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Brain Stem Responses and Cochlear Action Potential in Cases of Post-Traumatic Disorders of Head and Neck Accompanied by Auditory Disturbances with Special References to Topographic Recording of Brain Stem Responses over the Scalp

(brain stem responses/head injury/topographic recording)

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The relationship between the threshold of AP or BSR and the threshold for air conduction of pure tone was examined in 72 patients with post-traumatic disorders of the head and neck accompanied by hearing disorders. In most patients, the threshold of AP and BSR clearly corresponded to the threshold for air conduction of pure tone in the frequency of stimulated sound. Topographic recording of BSR waves was attempted, despite the absence or scarcity of difference in threshold for air conduction of pure tone between right and left ears. The BSR waves were low on the operated side over the scalp, in 4 of 7 who had undergone surgery.

In such cases the I–V BSR waves differed in form the left. The topographic recording of BSR of cases of post-traumatic disorders of the head and neck were accompanied by central nervous system disorders, and showed responses different from those with normal hearing.

Thus, recording and examination of induced auditory responses, such as BSR and AP provide informations for objective determinations of auditory disturbances, central nervous system disorders, and psychological or psychic disturbances.

There are many reports of auditory disturbances or central nervous system disorders, as assesed by auditory evoked responses (1–5). However, there is little documentation concerning objective measurements of hearing disturbance in patients with post-traumatic disorders of the head and neck following clinical application of early auditory evoked responses. Recently, the numbers of such patients are increasing due to traffic and labor related accidents. It is, therefore, necessary to clinically determine the condition of disturbance in those patients with a view to rendering reasonable compensation for hearing disturbancs by means of subjective medical procedures.

The present study relates to this problem and I attempted to design an effective procedure for the determination of the level or extent of the hearing loss. Topographic recordings of brain stem responses were made to assess

the relationship between the brain stem and the site of disturbance.

The study consists of two areas of observations on patients with post-traumatic disorders, one the relationship between the pure tone threshold, and the brain stem responses (BSR), and the other the topographic observation on of brain stem response on the scalp.

SUBJECTS AND METHODS

Early auditory evoked responses (AP and BSR) were obtained and recorded in the case of 72 patients with suspected auditory disturbance following head and neck injury. Included in this study were the results of 7 out of 9 cases of craniotomy carried out for trauma of the head and neck, 6 with unilateral deafness, 1 with conductive deafness and 22 with bilateral sensorineural hearing loss. AP was recorded by the extratympanic method, the active electrode fixed to the deep and superior portion of the external canal with reference electrodes placed on the ear lobes and the third electrode used for grounding purposes. BSR was picked up by needle electrodes attached to the vertex, with reference electrodes on the ear lobes and the third electrode grounded.

Both ears of the subjects were separately stimulated by a sound signal through the head-phone, delivered in a signal 4 KHz sinewave length at 105 msec repeated time from a DANAJAPAN 500 stimulator. Sound stimuli were given at a repetition rate of 1500/sec. The level of stimulating sound was varied from 100dB to 0dB SL. Sweep time of summing computor SANEI 7T07 was set at 20msec. Filters of amplifiers were set at 300 to 3000 Hz. Computed responses were recorded using a xy recorder. Amplitude of AP was measured from the tracing base line and that of BSR from the peak-to-peak on each component of BSR, especially the height of VI and V waves. The threshold of evoked responses was determined on the basis of the estimate compared with the results of a silence controlled condition in which the signal delivered 0dB. In this study, the threshold was determined on 10 to 15dB above the total diminishing of AP peak and VI and V or V wave of BSR, because the intensity of the stimulating signal was stepped down by 10dB descending procedures. The AP and BSR threshold were compared with the conventional hearing thresholds of each ear of the patients.

The topographic brain stem responses were determined using needle electrodes attached to the 10−16 points on the surface of the scalp in accordance with the 10−20 EEG electrode placement. Point 4 is in the middle between Fp1 and Fp2, and point 17, O1 and O2 as shown in Fig. 1.

Intensity of the sound stimulas for the subjects was defined by 100dB SL. Other conditions of responses guidance were the same as the AP. The amplitude of the brain stem responses picked up on the scalp was expressed in its intrinsic percentage of the amplitude of response on the Cz. The values obtained were compared with each other and also with those of adults with normal hearing acuity and then plotted on a figure of the scalp (Fig. 2).

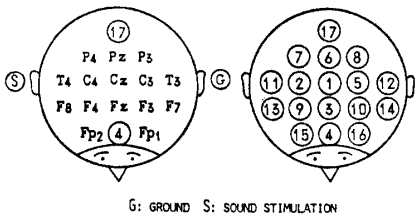

Fig. 1. Location of electrodes of topographic recording of BSR over the scalp.

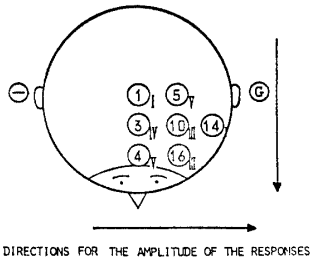

Fig. 2. Electrode positions which provided the highest (amplitude) BSR IV and V waves, I, II, III, IV, and V stand for the number of ears, on 22 ears of normal hearing adults.

RESULTS

Cases of Craniotomy

Case 1 : Right temporal craniotomy

The pure tone auditory threshold at 4 KHz was −5dB for the left ear and 10dB for the right. The AP threshold was 30dB for both ears, corresponding to the pure tone auditory threshold. The BSR threshold corresponded at 30dB in both ears. The formation of I−V waves of the right BSR was satisfactory, the amplitude of the left being slightly higher than that of the right.

Case 2 : Left temporal craniotomy

The pure tone auditory threshold at 4KHz was 15dB. This case showed definite and typical AP waves corresponding to the pure tone auditory threshold with differences of 30−35dB. In the BSR on the right, while I wave was large, III−V waves were clear but low in amplitude. V wave was large, being higher than the right. The BSR threshold corresponded to the pure tone auditory threshold with differences of 35−45dB.

According to the topographic recording, V wave picked up over the right half of the scalp was higher than the wave over the left.

Little difference was observed in the height of V waves obtained from the frontal and occipital regions.

Case 3 : Left temporal craniotomy

The pure tone auditory threshold at 4 KHz was 0dB for the left ear and 14dB for the right. The BSR threshold corresponded to the pure tone threshold at 4 KHz with differences of 15dB in the left and 20dB in the right. The height of BSR wave formation was in the order of I V III in the left and V III I in the right. Very clear and regular responses were obtained on bilateral vertex and earlobe recordings. However, there was a severe hearing loss only at 8 KHz on the pure tone audiogram in the right ear. The difference in deafness of both ears may be due to the difference in the wave formation of BSR.

Case 4 : Left temporal craniotomy

The pure tone auditory threshold at 8 KHz was 15dB in the left ear and

10dB in the right. AP was satisfactorily evoked. The AP threshold corresponded to the pure tone threshold with a difference of 40dB. As regards BSR, appearance of I and II waves was poor but V wave was somewhat clearly seen. The right BSR showed satisfactory formation of I, III and V waves. V wave of BSR in the left tended to be slightly lower than the right.

Case 5 : Right temporal craniotomy

The pure tone auditory threshold at 8 KHz was 20dB in the left ear and 55dB in the right. BSR was induced in both ears with a threshold difference of 30dB. The amplitude of V wave of the right BSR was noticeably low. Formation of I, II and III waves of the left BSR was poor but IV and V waves were clear and ample. Although the BSR was picked up from the operated side of scalp, the amplitude was generally low.

Case 6 : Left temporal craniotomy

The pure tone auditory threshold at 4 KHz was 5dB in the left ear and 15dB in the right. The right BSR threshold corresponded to the pure tone auditory threshold with a difference of 30dB. Although I wave of BSR was formed satisfactorily and clearly on both sides of recording, II, III, IV and V waves were low. In the topographic recording, the stimulation of the left ear caused a slightly higher elevation of V wave in the right half of the scalp than that of the left half and also somewhat higher elevation of the waves of the frontal region than those of the occipital region. The stimulation of the right ear, however, produced little difference in the amplitude of V wave of BSR between what was picked up on the left half of the scalp and that on the right, but the waves of frontal region were higher than those of occipital region.

All the APs obtained from 6 ears of 3 of the above patients appeared with threshold differences of 30—40dB from the threshold for air conduction of pure tone. The BSR wave formation was low on the operated side, with difference in the form in cases 1, 2, 4, and 5.

According to a topographic recording, the difference in the height of BSR waves on either half of the scalp and between the frontal and occipital regions tended to be small. In either temporal region, the differences in amplitudes of BSR picked out at T4 and T3, or at F8 and F7 were observed.

Cases of Unilateral Traumatic Deafness

Case 1 : The temporal tone auditory threshold at 4 KHz was 30dB for the left ear and above 90dB for the right. Stimulation of the right ear with 109dB did not result in a formation of BSR. A very typical BSR was recorded from the left ear, the threshold presumably being 50dB.

Case 2 : The pure tone auditory threshold at 4 KHz was 90dB for the left ear and 35dB for the right. The right AP was formed at 60dB but the left AP failed. The right BSR was formed at 50dB and the slight V waves appeared in the left BSR at 109dB. The left BSR suggested a cross hearing.

Case 3 : The pure tone auditory threshold was 10dB for the left ear and 90dB

for the right. The left ear produced a satisfactory AP at 30dB. From the right, AP was not recorded. The left BSR could be clearly observed up to 40dB. Only V wave was observed up to 100dB in the right BSR. Very clear typical BSR was recorded by stimulation of both ears at 4 KHz through delivery of right BSR, thus allowing for a successfull observation of V wave up to 20dB. The left BSR seemed to be formed by stimulation with less

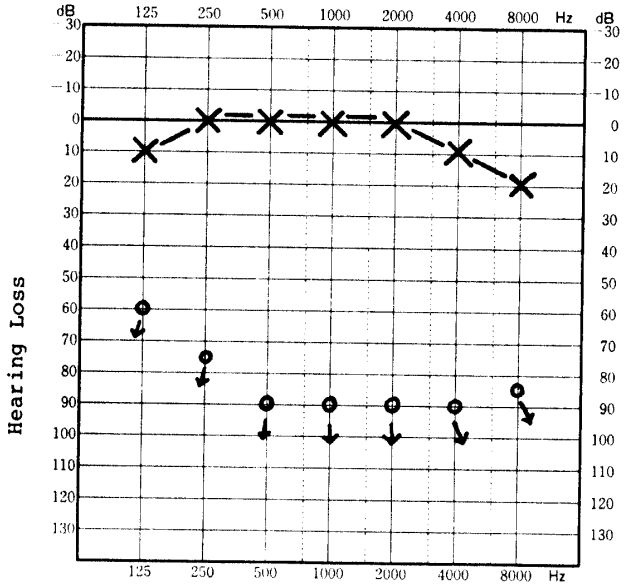

Fig. 3. Audiogram of Case 3.
Left ear : pure tone threshold at 4 KHz was 10dB.
Right ear : total deafness.

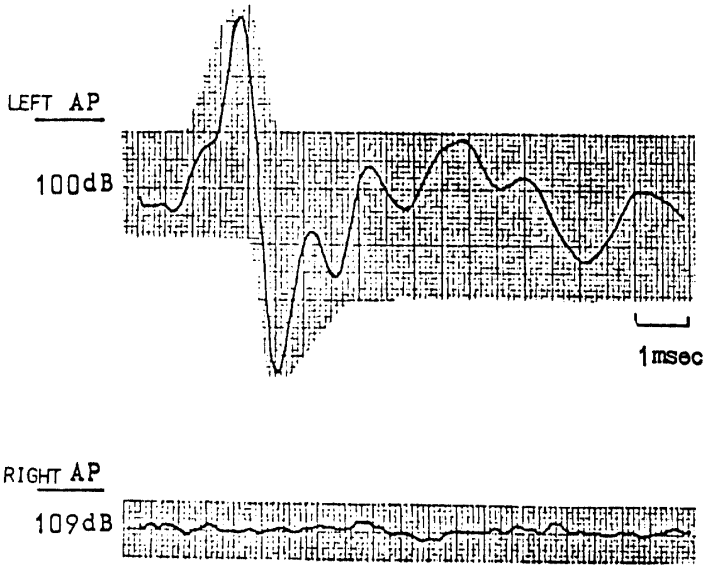

Fig. 4. Electrocochleogram (AP) of Case 3.
Left ear : clearly AP was obtained by 100dB HL, 4 KHz 1 sine wave stimulation.
Right ear : AP was not obtained.
Conditions : sampling traces 1500
sweep time 10 msec
Y points 2040
filter 300−3000 Hz

than 40dB (Figs. 3—5).

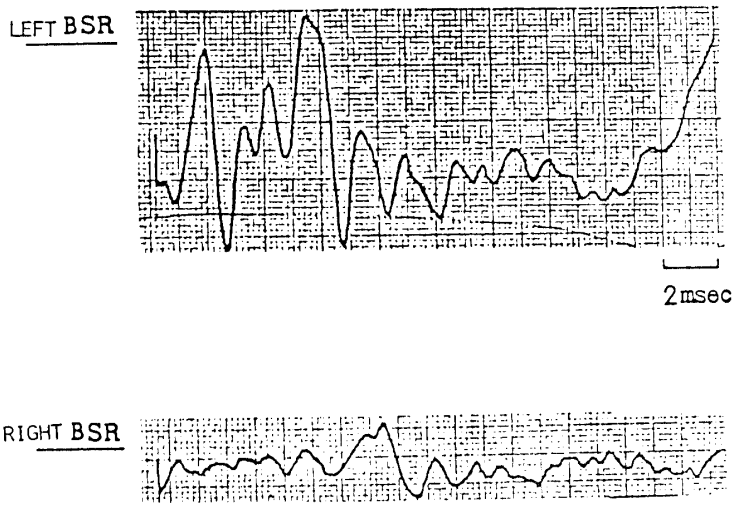

Fig. 5. Brain stem responses (BSR) of Case 3. Typical clear BSR were obtained by stimulation on the left ear. On the left ear stimulation, only IV—V wave of BSR was obtained.
Conditions : 100db HL at Left ear, 109dB HL at Right ear, 4 KHz
1 sine wave stimulation
sampling traces 1500
sweep time 20msec
Y points 2040
filter 300—3000 Hz

Case 4 : The pure tone auditory threshold was 30dB for the left ear and 90dB for the right. The left BSR was seen clearly forming a V wave up to 20dB. V wave was seen at 100dB in the right BSR, thereby suggesting a cross hearing.

Case 5 : The pure tone auditory threshold was 90dB for the left ear and 55dB for the right. The left BSR showed no response but the right formed V waves up to 50dB. Stimulation with 100dB produced satisfactory II, III, IV, V and VI waves but failed to produce I wave, which represented the hearing acuity C^5 dip. The thresholds were 5dB at 2 KHz and 35dB at 8 KHz.

Topographic recording of the right ear stimulated by 100dB showed no remarkable difference in the height of V waves at 6 points on the scalp.

Case 6 : This is a case of high tone deafness of the gradual inclination type, with above 90dB at 4 KHz in the left ear and 70dB in the right followed by 30dB at 2 KHz, 15dB 1 KHz and 5dB 0.5 KHz. Stimulation at 4 KHz produced no BSR formation on either side. Only V wave of left BSR was recorded by stimulation of the left ear (not the right) with 100dB at 2 KHz, but this was suspected to be cross hearing in the right ear. In the case of severe hearing loss or deafness, such were considered as cases of cross hearing. The AP and BSR presented the threshold closely corresponding to the pure tone auditory threshold. In the topographic recording of BSR in both ears, there was little height of the V wave.

Cases of Bilateral Sensorineural Hearing Loss, Post-Traumatic to Head and Neck Injury

Differences in the pure tone auditory threshold and the threshold of induced responses of 5dB—45dB were observed both in APs and BSRs in the case of 25 ears with bilateral sensorineural hearing loss. However, AP threshold differences were 40—45dB and BSR, 0—30dB. Most of the cases with this difference showed the threshold of induced responses corresponding to the pure tone threshold of 4 KHz. The wave formation varied in accordance with the degree of deafness and of the type of auditory acuity. Except in one case, labyrinthine deafness was the primary constituent of deafness. Three special cases are described below.

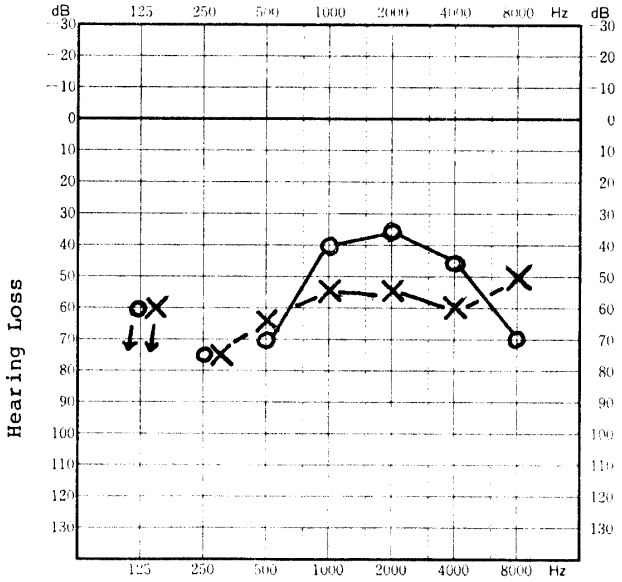

Fig. 6. Audiogram of Case 1 which involved a post-traumatic bilateral sensorineural hearing loss. The audiogram showed bilateral severe hearing loss.

Case 1 : Fig. 6 shows the hearing loss. The discrimination score was 44% in the left ear and 35% in the right. TTD was prominent. BSR was not formed by the first stimulation in either ear. By the second stimulation with 109dB at 4 KHz, the right ear did not respond, but produced only I wave with 105dB at 1 KHz. I wave alone was observed in the left ear with 90dB at 4 KHz which was clearly formed with 95dB at 1 KHz. From other neurological test results, injuries to the brain stem and cerebrum were found.
Case 2 : Fig. 7 shows the hearing loss. The threshold in the Békésy audiogram was satisfactory and was accompanied by TTD at 2 KHz and 4 KHz. Recruitment phenomenon was not clear and the discrimination score of speech test was also satisfactory. At the time of a visit of the patient to the hospital one year later for rectification of disturbance, hearing capacity as drawn in Fig. 8 was observed. The BSR of the right BSR formed only V wave at 60dB at 4 KHz. The right BSR formed only V wave at 60dB

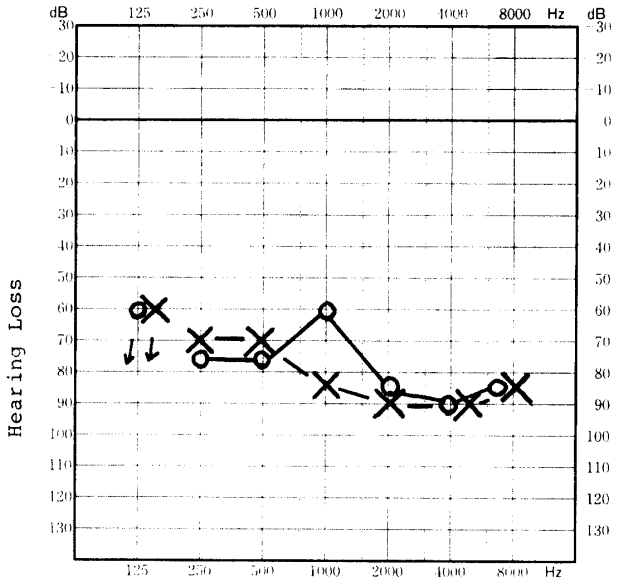

Fig. 7. Audiogram of Case 2. The audiogram showed bilateral severe hearing loss in a 53 year old man, post-traumatic disorders of head and neck injury.

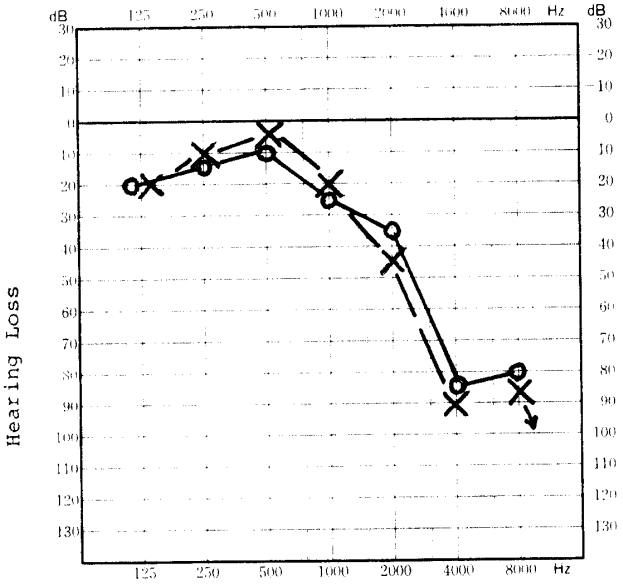

Fig. 8. Audiogram of Case 2. (same patient in Fig. 7) Audiogram was recorded at one year later from the first recording (Fig. 7). The hearing acuity in low and middle frequency range showed recovery.

and even at 100dB, it was only the V wave which appeared. At 1 KHz 1, III and V waves were clearly observed in the BSR of the left ear. The hearing acuity shown in Fig. 8 was confirmed by the delivery of BSR at 1 KHz and 4 KHz. On the other hand, the fact that the stimulation by a single wave length at 100dB 4 KHz produced only V waves at 1 KHz, indicated the correlation of the frequency zone of the stimulating sound and the appearance of I—IV waves. In addition, the suspicion of a tendency of simulation and deafness due to psychogenic disturbances was ruled out by the recording of BSR in this case. The exact same findings were observed

in another patient.

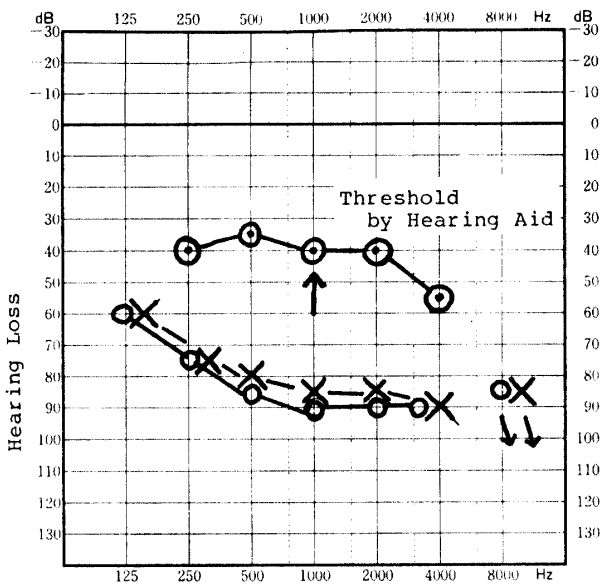

Fig. 9. Audiogram of Case 3. A case of bilateral severe hearing loss.
——◎——◎—— : Hearing threshold with a hearing aid.
↑
(DANAVOX 727ppE, N, vol. 8.)

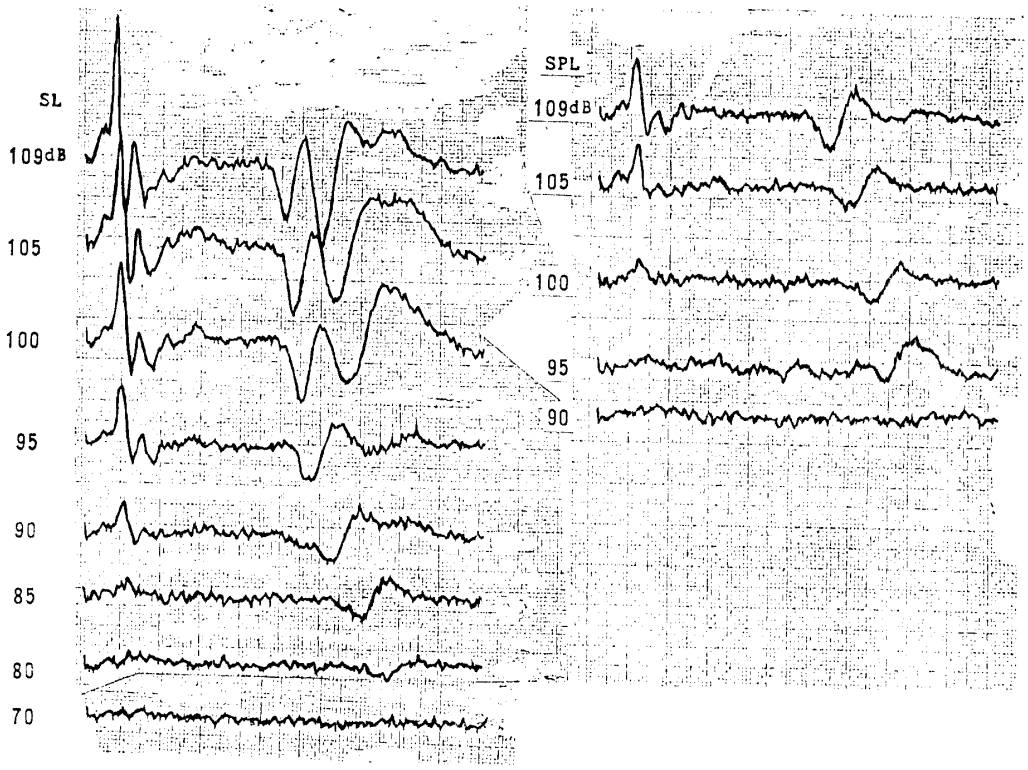

Fig. 10. AP obtained from Case 3. (same case of Fig. 9). Left AP threshold was 80dB.
Conditions : 4 KHz SL, 1 sine wave stimulation
sampling traces 1000
sweep time 20msec
Left side responses in Figure were obtained by 70–109dB SL stimulation. Right side responses were recorded by 95–109dB SL stimulation.

Case 3 : This is a case of certification of disturbance, as shown on the audiogram in Fig. 9. By stimulation with 4 KHz the AP threshold of the left ear was 80dB (Fig. 10) and 70dB at 2 KHz. The left BSR was 70dB by stimulation with 4 KHz. Stimulation by 100dB produced I—V waves, the formation of which was made clear at 2 KHz. It was assumed from the AP threshold and appearance of the wave form of BSR that the pure tone auditory threshold would be lower than the one shown in the audiogram (Fig. 9) by approximately 20dB. Although patients complained of an embarrassing increased difficulty in conversation, the threshold of was obtained by using a hearing aid, DANAVOX 727 ppE, N, Vol. 8. The articulation test was performed on the patients wearing this aid and a 100% discrimination score was obtained. In this patient there was toward simulation.

Cases of Conductive Deafness

Case 1 : While the left ear had normal hearing acuity, the right ear showed loss of mean hearing level at 40dB. Bone conduction was satisfactory. There was no tympanic membrane abnormality. This was considerd to be a cases of conductive deafness due to disturbances in the ossicular chain. The left AP showed clear and normal waves and the threshold could be followed up to 40dB. The latency of the left AP was 1.5 msec (Fig. 11). The left BSR growth was prominent ; I was being the highest, followed by the order of II to V. The right BSR waves did not grow satisfactorily. The threshold

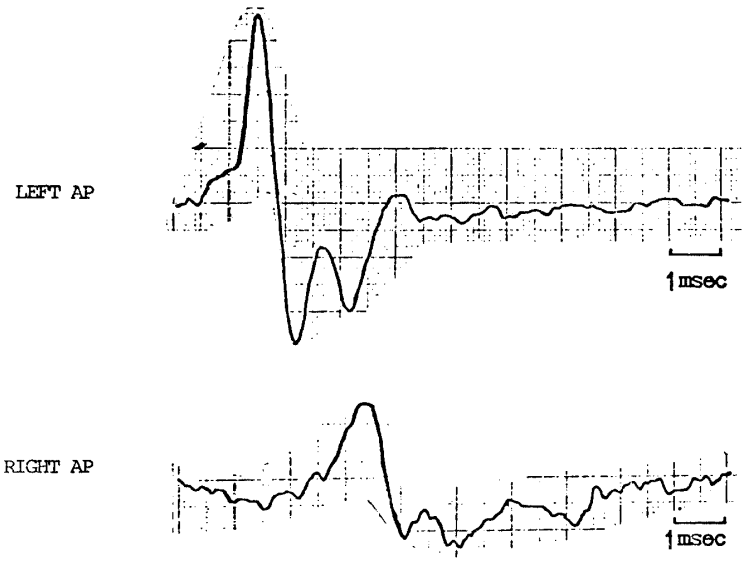

Fig. 11. AP obtained from a case of right conductive hearing loss.
Left AP : normal AP was obtatined.
Conditions : 4 KHz 100dB SL, sitmulation
sampling traces 700
sweep time 20msec
Right AP : Latency of AP was increased, amplitude was low and form was prominent.
Conditions : 4 KHz 100dB HL, stimulation
sampling traces 2000
sweep time 20msec

being 70dB, V wave was clear but I to III waves very low (Fig. 12).

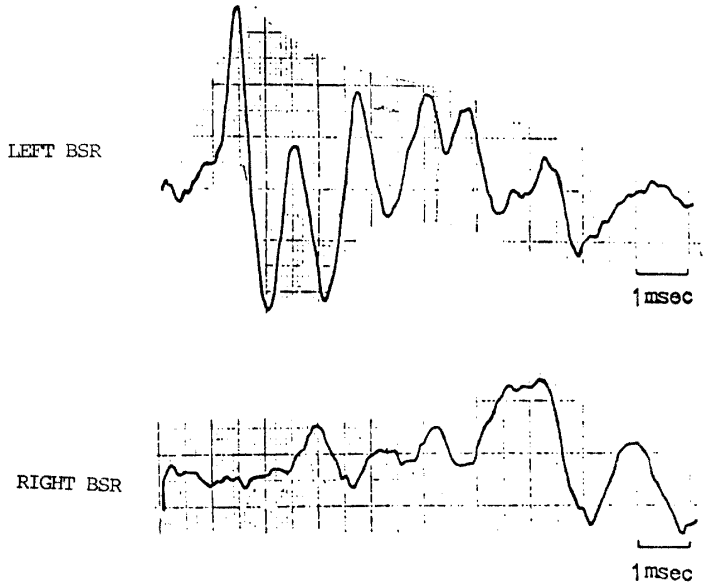

Fig. 12. BSR obtained from same Case of Fig. 11. Left BSR showed normal and clear responses.
Conditions : 4 KHz 100dB SL, stimulation
sampling traces 1500
sweep time 10msec
Right BSR, IV−V wave was prominent, amplitude of I II III waves was decreased and the latency of each wave was increased.
Conditions : 4 KHz 109dB HL, stimulation
sampling traces 1500
sweep time 10msec
responses threshold was 70dB SL.

The other 2 cases showed a correspondence between the threshold of BSR and that of the hearing level of pure tone.

DISCUSSION

From the point of view of auditory disturbance, AP demonstrated the functions centering around the inner ear and auditory nerve, and BSR showed the function of conduction of auditory information to the central nervous system. Our patients were classified in accordance with the threshold, the amplitude and the mode of appearance of latency of AP and BSR into 4 groups, i. e. cases of craniotomy, unilateral deafness, perceptive deafness and conductive deafness.

Threshold

The threshold of AP and BSR apperarance (disappearance) was considered to provide objective data for comfirmation of pure tone audiogram, diagnosis of simulation and phychogenic auditory disturbances (1−3). When there is a difference between the threshold of BSR and the pure tone threshold (the frequency of stimulation sound), the middle and low tones may be preserved

in cases of high tone deafness in the form of abrupt hearing loss and of gradual hearing loss, as shown in the audiogram in Fig. 8. This suggests correlation between the BSR threshold and type of earing loss. In cases of craniotomy, the threshold of AP and BSR corresponded well to the pure tone auditory threshold.

Those unilateral deafness were characterized by no or few responses that appeared as cross hearing to the contralateral ear from the stimulation to the disturbed ear. Measurement of the threshold of AP and BSR proved usefel for the objective determination of advanced unilateral hearing loss or deafness.

In cases of conductive deafness, the threshold of AP and BSR obtained corresponded to the pure tone auditory threshold, and the differences in the mode of wave formation were found of interest (Figs. 11—12). However, caution should be given to distinguishing cases of unilateral deafness in which

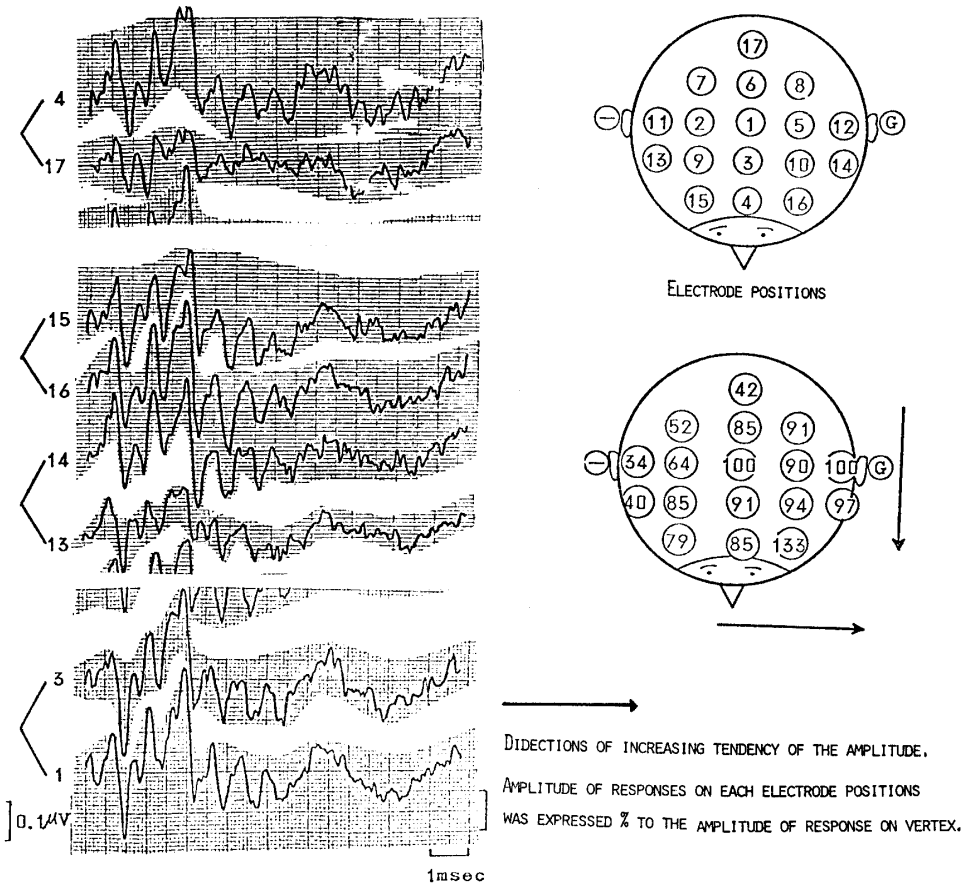

Fig. 13. An example of brain stem responses (BSRs) obtained in a woman with normal hearing female subject. (Topographic recording over the scalp) M. Y. Age 40, Female.
Conditions : 4000Hz, 100dB HL

interval	103msec
duration	0.2msec
1 sine wave, stimulation	
sampling traces	1500
Y points	1024
sweep time	20msec
filter	300—3000 Hz,
no medicine.	

similar tendency.

The Wave Form

There was no response in the form of AP in the cases of unilateral deafness. The BSR showed only the V wave, suggestive of cross hearing at the side of the ear involved.

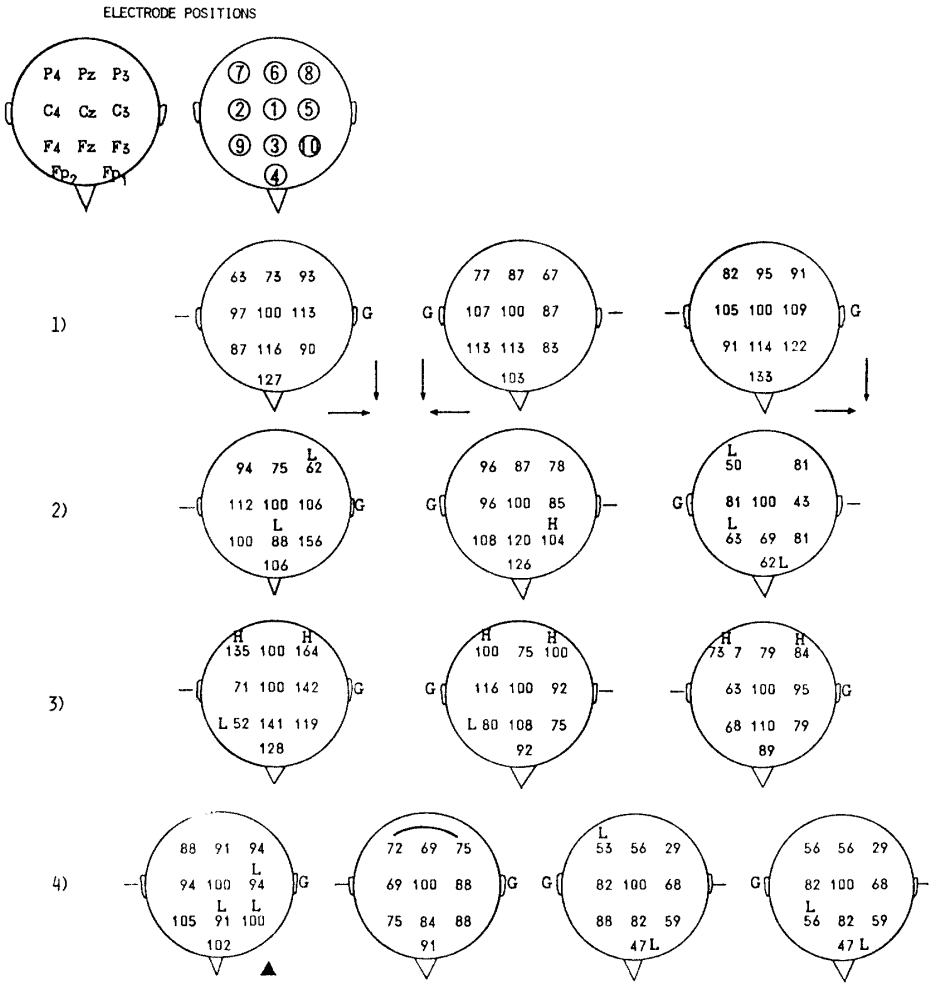

Fig. 14. Amplitude distribution of BSR 4—5 wave or 5 wave over the scalp of the post-traumatic disorders. The amplitude of responses on each electrode positions was expressed % to the amplitude of response on vertex.

— stimulated ear L : Low voltage

G : ground H : High voltage

⟶ : Direction of increasing tendency of the amplitude.

1) An normal response obtained from an normal hearing, 38 year old woman.
2) A case of head injury, brain stem disorders, 58 year old man.
   L : Left ear hearing loss at 4 KHz was 50dB.
   R : Right ear hearing loss at 4 KHz was 10dB.
3) A case of head and neck injury, cervical cord injury, 58 year old man.
   L : Left ear hearing loss at 4 KHz was 20dB.
   R : Right ear hearing loss at 4 KHz was 35dB.
4) A case of head and neck injury, brain stem disorders, 67 year old man.
   L : Left ear hearing loss at 4 KHz was 40dB.
   R : Right ear hearing loss at 4 KHz was 20dB.

The AP of those with conductive deafness (unilateral) presented clear wave forms depending on the degree of hearing but the latency was extended.

In all cases of craniotomy there was an apparent accompanied with definite sequelae including symptoms of brain stem damage and other pscyhic symptoms. The amplitude of BSR waves obtained over the scalp was low at operated side in 4 of 7 cases. This, as well as the absence of any significant differences in the from I to V waves failed to appear, despite a relatively satisfactory pure tone threshold, which was considerd as suggestive of the relevance between variations of the amplitude of BSR and central nervous system disorders (2, 4, 8, 10).

Topographic Recording of BSR

The standard evoked response has not been definitely established in the topographic recording of BSR (4—9). The map of responses obtained on the scalp of adults with normal hearing is shown in Fig. 13. Here, the amplitude of IV and V waves are high from the vertex to the frontal region of the scalp opposite to the stimulated ear, and there is a prominent difference in the height of response wave between T3—T4 and F8—F7, and between point 4 and Pz or point 17.

In the case of craniotomy and also patients with central nervous disorders, there was a tendency toward a reduction in sides on the scalp with no difference between the right and left, and further, a similar tendency was observed in the anterio-posterior difference (Fig. 14).

These findings differed from the distribution of the height of response wave in normal persons. The comparison with the physiology of auditory nervous system and intracranial diseases was considerd neccesary for topographic recording of BSR by sound stimulation (7—9).

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