, and EEG abnormality.

1) EEG abnormality of the head injuries most frequently appeared in the children (49%), less frequently in the aged (35%), and least frequently in the adults (24%).

2) As to the relationship between the consciousness disturbance and EEG abnormality, 10 mins interval of the unconsciousness became a borderline; the abnormal EEG more frequently appeared, when the unconsciousness was more than 10 mins.

3) The diffuse abnormality frequently appeared in the children, and the frequent focal abnormality was found in the aged.

4) About half of the patients of skull fracture showed the abnormal EEG.

5) As to burst, theta waves frequently appeared in the children; alpha range wave in the adults; and delta waves in the aged.

6) Spike, spike and wave complex, and sharp wave were mainly found in

the children.

7) The slowing trend like diffuse slow wave, posterior half slowing and such was found in the aged.

8) Slow wave of high amplitude like posterior half random δ , θ waves were found many in the children.

9) Abnormal wave activated by the hyperventilation and photic stimulation was observed frequently in the children and rarely in the aged.

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