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AUDITORY BRAIN-STEM (ABRs) AND MIDDLE LATENCY AUDITORY RESPONSES (MLRs) IN THE PROGNOSIS OF SEVERELY HEAD-INJURED PATIENTS

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Summary Auditory brain-stem responses (ABRs) were studied in 66 subjects with severe head trauma. Middle latency responses (MLRs) were also recorded in 22 of them. Patients were carefully selected to avoid conditions such as pre-existing or acute deafness, hypothermia or ethanol intoxication. In order to evaluate the usefulness of potentials in predicting recovery, patients were classified according to the Glasgow Coma Scale (GCS). ABR tracings were classified into 5 groups and MLR into 2 groups. The recovery was good in the presence of a type 1 ABR, poor in the presence of types 3, 4 and 5. Concerning type 2 ABR, the outcome is related to the MLR type, and to the presence of an electrophysiological improvement within the first 3 months following trauma. The reliability of ABR and MLR in predicting the outcome of severe head injury appears to be greater than other usually considered clinical and instrumental data (age, GCS, CT scan, EEG).

Keywords: *head-injured patients – outcome prediction – auditory brain-stem responses – middle latency auditory responses*

The recovery of severely head-injured patients depends to a large extent on damage to the brain-stem. Usually such damage is evaluated from clinical data: caloric vestibulo-ocular response (Blegvad and Denmark 1962), orbicularis oculi reflex (Serrats et al. 1976) and, more recently, various evoked potentials (Greenberg et al. 1977a,b; Seales et al. 1979; Tsubokawa et al. 1980; Narayan et al. 1981; Walter and Blegvad 1981; Hall et al. 1982; Karnaze et al. 1982; Newlon et al. 1982; Mjøen et al. 1983; Molinari et al. 1984).

The aim of the present paper is to evaluate the reliability of auditory brain-stem responses (ABRs) and of middle latency responses (MLRs) in predicting the recovery of severely head-injured patients.

Methods

ABR was studied in 66 head-injured patients, 50 males and 16 females, aged between 2 and 58 ($M = 33 \pm 5$), hospitalized in the Intensive Care Unit of the University of Perugia where recordings were performed.

Selection criteria were: absence of a history of otologic pathology; absence of clinical and X-ray signs of temporal bone fracture; type 'A' tympanograms; no hypothermia; no ethanol intoxication, in order to eliminate both functional impairment due to peripheral otologic lesions and other conditions able to slow nervous conduction (Siu et al. 1977; Squires et al. 1978).

The MLR was studied in only 22 patients, 18 males and 4 females, aged between 5 and 55 (35 ± 14). The reduced number of patients studied by MLR was due in part to the fact that MLR was introduced later in our protocol, in part to the hyperreactivity of some patients shortly after trauma and to the effect of barbiturate therapy, which is known to affect the middle components (Kraus et al. 1982).

Clinical conditions were evaluated by means of the Glasgow Coma Scale (GCS; Teasdale and Jennet 1974) and patients were classified into 3 subgroups based on the GCS score (I: 3–5; II: 6–8; III: 9–12) considering the overall figure of the 3 responses. Patient's outcome was evaluated by means of the Glasgow Outcome Scale (GOS; Jennet and Bond 1975). Cerebral CT scan and EEG were always performed within 24 h of when

ABR and MLR recordings were completed.

Initial ABR and MLR recordings were performed 48 h after the trauma. Follow-up was carried out monthly up to the time of either the occurrence of a stable condition or death. Recordings were performed at the bedside by means of an Amplaid MK 6 evoked potentials signal processor. Three miniatured (1.1 cm diameter) Beckman electrodes were positioned on the upper forehead (active), on the stimulated mastoid (reference) and on the contralateral one (ground). The skin had been scrupulously cleaned and the impedance of the electrodes, measured by means of an Amplaid electrode tester, was below 3 kΩ in all cases. The obtained tracings were visualized on a Tektronix 4006/1 oscilloscope, recorded by an analogue recorder and finally stored on floppy discs. Stimuli, whose characteristics were programmed on a Tektronix 4006/1 keyboard, were produced by an AS 501 acoustic stimulator and presented monaurally via a TDH 49 headphone.

When performing ABR, 2048 rarefaction clicks, generated by rectangular electrical pulses (0.1 msec duration) at a repetition rate of 21/sec, were employed. The click power spectrum is reported in a previous paper (Maurizi et al. 1984a). The responses were amplified $\times 10^5$; the passband filter was between 200 and 2000 Hz (−3 dB down; 6 dB per octave slope) and averaging was performed over a 10 msec time base. Sampling time was 10 μsec. Stimuli were presented at 70 dB nHL intensity level (normalized to the psychoacoustical threshold of 15 normally hearing adults).

When performing MLR, 1024 rarefaction clicks were presented at a 9 Hz repetition rate. The passband filter was 20–100 Hz (−3 dB down; 6 dB per octave slope). Analysis time was 100 msec and sampling time was 10 μsec.

The main criterion for recognizing the responses was based upon wave replicability. Three separate averages were recorded per ear and the obtained tracings were superimposed. As reference values, those reported in previous papers (Maurizi et al. 1984a,b) were chosen.

ABR tracings were classified into 5 groups according to Mjøen et al. (1983) (Fig. 1), and the MLR into 2 groups. MLR tracings were classified on the presence of wave Pa, which is considered the most stable one (Özdamar and Kraus 1983) (Fig. 1).

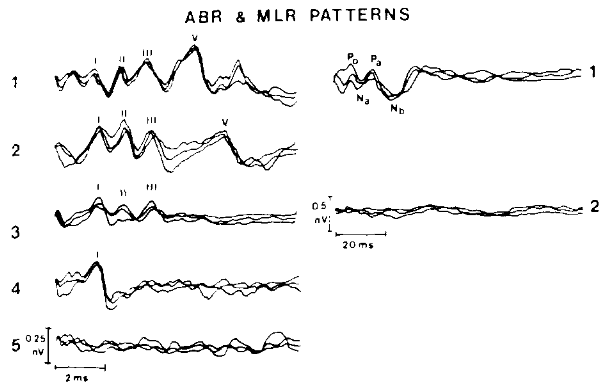

Fig. 1. ABR tracings were classified in 5 types according to Mjøen et al. (1983) and MLR tracings in 2. Type 1 ABR is characterized by normal parameters, type 2 by an increased V–I interval, type 3 by the absence of waves IV and V, type 4 by the absence of all waves except I, type V by the absence of all waves. Type 1 MLR is characterized by the presence of wave Pa, which is considered the most stable one and type 2 by its absence.

Results

Auditory brain-stem responses

Type 1 ABR was detected in 10 cases, type 2 in 21, type 3 in 12, type 4 in 10 and type 5 in 13. The relationships between ABR and MLR and the

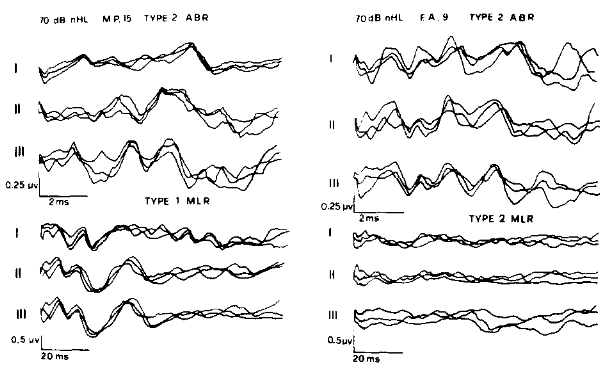

Fig. 2. Type 2 ABR patients show a different outcome depending on the presence of an electrophysiological improvement within 3 months after the trauma and on the recording of type 1 MLR (left traces). When an early electrophysiological improvement is not evident or a type 2 MLR is recordable, the outcome is usually poor (right traces).

TABLE I

Prognostic value of ABR and MLR related to clinical and instrumental data. In this and in the subsequent tables the overall GCS figures are represented. Concerning CT scans and EEG: + +, normal; + −, mildly altered; −, moderately altered; − −, severely altered.

	GCS	CT	EEG	Outcome	MLR
Type 1					
M.Z., 6	9	+ +	+ +	G.R.	
D.M., 21	9	+ +	+ −	G.R.	
Z.N., 21	9	+ +	+ −	G.R.	
F.C., 23	10	+ +	+ −	G.R.	
D.C., 25	9	+ −	+ −	G.R.	
E.S., 31	9	+ +	+ −	G.R.	1
F.F., 33	9	+ +	+ −	G.R.	
S.A., 37	8	+ −	+ −	M.D.	1
B.G., 41	9	+ −	+ −	G.R.	
G.S., 47	9	+ −	+ −	G.R.	
Type 2					
P.C., 2	7	+ −	+ −	G.R.	
C.D., 5	6	−	−	G.R.	
A.G., 7	7	+ −	−	M.D.	1
F.A., 9	6	+ +	−	S.D.	2
G.P., 12	7	+ −	+ −	M.D.	1
M.P., 15	6	−	+ −	M.D.	
B.L., 1	7	+ −	+ −	Dead	
F.O., 20	7	+ −	−	M.D.	
B.F., 25	6	+ −	+ −	M.D.	
T.O., 25	6	+ −	+ −	Dead	2
P.S., 38	7	−	+ −	G.R.	
M.M., 40	8	+ −	+ −	G.R.	
M.A., 41	9	−	+ −	M.D.	1
A.F., 43	7	+ −	−	M.D.	2
T.B., 45	7	−	+ −	M.D.	
C.S., 46	6	−	+ −	M.D.	1
I.L., 47	8	+ +	+ −	Dead	
C.C., 55	8	+ −	+ −	M.D.	1
M.R., 55	6	+ −	−	M.D.	
C.M., 55	6	+ −	+ −	M.D.	1
D.L., 58	7	+ −	+ −	M.D.	
Type 3					
G.A., 19	4	+ −	−	Dead	
F.S., 23	5	+ −	−	V.S.	2
C.C., 25	4	−	+ −	V.S.	1
B.E., 25	3	+ −	−	Dead	
M.A., 33	6	−	−	Dead	
P.T., 37	5	−	+ −	Dead	
F.S., 39	4	−	− −	Dead	2
C.G., 42	4	−	− −	Dead	2
R.L., 48	5	+ −	− −	V.S.	1
C.I., 55	6	−	+ −	Dead	
G.V., 58	6	−	−	Dead	
S.N., 59	5	+ −	−	V.S.	

TABLE I (continued)

	GCS	CT	EEG	Outcome	MLR
Type 4					
P.A., 12	4	− −	− −	Dead	
B.M., 19	3	+ −	−	Dead	
G.C., 23	4	+ −	−	Dead	
M.M., 25	3	−	− −	Dead	
S.R., 26	4	+ −	− −	Dead	2
S.S., 27	3	−	− −	Dead	
Z.A., 30	3	+ −	−	Dead	
Z.C., 36	4	+ −	−	Dead	
M.N., 55	3	+ −	−	Dead	
C.Z., 57	3	+ −	+ −	Dead	2
Type 5					
L.M., 15	3	−	−	Dead	
G.A., 19	4	+ −	−	Dead	
B.R., 20	3	−	− −	Dead	
M.M., 23	3	− −	− −	Dead	
R.G., 24	3	−	−	Dead	
L.S., 37	4	−	−	Dead	2
A.V., 40	3	−	−	Dead	
R.P., 46	4	−	−	Dead	2
C.A., 48	3	−	− −	Dead	
B.M., 50	3	− −	− −	Dead	2
P.A., 50	3	− −	− −	Dead	2
T.P., 50	3	−	− −	Dead	
V.S., 55	3	−	− −	Dead	

clinical data (GCS, GOS, age, CT scan, EEG) are reported in Table I. All the patients with a *type 1 ABR* had a good outcome. The GCS was below 9 only in 1 case and CT scan altered in 4, while the EEG was abnormal in all except one (Fig. 2). Seventeen patients with a *type 2 ABR* had a good outcome, 1 a poor one and 3 died. The GCS was between 6 and 9, without a clear relationship with the outcome. The CT scan was normal only in 2 patients (1 poor outcome and 1 death) and the EEG always altered (Fig. 3). All the patients with a *type 3 ABR* died, except for 3 who showed a poor outcome. The GCS was between 3 and 6. All the patients with *type 4 and 5 ABRs* died. The GCS was between 3 and 4, the CT scan and the EEG being altered in all the cases (Fig. 4).

Middle latency responses

A type 1 MLR was recorded in 10 cases and a type 2 in 12. *Type 1 MLR* was related to a good outcome in 8 cases and to a poor outcome in 2,

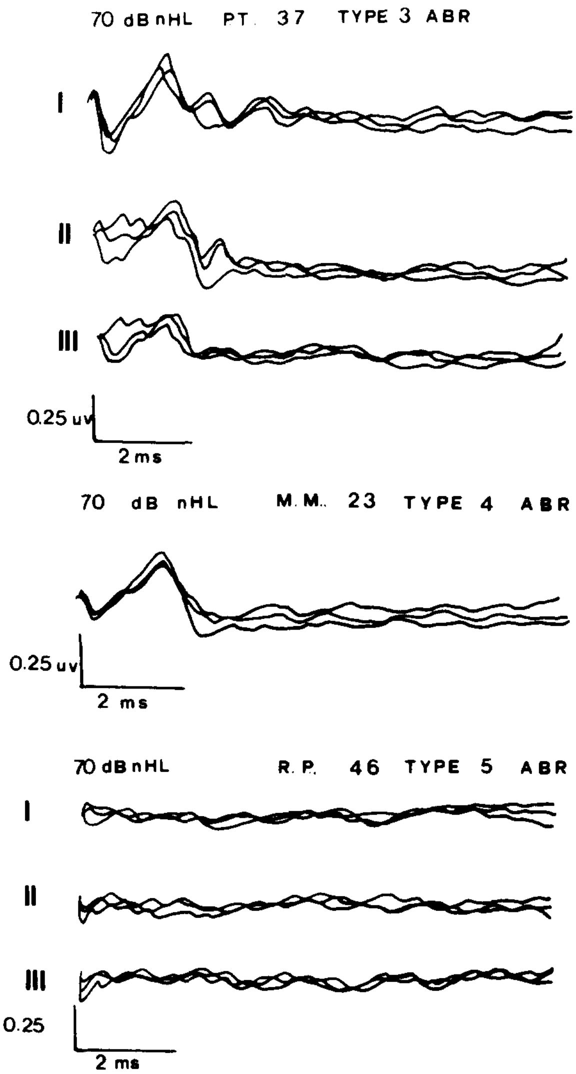

Fig. 3. Type 3 (upper traces), 4 (middle traces) and 5 (lower traces) ABRs are usually followed by death. Concerning type 3 ABR, this occurs especially when an electrophysiological deterioration is detectable, as in the above reported case, and a type 2 MLR is recordable. CT scan revealed marked oedema at the supratentorial level in the type 3 ABR case, a displacement of the midline structures to the left in the type 4 and marked cerebral oedema, with disappearance of all the cisternal spaces, in the type 5 one. In this latter case, death occurred although a follow-up CT scan had revealed an almost complete regression of the oedema.

while *type 2 MLR* was related to a good outcome in 1 case, poor in 2 cases and to death in 9. Type 1 MLR patients showed a GCS between 9 and 4, the EEG and the CT scan being altered in all cases except one. In type 2 MLR patients, GCS was between 7 and 3 and only in 1 case the CT scan was normal.

TABLE II

The MLR type can greatly define the outcome of type 2 ABR patients. In fact a good outcome is usually present when a type 1 MLR is associated with a type 2 ABR.

ABR + MLR type	GCS	CT	EEG	Outcome
1 + 1				
E.S., 31	9	+ +	+ −	G.R.
S.A., 37	8	+ −	+ −	M.D.
2 + 1				
A.G., 7	7	+ −	−	M.D.
G.P., 12	7	+ −	+ −	M.D.
M.A., 41	9	−	+ −	M.D.
C.S., 46	6	−	+ −	M.D.
C.C., 55	8	+ −	+ −	M.D.
C.M., 55	6	+ −	+ −	M.D.
3 + 1				
C.C., 25	4	−	+ −	V.S.
C.I., 55	6	−	+ −	Dead
2 + 2				
F.A., 9	6	+ +	−	S.D.
T.O., 25	6	+ −	+ −	Dead
A.F., 43	7	+ −	−	M.D.
3 + 2				
G.A., 19	4	+ −	−	Dead
F.S., 39	4	−	− −	Dead
C.G., 42	4	−	− −	Dead
4 + 2				
S.R., 26	4	+ −	− −	Dead
C.Z., 57	3	+ −	+ −	Dead
5 + 2				
L.S., 37	4	−	−	Dead
R.P., 46	4	−	−	Dead
B.M., 50	3	− −	− −	Dead
P.A., 50	3	− −	− −	Dead

ABR vs. MLR

The crossed ABR and MLR prognostic value is reported in Table II. It cannot be stated that a clear-cut relation between ABR and MLR exists, as a type 2 MLR can be related to a type 2 ABR and vice versa. This poor correspondence concerns only type 2 and 3 ABRs which showed a potentially varied outcome (good, poor or death). From

TABLE III

Prognostic value of ABR changes in severely head-injured patients; outcome (N = 52) related to the initial ABR type.

Outcome	Improved ABR		No change in ABR		Deteriorated ABR	
	1–2	3–4–5	1–2	3–4–5	1–2	3–4–5
Good (G.R./M.D.)	17 *	–	10	–	–	–
Poor (S.D./V.S.)	1 **	–	–	4	–	–
Dead	–	–	1 ***	10	2	7
Total	18	–	11	14	2	7

* Improved within the first 3 months following trauma.
** Improved beyond the third month following trauma.
*** Dead from extracerebral causes.

this point of view, even if the subjects are rather limited in number, it seems that the MLR type may considerably define the outcome prediction based upon ABR data, as a good outcome can be predicted for a type 2 ABR associated with a type 1 MLR. For a type 3 ABR, a poor outcome instead of death seems predictable if associated with a type 1 MLR.

Outcome vs. ABR and MLR changes

The prognostic value of ABR and MLR changes are reported in Table III. The follow-up concerns only 52 patients (78.6%), as the others died within the first month following trauma. *Type 1 and 2 ABRs* (N = 31) did not change or improved in 29 cases (93.6%) and the outcome was good in 27 (87.2%), poor in 1 (3.2%), while 1 patient (3.2%) died from extracerebral causes. In the last 2 patients (6.4%), the tracings deteriorated and they died. *Type 3, 4 and 5 ABRs* (N = 16) never improved. Only 4 patients had a poor outcome, while the others died. *MLR tracings* never showed changes at the follow-up.

Discussion

Our data show that, on the whole, type 1, 3, 4 and 5 ABRs were related to the outcome almost in 100% of cases, even if the interpretation of a type 5 ABR has to be cautious, owing to possible unknown factors able to slow or block neural transmission (pre-existing or acute deafness, etc.); if previous post-traumatic records, instead, had shown identifiable waves, a type 5 ABR indicated an unfavourable clinical evolution. For such reasons we agree with Starr (1976) and Mjøen et al. (1983), who take into account 5 ABR types, rather than with other researchers who identify only 4 patterns (Greenberg et al. 1977a, 1981). An accurate selection is, therefore, of great importance.

Concerning type 2 ABR, the outcome depends more on the time needed to observe an improvement of the electrophysiological parameters. In fact, clinical recovery can be observed if the ABR improvement occurs within 3 months after trauma. The different behaviour of type 2 ABR could be due to transient and reversible dysfunction of the auditory brain-stem structures, that can recover within 2–3 months after the trauma or deteriorate towards death (Seales et al. 1979).

Middle latency responses, whose generators are probably located at the level of the thalamo-cortical projections (Picton et al. 1974), have been widely employed in the prediction of auditory threshold, due to their reliability, but seldom in the diagnosis of cerebral lesions (Parving et al. 1980; Kraus et al. 1982; Özdamar et al. 1982). According to our experience, MLR recording is very often more difficult than ABR in an intensive care unit, due to the patient's hyperreactivity and to the frequency content of the MLR, which requires a better electrically shielded environment to avoid artifacts. Nevertheless, Kaga et al. (1985) claim that the MLR can be useful in outcome prediction in comatose patients because it may be elicited along the auditory radiations and primary cortex, so that these pathways, as well as brain-stem function, must be preserved to sustain a response. It is known (Kraus et al. 1982) that only the Pa wave is definitely unaffected by mild sedatives such as diazepam and chloral hydrate and this can explain the difficulty in obtaining reliable tracings shortly after trauma if barbiturate treatment has been carried out in these patients.

Concerning our series, type 2 MLR is mostly followed by a poor outcome, while type 1 by a good outcome. Moreover, its significance is greatly increased by relating ABR and MLR data, as a good outcome can be observed when a type 2 ABR is associated with a type 1 MLR.

In terms of site of lesion, we can hypothesize that a type 1 ABR is related to a normal brain-stem pathway, type 2 to an upper brain-stem lesion, type 3 to a pontine lesion, types 4 and 5 to a lower brain-stem lesion (Uziel and Benezech (1978), even if such a schema is rather simplistic. Considering the MLR, although the presence of the Pa wave should be related to normal function at the upper brain-stem level and thalamo-cortical projections, its topodiagnostic value seems much less reliable.

On the whole, ABR and MLR appear to be reliable and harmless methods to identify patients with a probably or possibly good outcome from those with a poor one.

Résumé

Réponses auditives du tronc cérébral et réponses auditives à latence moyenne dans le pronostic de patients présentant un grave traumatisme crânien

Les auteurs ont étudié les réponses evoquées auditives du tronc cérébral chez 66 sujets après un grave traumatisme crânien. Chez 22 d'entre eux ils ont étudié aussi les réponses auditives de latence moyenne. Les sujets avaient été soigneusement sélectionnés afin d'exclure des causes comme surdité grave, préexistante au traumatisme ou aiguë, hypothermie, intoxication, alcoolique. Les sujets avaient aussi été classés d'après l'Echelle des Comas de Glasgow (ECG), pour vérifier l'utilité des potentiels auditifs évoqués dans l'établissement d'un pronostic. Les tracés ABR ont été classés en 5 types et les tracés MLR en 2. La récupération a été bonne en présence d'un tracé ABR de type 1, mauvaise en présence de tracés 3, 4 et 5, tandis-que, en ce qui concerne les tracés de type 2, il faut souligner l'importance du type de tracé MLR associé et d'une amélioration électrophysiologique dans les 3 premiers mois suivant l'accident. La fiabilité des réponses auditives évoquées dans le pronostic du patient traumatisé paraît ainsi supérieure à celle des autres paramètres généralement considérés (âge, ECG, TC, EEG).

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