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Simultaneous Recordings of Human Auditory Potentials: Transtympanic Electrocochleography (ECoG) and Brainstem-evoked Responses (BER)

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Simultane Registrierung der Hörpotentiale des Menschen: Transtympanale Elektrokochleographie (ECoG) und Hirnstammpotentiale (BER.)

Zusammenfassung. Die simultane Registrierung der Elektrokochleographie (ECoG) und der Hirnstammpotentiale (BER) ermöglicht, die I-V-Intervalle leichter zu erkennen und erhöht so die Zuverlässigkeit und den prognostischen Wert der elektrophysiologischen Messungen des akustischen Systems.

Schlüsselwörter: Elektrokochleographie – Hirnstammpotentiale

Summary. The simultaneous recording of the electrocochleography (ECoG) and the brainstem-evoked responses (BER) enables the I-V interval to be known easily and thus increases the reliability and prognostic value of electrophysiologic measurements of the auditory system.

The correlation between the first negative peak of the action potential (N_1 in ECoG) and the wave I (BER) is evident.

Simultaneous recording of the ECoG and the BER objectifies other correlations, especially N_2 and wave II.

Wave I, like Wave II, would result from the summation of the cochlear nerve responses and those of the cochlear nuclei. Wave I would be the early cochlear responses and wave II the late cochlear responses corresponding to the high and low responses, as described in ECoG.

Key words: Electrocochleography – Brainstem-evoked responses

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Introduction

Electrocochleography (ECoG) analyses the first bioelectric potentials evoked by acoustic stimulation, produced from the organ of Corti and the cochlear nerve.

These are, on the one hand, *sensorial responses* – cochlear microphonic potential (CM) and summating potential (SP) – and on the other hand the *action potentials* (AP) of the cochlear nerve fibres.

In clinical audiology, two types of AP are studied:

1. *whole-nerve action potential* (WNAP) obtained by wide-band click stimulating virtually the entire basilar membrane;
2. *compound action potential* (CAP) resulting from more limited stimulation of the cochlea by more specific acoustic stimuli (e.g., tone bursts).

The WNAP is characterized at high intensity (e.g., 100 dB H.L.) by a first negative peak (N_1) followed by a second, less ample, negative peak (N_2) (Fig. 1). On decrease in the intensity of the acoustic stimulus, the N_1 amplitude decreases while that of N_2 increases. Towards 50 dB HL, the AP may take the shape of a "W". At very low intensity, it is often only N_2 that is discernible [1]. As amplitude decreases, latency time increases.

Study of the derived action potentials [2, 3] and the results obtained in the case of recruitment lead one to think that (a) *the early components of AP* (N_1) correspond to the nerve responses originating from the basal turn of the cochlea and are preponderant at high intensity and (b) *the late components* (N_2) correspond to those from the second turn of the cochlea and are preponderant at low intensity.

The normal electrocochleogram has therefore a twofold response: (1) *early*, corresponding to N_1 and the basal cochlear turn known as the High or H-response [4], and (2) *later*, corresponding to N_2 and the second cochlear turn, known as the low or L-response.

The brainstem-evoked (or electrical) responses (BER) are those from the evoked auditory potentials of the cochlea and brainstem recorded by surface electrodes. The normal early evoked response shows seven successive positive waves with respect to vertex (Fig. 1). For each wave there would appear to be several *generators*, even bilateral generators. Classically [5], the simplified neurophysiologic correlation is the following: acoustic nerve (wave I), cochlear nuclei (II), superior olivary complex (III), lateral lemniscus (IV), inferior colliculus (V), medial geniculate body (VI), and auditory radiations (VII). Each wave is the summation of several neuronic groups that come into activity during one and the same space of time [6].

In otoneurology, the aim is to establish the *latency times* of the three most readily identifiable waves: I, III, and V. The interval of time between two waves (I–III, III–V, and I–V) is of major importance since it represents the time of conduction between two nerve relays.

From a diagnostic point of view, the interaural latency differences (IT) have the highest value, chiefly the IT V and IT I–V. Their mean value is nil in the normal subject [6]. Study of IT is the best test for the *diagnosis* of retrocochlear auditory pathology.

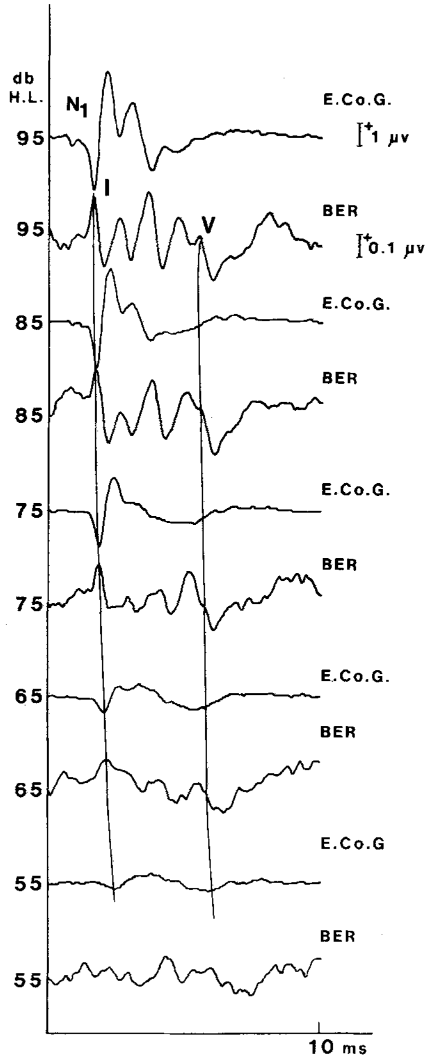

Fig. 1. Simultaneous recordings of transtympanic ECoG and BER

The IT V identifies the presence of an acoustic neuroma in 93–96% of the cases [7–9].

The IT I–V is even more reliable. Above 0.35 ms, it would appear to be 100% indicative of retrocochlear pathology [10].

In the absence of profound deafness, the BER enable a pure cochlear pathology to be distinguished from a retrocochlear pathology. The *key element* is the knowledge of the *I–V interval.*

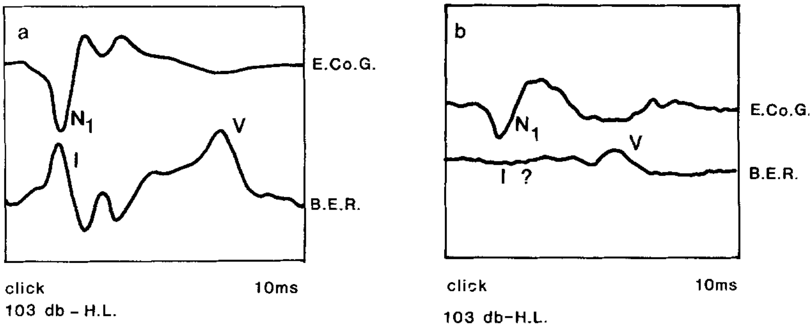

Fig. 2. Simultaneous recordings of ECoG and BER in two comatosed patients. **a** Normally hearing subject. Waves I and V are identifiabel (BER). **b** Cochlear hearing loss. Wave I is unidentifiable (BER) but N_1 is easily identifiable (ECoG) (Nicolet C.A. 1000)

First Thesis

The I−V interval and the IT I−V of the BER are the key elements to define when establishing diagnosis of retrocochlear hearing loss or of degenerative nerve lesion of the brainstem [11], or when making the assessment of a comatosed patient [6].

However:
1. *Wave I* is, in many cases, *difficult* to bring reliably into evidence, principally in the case of deafness (It should be remembered that, for a patient with normal hearing, at 50 dB HL, wave I is unidentifiable in 15% of the cases [6]).
2. N_1 (AP in ECoG) corresponds to wave I [12]. The N_1−N_2 complex remains easily identifiable up to the threshold [3].
3. *Wave V* also is identifiable up to the psychophysiologic threshold.

Therefore:
The *simultaneous* recording of the ECoG and BER (1)enables the N_1 (I)−V interval to be known easily; (2) increases the reliability and prognostic value of electrophysiologic measurement of hearing (Fig. 2).

Second Thesis

If the correlation between the first negative peak of the AP (N_1 in ECoG) and wave I (BER) is evident [12, 13], simultaneous recording of the ECoG and BER would perhaps enable *other correlations to be objectified.* By placing the ECoG reference electrode on the vertex rather than on the ear lobe IL, several negative peaks are objectified on the trace. These peaks are superimposable and have latencies identical to the waves observed in the BER. Their correspondence is

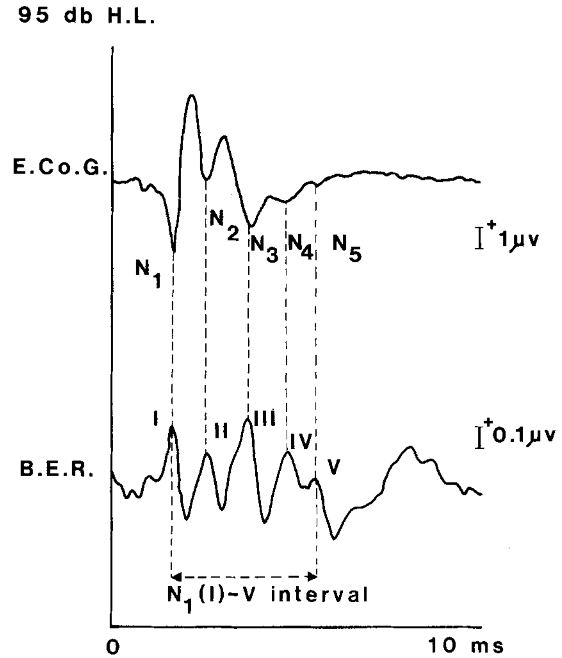

Fig. 3. Simultaneous recordings of ECoG and BER: normal-hearing subject, stimuli: clicks at 95 dB HL

yet more readily visualized on the oscilloscope since the ECoG and BER peaks lie in opposite directions (with respect to vertex): negative for the ECoG and positive for the BER.

Therefore, at high intensity, e.g., 100 dB H.L., waves I, II, III, and V have their correspondence in ECoG, which may be known as N_1, N_2, N_3, and N_5. N_1 and N_2 are the most easily objectifiable (Fig. 3).

It then follows that,
if N_1 (AP in ECoG) corresponds to wave I (BER) and N_2 to wave II, it would be logic to suppose that *wave II*, like N_2, is a response of the cochlear action potential (cf. Introduction). The generator of wave II would not be confined to the cochlear nuclei alone [5], but would also (and perhaps mainly) be a population of the cochlear nerve.

Therefore,
wave I, like wave II, would result from the summation of the cochlear nerve responses and those of the cochlear nuclei. *Wave I* would be the *early cochlear response* (basal turn of the cochlea) and *wave II the late response* (second turn), corresponding to the high and the low responses[4]. Their differences in latency would be linked to a difference in mechanical cochlear transmission time.

Comments

1. In ECoG, according to level of sound intensity or to type of auditory pathology, the AP will be N_1 (N_2), N_1-N_2 or (N_1)N_2.

The interval between the AP and wave V of the BER can therefore be either the true I−V interval or the II−V interval.

2. In some cases, the ECoG response represents the sum of SP and AP, and the AP latency is less evident. Substraction techniques enable the SP to be extracted and the AP latency to be known with precision.

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