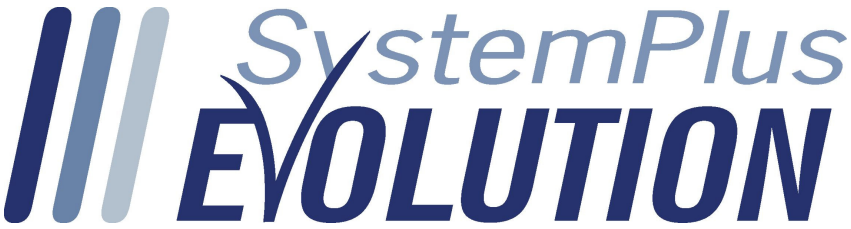
EP
Application Note



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EVOKED POTENTIALS

Evoked potentials (EP) are bioelectric signals generated by the activation of specific nervous paths as a consequence of a stimulation. Since nervous paths are located deeply and far from the recording points, the EP signal has a very low amplitude (few µV) an it is almost covered by other bioelectric signals like EEG, ECG, muscular activity and surrounding electromagnetic noise. In order to get the EP signal, it is very important to:

- connect the electrodes in the exact locations as defined by the literature (note the electrodes are often quite far each other in order to permit to catch the deep nervous electrical activity),
- use the synchronized average technique,
- get patient collaboration (if awake), in order to beat down artifactual activity.

Practical experience is another important factor to obtain a good signal; quality of the examination mostly depends on technician experience and patient collaboration, rather than on the quality of the recording machine.
Here below, general rules and precautions are described in order to execute different EP recordings.

Synchronized average

Synchronized average is a technique used to extract an electrophysiological signal, evoked by a stimulus, in a situation where this signal is hidden by noise or different electrophysiologic signals (electric waves with a low signal/noise ratio). The technique consist in averaging the recordings immediately following a trigger condition, often related to a stimulation. The system should know the exact times the stimulations are delivered in order to distinguish between the patient response correlated to the stimulus and the uncorrelated electrophysiologic or noisy signal.

In order to improve the quality of the evoked potentials and to reduce the time requested to obtain a good evoked potential, the acquisition system does not take in consideration the slices of recording whose recorded values are higher than a defined threshold level (also called rejection level). The rejection level should be set to some µV (generally from +/- 40 to +/- 80) in order to exclude artefacts caused by patient movements, eye blinking, ECG signal, and so on…

Signal/noise ratio it the parameter used to evaluate the quality of an EEG/EP recording, higher values mean the “important” signal is clearly distinct from thebackground noise. Applying the synchronised average technique, the signal/noise ratio increases following the square root of the number of averaged signals. As an example, it increases 30 times by averaging 1000 traces, it increases only 10 times more (40 times) by averaging 2000 traces. If EEG traces have a main activity at 50µV, after 1000 averages the residual activity will be 1.6 µV, thus permitting to identify an evoked potential of 5 µV. but not sufficient to identify an brainstem evoked potential, which often has amplitudes lower than 1 µV.

Normally, for practical reasons, average is split in 2 or 3 trials (as an example: 2400 averages are divided in 3 groups of 800 stimulations each). At the end of each trial, the EP is saved and compared to the result of the other trials. All EPs obtained by the different trials must be similar each other: EP reproducibility indicates the good proceeding of the test. Take also care, the more the stimulations, the more the brain adapts to them, thus reducing the amplitude and modifying the shape of the evoked potential (adaptation).

Recording place and patient condition

The awake patient has to be relaxed and resting, in order to reduce the electrical activity caused by muscular contraction and movement artefact. Patient collaboration may be obtained by taking care of ambient conditions (like illumination, noise, comfortable position, psychologic disease, and so on…). If patient is not relaxed during the examination, it is always better to stop it; in some case, forcing a straining patient to complete the examination, will decrease the recording quality.

Tests on comatose patients are easier to accomplish since there are no movement or muscular contractions (the main source of artefacts). On the other side, environment conditions in ICUs are worse than in standard laboratory examinations, because patient would probably be close to many other different monitoring or measurement instrumentations creating electromagnetic interferences.

In general it's better to keep the amplifier as far as possible from other machineries and to avoid recording cables to run close to other electrical cables. Normally, better to use electrode cables no longer than 70-80 cm; in every case, twisting the recording cables each other will decrease the noise.

An important and frequent noise source is the presence of electromagnetic interference of telecommunications devices like radio and telephones. Radio waves are often very strong in the hospitals as well as the presence of wireless telephones close to the patient or to the acquisition machine. Even when not used, radio-telephones periodically transmit acknowledgement signals to the wireless network, thus creating interference during the recording. The acquisition systems are protected from radio interferences by using special hardware filters, but filters do not erase interferences at all. Better filters against radio frequencies cause a deterioration of amplifiers Common Mode Rejection Ratio CMRR, thus not permitting to record the evoked potentials.

The complete EP recording system is constituted by the acquisition headbox with stimulator and a PC used for the data displaying and memorization. The PC itself, laptop or desktop, is a big electromagnetic noise source and it must never be positioned too close to the patient (even for safety reasons) or to the acquisition headbox.

Electrode application

Good electrode connection is very important in evoked potential recordings. Quality of an electrode connection depends on the place the electrode is placed and on the contact impedance. While electrode position veries depending on the tests, you have always to pay attention to the contact impedance which depends on the type of electrode and on the application modality. If contact impedance is low, you can easily obtain a good recording. The common mode rejection ratio (CMRR) is as high as the contact impedance is low and balanced between the two amplifier inputs. The noise from external signal are rejected well when CMRR is high and there is a low contact impedance.

Silver cup electrodes connected with conductive EEG gel, on clean and ungreased skin, have a 2-3 KΩ contact impedance. If they are positioned on a not cleaned and ungreased skin, even if using a good conductive gel, have an impedance of 20-40 KΩ. Therefore it's very important to always measure the contact impedance before to start the recording.

Needle electrodes, stuck in the skin, have a contact impedance of 3-5 KΩ independently on the skin quality (conductive gel is not used with those electrodes). Take care needle electrodes often hurt the patients in a way they could start not to collaborate (i.e. children tends to move increasing the movement artefacts). Take also care needle electrodes tend to polarize more than cup electrodes (with consequent signal deterioration) and they weaken low frequency signals (under 3-4 Hz).

Filters

The use of hardware filters is a must during EP recordings. The system has both on-line and off-line powerful digital filters, and an hardware customizable high-pass filter. In analogue to digital conversion theory, the lower band limit of the signal to convert has not influence on the quality of the conversion itself; only the higher band limit has to be limited to lower than half of sampling rate (sampling theorem). In practice, the opposite is much more important, because the system automatically controls the upper bandwidth limit by hardware, (in function of the sampling rate) but, since in EP we acquire short slices of EEG, the lower band limit has a greater practical importance in order to avoid offset in the amplifier and its saturation for a long time in case of low frequency artefacts.

Sometimes, in particular when recording very long latency evoked potentials, wide band (DC) amplifiers are required. Take care that the lower the band limit of the amplifier, the more difficult is to record a

signal since offset potentials (mainly due to electrode polarization) saturate the amplifiers thus not permitting to record the signal for long time. Increased bandwidth also causes longer recovery times from amplifier saturation.

Hardware notch filter eliminating 50 (or 60 Hz) is not to be used since most of the times it erases important signal components of EP. It is always better to take advantage of amplifier high CMRR and take care of contact impedance and cable positions in order to lower down 50 Hz noise that can be further eliminated by synchronised average using stimulation rates not multiple of 50 Hz.

Stimulation artefacts

The mostly used EP stimulators are electric, visual and acoustic. Stimulators produce electric energy thus inducing an electromagnetic field close to the patient and synchronous with the beginning of the EP; therefore stimulation artefact is not erased by synchronised average technique.

The stimulation artefact is always present in EP recordings, but its amplitude must be reduced in order not to get some interference with the evoked potential. The stimulation artefact duration is generally short and usually it finishes before the beginning of the evoked potential. However, sometimes the stimulation artefact overlap the evoked potential (as an example, the first component of the brainstem potential which has a latency of 2 ms).

Reduction of stimulation artefact can be accomplished by mean of patient skin preparation (for the electric stimulation) that reduces the contact impedance and the required voltage to produce the electric stimulation. It is also important to avoid stimulator cables are close to the electrode cables (keep always separate stimulation and recording cables) and to use the minimum stimulus duration and intensity stimulation required to excite the patient.

Evoked Potential Types

EPs are mainly divided in 3 categories depending on the latency: EP with short, mean and long latencies. EPs are defined “short term” if they appear within 10 ms after stimulus (i.e.: brainstem evoked potentials); the EPs appearing within 100 ms are defined as “mean term” latency (as the somatosensory potentials). If EPs have a latency higher than 100 ms, they are called “long term” latency (examples are the late components of every EP, which are called cortical). As a general rule, the higher the lantency, the more the brain is involved in the interpretation of the stimulus.

EPs can also be classified using a physical-physiological standard, depending on the kind of stimulation used or on the nervous path interested by the stimulation. The somatosensory EPs are generated by the use of electric stimulation of sensory nerves. Auditory EPs are generated by acoustic stimulations. Visual EPs are generated by the retinal stimulation using short flashes. There are also many other evoked potentials obtained by complex stimulations (sounds with different tonalities, words, pictures, …); such a kind of evoked potentials are more used in research rather than in clinical applications.

The EP morphology and its latency depends both on the kind and the place of stimulation, and on the electrode positions. The EP, actually, is the recording of the variation of dipole direction, generated by polarisation and depolarisation of axonal membranes; such a dipole is generated on the stimulation area for somatosensory EPs, on the retina for visual EPs and on the cochlea for acoustic EPs. The dipole moves along the sensitive, visual or acoustic paths until the endocranic level, distributing then on the cerebral cortex areas. At this level the dipole scatters, originating many smaller dipoles in different directions, that are not recordable with precision.

If the dipole evoked by an electric stimulus on a nerve is recorded in another point along the nervous path to the brain, using two electrodes, one close to the other and positioned over a random point in this path, we obtain a biphasic action potential, with the latency depending on the distance from the stimulation site. This is what happens recording a somatosensory EP by using electrodes on the ERB and cervical points.

If electrodes are positioned far from each other (meaning we can catch electrical activity more deeper in the brain), the evoked potential has more a complex morphology, depending both on the shifting and on the changing of dipole position. A typical example is given by brainstem potentials, where you can find 5 components recording with an electrode on the vertex and another one on the mastoid. The dipole begins at the coclea, propagate along the acoustic nerve, then on the bridge, then in the midbrain and finally through the temporal cortex. Such a dipole changes position many times; it runs close to the mastoideus electrode too, then it goes away and finally it returns close to the mastoideus electrode again. For this reason many waves with different amplitude and latency are recorded.

In order for the EP to be correctly evaluated, correct stimulation and recording electrode positioning are crucial. In order to obtain repetitiveness of multiple examinations on the same patient, it is essential to pay attention and keep the same recording electrode recording points during the time.

The different peaks composing the EP, have a standard naming convention composed by a letter and a number where:

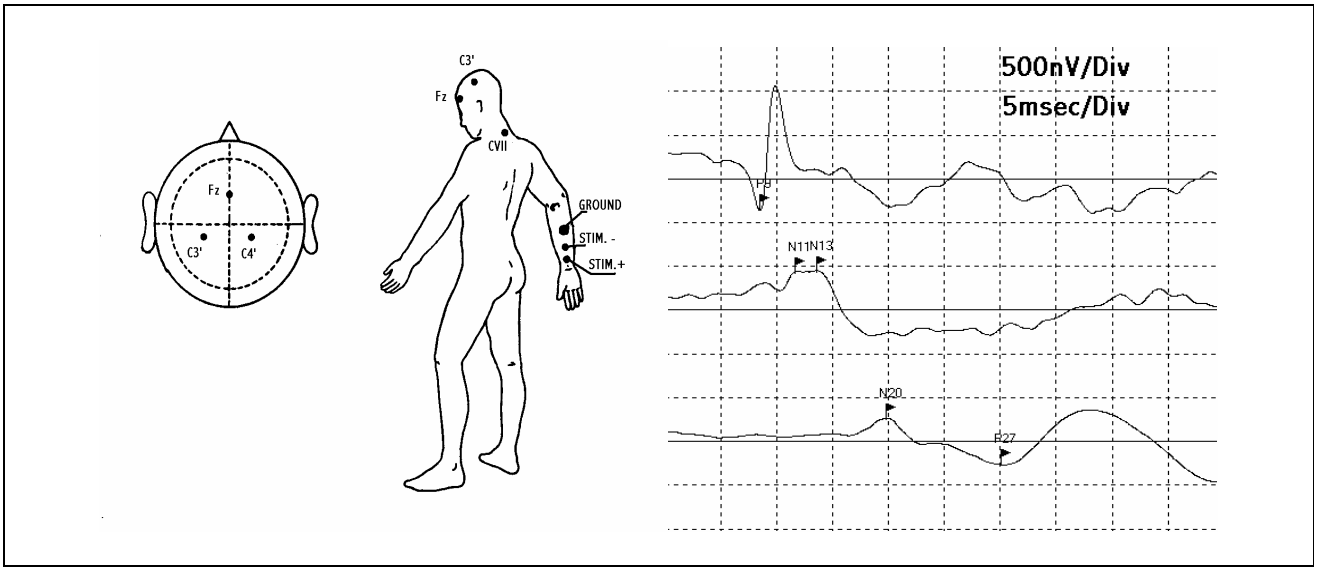
- The letter (P or N) means positive or negative (where negative peaks are the ones having positive amplitudes),
- The number represents the typical latency of the peak in µs.

As an example N100 means an “upper” peak at a latency of 100 µs.
The electrodes used to acquire a single EP channels, also have a standard naming convention:

- Active is used to designate the negative electrode (in black),
- Reference is used to designate the positive electrode (in red).

SOMATOSENSORY EVOKED POTENTIALS – UPPER LIMB

The median or the ulnar nerves are stimulated on the wrist (the anode is placed just proximal to the palmar crease, and the cathode is placed between the tendons of the palmaris longus muscle, 3 cm proximal to the anode) and the signal is recorded in several points on the neck and on the scalp. The most frequent recording points are on the supra-clavear region (ERB), on the cervical column (C5, C7) and on the scalp (Fpz,C3', Ppz, C4').
Ulnar nerve SSEPs are preferred to median nerve SSEPs for assessing the lower cervical spinal cord, especially during intraoperative monitoring when this part of the spinal cord is at risk, because the ulnar nerve originates from spinal roots C8-T1, whereas the median nerve originates from C6-T1. Ulnar nerve SSEPs will detect dorsal column damage at the C7-C8 level, but the median nerve SSEPs may persist, mediated by sensory fibers that enter the spinal cord at the C6 level.
A lesion can be everywhere on the nervous system from wrist to the scalp and can take signal alterations. The signal recorded under the lesion point could be normal. For example a medullar sufferance by hernia can change potential in C5 and C7 and in the scalp without changing potential on the ERB.
Increase in latency of SSEP is very important in order to detect abnormalities in the nervous path, also signal shape alteration or its disappearance are important, even if less frequent. Since the latency time is related to the distance between recording and stimulating points, taller patients have higher latency times than shorter ones. The normal latency times tables have to be related to the patient height.
Potentials obtained by median nerve stimulation are normally sharper and wider than the ones obtained by ulnar stimulation. Median nerve has often a common peripheral pathology (called carpal tunnel), so it is very important to proceed with ulnar stimulation before starting an evoked potential using the median stimulation.
The somatosensory potentials on the scalp have a very complex and varying morphology, so they are not described in this application note.



Electrode position

Acquisition is performed by using 3 channels :

- channel 1 acquires signal at ERB position with ERB right (active), ERB left (reference) as recording points,
- channel 2 acquires signal at C5 with Fz as reference,
- channel 3 acquires with C3'or C4' as active electrode depending if we are studying a right or left stimulation and reference at Fpz.

Ground can be positioned on the limb between the stimulator and the scalp.

Stimulation

Type :	Electric
Duration :	100 µsec
Intensity :	varying, the minimum value sufficient to evoke a movement on the hand when stimulation the median or the ulnar nerve (twitch)
Rate :	2.5Hz; rapid stimulus delivery rates (over 6 Hz) should be avoided, as they degrade the SSEP waveforms; always avoid stimulation rates that are subarmonics of 50 or 60 Hz since their use would lead to contamination of the averaged SSEPs by large artifacts of the line frequency (50 or 60 Hz).

Acquisition parameters

Number of channels:	3 or 4
High Pass Filter:	20Hz
Low Pass Filter:	500 - 1000Hz
Base Time:	50 ms
Max Signal:	±200 µV
Gain/Div:	10 µV/div

Average

Average:	1000
Gain/Div:	1 µV/div

Working modality

Use synchronised average for 1000 times. The EP should become clearly visible after 300-400 averages. The patient has to be relaxed especially with his paravertebral and cervical muscles; so he must lie down with a lightly flexed neck on a comfortable cushion.

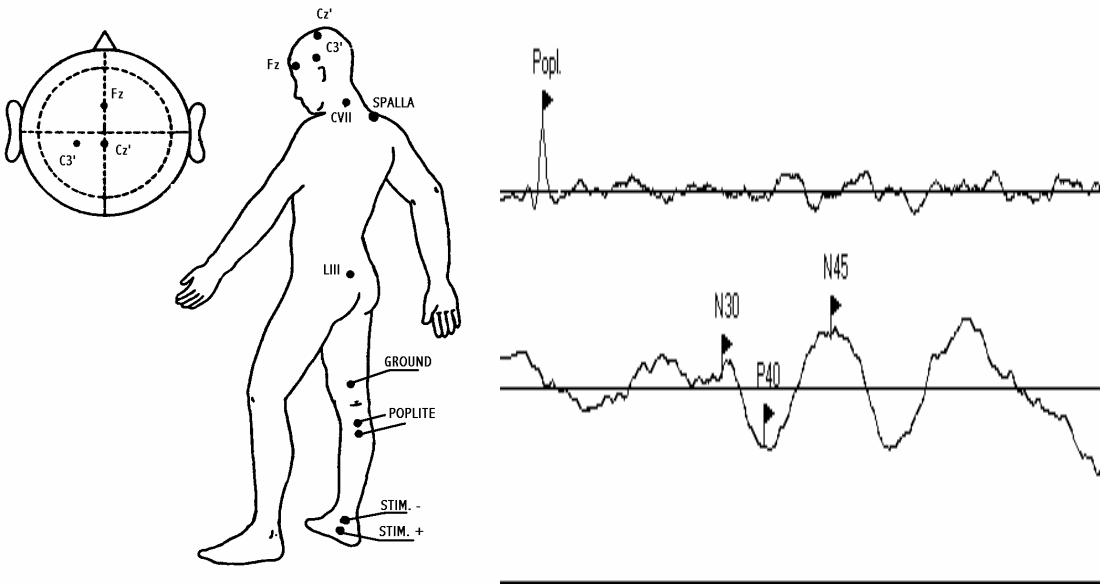
SOMATOSENSORY EVOKED POTENTIALS – LOWER LIMB

Two stimulation ways are normally used: posterior tibial and peroneal nerve.
For recording posterior tibial nerve SSEPs, the nerve is stimulated at the ankle, with the cathode midway between the Achilles tendon and the medial malleolus and the anode 3 cm distal to the cathode.
For recording peroneal nerve SSEPs, the common peroneal nerve is stimulated at the knee, with the cathode inferior to the leg crease just medial to the tendon of the biceps femoris muscle and the anode 3 cm distal to the cathode.
In the lower limb, posterior tibial SSEPs are generally preferred because of the following:

- in clinical diagnostic use, they are larger and display less intrasubject variability,
- in intraoperative settings, they produce less patient movement,
- in intraoperative settings, electrodes at the ankle are more accessible, and thus more easily replaced should they malfunction, than those at the knee,
- the peripheral nerve compound action potential (CAP) is easily recorded at the popliteal fossa and can be used to determine whether the nerve is being adequately stimulated. This is crucial when the rostral SSEPs deteriorate during intraoperative monitoring to indicate whether the SSEP changes are caused by spinal cord compromise or by technical problems with nerve stimulation.

However, peroneal nerve stimulation may be better in some cases because of the following:

- some patients can tolerate peroneal nerve stimulation but find posterior tibial nerve stimulation too uncomfortable,
- the posterior tibial nerve may be difficult to stimulate adequately in some patients,
- in some patients with peripheral neuropathy (which may tends to affect longer nerves more severely), peroneal nerve SSEPs may be present whereas no posterior tibial nerve SSEPs are identifiable.



SEP inferior limbs recorded in 2 channels with poplite and vertex recording points

Electrode position

When using two channels, as in the previous example, the recording channel positioned on the scalp has the active electrode in Cz and the reference in Fz, while the peripheral channel is on the popliteal muscle.
When using 4 channels, the additional two recording points are placed on the vertebral column with actives electrodes in LIII and CVII and reference electrode on the shoulder or on the ears.
To have a high signal quality the electrodes impedance should be lower than 5 KOhm and should be balanced between the different electrodes.

Stimulation

Type :	electric
Duration :	100 µsec
Intensity :	varying, the minimum value sufficient to evoke a movement on the toes when stimulation the ankles (twitch)
Rate :	2.5Hz; rapid stimulus delivery rates (over 6 Hz) should be avoided, as they degrade the SSEP waveforms; always avoid stimulation rates that are subarmonics of 50 or 60 Hz since their use would lead to contamination of the averaged SSEPs by large artifacts of the line frequency (50 or 60 Hz).

Acquisition parameters

Channel Number:	2 or 4
High Pass Filter:	4 Hz
Low Pass Filter:	500 - 1000 Hz
Base Time:	100 ms
Max Signal:	±200 µV
Gain/Div:	10 µV/div

Average

Average:	1000
Gain/Div:	1 µV/div

Working modality

Use synchronised average for 1000 times. The EP should become clearly visible after 500-600 averages.).

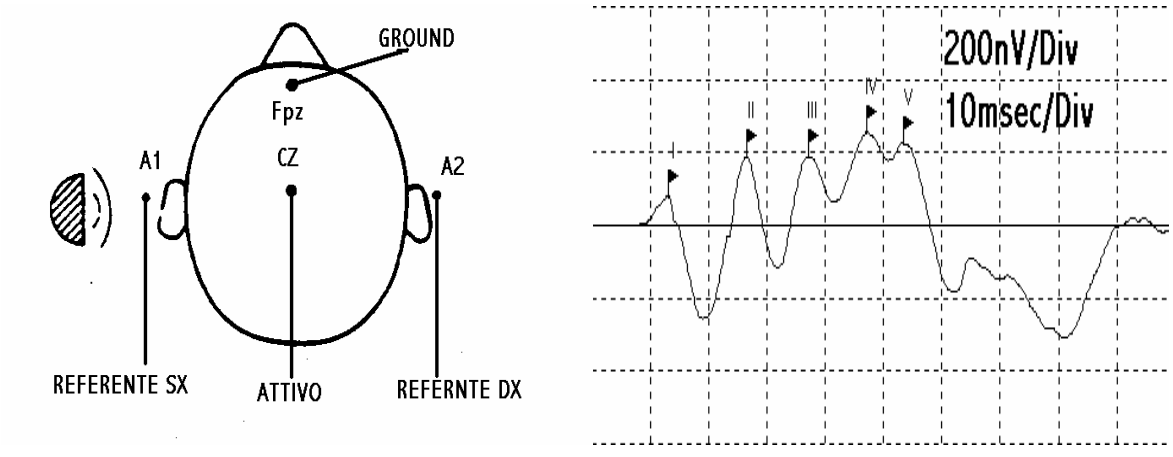
BRAINSTEM EVOKED POTENTIALS

Auditory brainstem response (ABR or BAEP) audiometry is a neurologic test of auditory brainstem function in response to auditory (click) stimuli. ABR audiometry refers to an evoked potential generated by a brief click or tone pip transmitted from an acoustic transducer in the form of an insert earphone or headphone. The elicited waveform response is measured by surface electrodes typically placed at the vertex of the scalp and ear lobes. The waveform peaks are labeled I-VII. These waveforms normally occur within a 10-millisecond time period after a click stimulus presented at high intensities (70-90 dB normal hearing level [nHL]).

Auditory brainstem response (ABR) audiometry typically uses a click stimulus that generates a response from the basilar region of the cochlea. The signal travels along the auditory pathway from the cochlear nuclear complex proximally to the inferior colliculus. ABR waves I and II correspond to true action potentials. Later waves may reflect postsynaptic activity in major brainstem auditory centres that concomitantly contribute to waveform peaks and troughs. The positive peaks of the waveforms reflect combined afferent (and likely efferent) activity from axonal pathways in the auditory brain stem.

Auditory brainstem response (ABR) technology has been used in testing newborns for the past 15 years. Approximately 1 of every 1000 children is born deaf. Many more are born with less severe degrees of hearing impairment, while others may acquire hearing loss during early childhood. Several clinical trials have shown automated auditory brainstem response (AABR) testing as an effective screening tool in the evaluation of hearing in newborns, with a sensitivity of 100% and specificity of 96-98%.

Auditory brainstem response (ABR), often used intraoperatively with electrocochleography, provides early identification of changes in the neurophysiologic status of the peripheral and central nervous systems. This information is useful in the prevention of neurological dysfunction and the preservation of postoperative hearing loss. For many patients with tumours of CN VIII or the cerebellopontine angle, hearing may be diminished or completely lost postoperatively, even when the auditory nerve has been preserved anatomically.



BAEP with the following latencies:
I=1.31msec, II=2.66msec, III=3.71msec, IV=4.70msec,V=5.34msec

Electrode position

2 channels are normally sufficient for BAEP application.
The active electrode is positioned on Cz, the reference on the mastoid or on the lobes (A1 and A2), and the ground on the forehead in Fpz.
To have a high signal quality the electrodes impedance should be lower than 5 Kohm and balanced between the different electrodes.

Stimulation

Type :	Click (normally alternating compression/rarefaction)
Mask :	Sometimes pink noise is introduced on the cap controlateral to the stimulation
Duration :	100 µs
Intensity :	70 - 80dB over auditory threshold
Rate:	11Hz or slightly less

Acquisition parameters

Channel Number :	1 or 2
High Pass Filter :	150Hz
Low Pass Filter :	3000Hz
Base Time :	10 ms
Signal max :	±50 µV
Gain/Div:	10 µV/div

Average

Average:	2000
Gain/Div:	200 nV/Div

Working modality

Test the patient auditory threshold and add 70dB before to begin the stimulation.
Continue averaging until you reach the programmed stimulation number (normally 2000, since the evoked potential amplitude has nanoVolt amplitude).
BAEP has 7 positive waves, labelled with roman numbers from I to VII and grouped in the first 10 ms after stimulus. The first 5 ones are the most important; you can find them in almost all BAEPs.

VISUAL EVOKED POTENTIALS

The VEP tests the function of the visual pathway from the retina to the occipital cortex. It measures the conduction of the visual pathways from the optic nerve, optic chiasm, and optic radiations to the occipital cortex. The most important fact to consider is that, although the axons from the nasal half of the retina decussate at the optic chiasm, the temporal axons do not. Therefore, retrochiasmatic lesions may not be detected by full-field checkerboard stimulation. VEPs are most useful in testing optic nerve function and less useful in postchiasmatic disorders. In retrochiasmatic lesions, the Partial field studies or MRI are a more useful test.

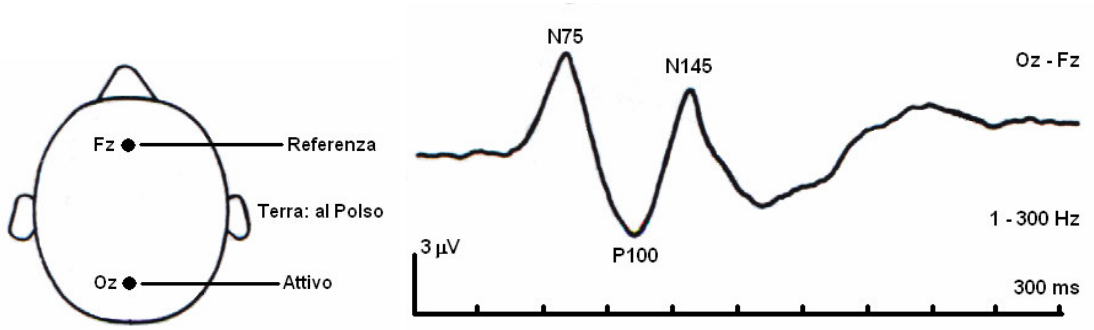
The VEP is very useful in detecting an anterior visual conduction disturbance. However, it is not specific with regard to etiology. A tumor compressing the optic nerve, an ischemic disturbance, or a demyelinating disease may cause delay in the P100; only additional clinical history and, often, MRI are needed to uncover the etiology.

The usual waveform is the initial negative peak (N1 or N75), followed by a large positive peak (P1 or P100), followed by another negative peak (N2 or N145). Maximum value for P100 is 115 milliseconds (ms) in patients younger than 60 years; it rises to 120 ms thereafter in females and 125 ms in males. Even though published norms are available in the medical literature, each individual laboratory should have its own norms to control for lab-to-lab variability in technique.

The W morphology of the VEP is most often an individual variation, although decreasing the stimulation frequency from the ubiquitous 2 Hz to 1 Hz usually converts the W shape into a conventional P100 peak. Check size and alternation rate are factors in this; the responses can be manipulated to a W or a conventional P100 response by changing these parameters. Large checks tend to produce VEPs similar to those produced by flash stimulation.

The usual VEPs are evoked by checkerboard stimulation and, because cells of the visual cortex are maximally sensitive to movement at the edges, a pattern-shift method is used with a frequency of 1-2 Hz. The size of the checks affects the amplitude of the waveform and the latency of the P100. In addition, pupillary size, gender, and age all affect the VEP. Visual acuity deterioration up to 20/200 does not alter the response significantly; large checks may be required. In some studies, women have slightly shorter P100 latencies. Sedation and anesthesia abolish the VEP. Some subjects, by "fixating" beyond the plane of stimulation, may alter or suppress P100 altogether.

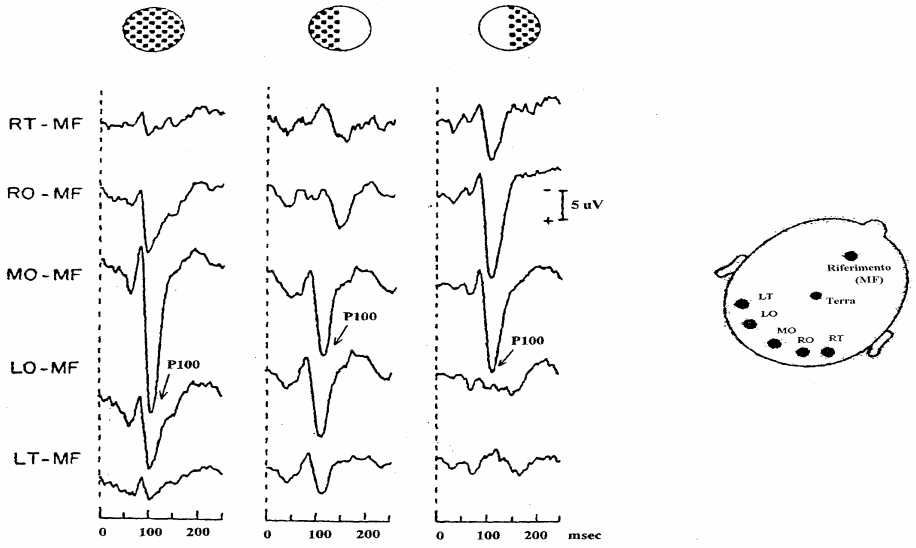
VEPs are mainly used to test sclerosis influence on visual functions and to test distribution of visual information at the very first stages of cortex elaboration. VEPs used with particular retina electrodes (ERGs) are useful to test several retinal pathologies. In general VEP gives indication about pathologies of the entire optical nerve, and pathologies of primary cortex elaboration of optical nerve information



VEP simplest electrode position and typical evoked potential

Electrode Position

Responses are collected over Oz, O1, and O2 and with hemifield studies at T5 and T6 electrodes using the standard EEG electrode placement.
To have a high signal quality the electrode impedance should be lower than 5 Kohm and it should b balanced between the different electrodes.



Example of Multichannel VEP

Stimulation

Type: Flash or Checkerboard, in case of checkerboard, 3 modes are used::

- Full screen
- Horizontal half field (4 recording channels required)
- Vertical half field (4 recording channels required)

Monocular stimulation is used to avoid masking of a unilateral conduction abnormality. Testing circumstances should be standardized, including seating distance of 70-100 cm from the monitor screen, giving a check size of approximately 30 seconds of visual angle. The vision should be corrected to the extent possible in case of a visual problem. Pupil size and any abnormality should be noted.

Visual angle: 15', 30', 60', 90' (an EP recording is mostly required for each angle)

Rate: 1 – 2 Hz

Contrast: 60% to 95% (typical)

Patient Distance: Micromed **PATTERN 10** stimualtor uses two standard distances for patient (called A e B) depending on the kind of monitor used:

Distance	Monitor 15"	Monitor 14"	Monitor 13"
A	**130.97 cm**	**122.24 cm**	**113.51 cm**
B	**109.14 cm**	**101.87 cm**	**94.59 cm**

NOTE. The values described refer to the stimulation unsing Micromed **PATTERN 10** stimulator.

Acquisition Parameters

Channel Number:	1 to 5; multiple channels are used for more selective VEP recordings when partially stimulating the fovea (half or quarter field stimulations)
High Pass Filter:	1 Hz
Low Pass Filter:	100 Hz
Base Time:	200 – 500 ms.
Signal max:	±200 µV
Gain/Div:	20 µV/div

Average

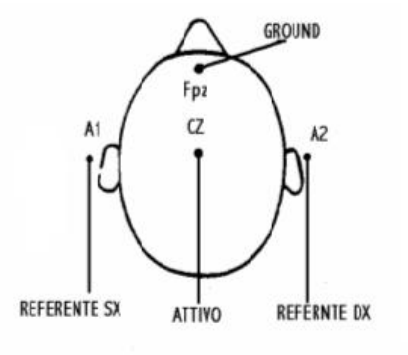
Average:	100 - 150
Gain/Div:	2 - 5 µV/Div

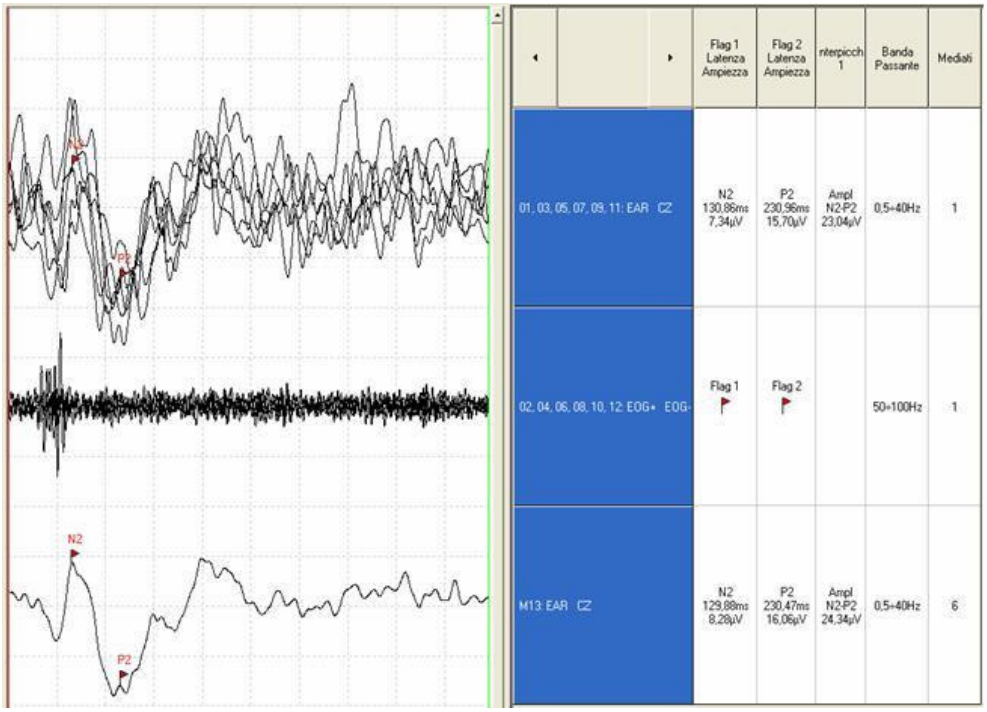
Working modality

Place the patient in a coherent position in front of the stimulator (visual angle, pattern dimension), then proceed with the stimulation until the programmed number of stimulations is reached, normally 100-150. Repeat the stimulation procedure at least twice for each eye.
In the evoked potential we usually detect 3 waves: N75, the first negative deflection, N100, the greatest and most reproducible positive wave, and N145.

LASER EVOKED POTENTIAL

Laser Evoked Potentials are used to examine pain disturbances.





2 channel LEP with latency peak:
N2=129,88msec and P2=230,47msec.

Electrode position

One or two channels are normally used; in case of one channel applications, active electrode is positioned on the vertex Cz and reference on the nose or on the lobe A1-A2, ground is connected to the forehead Fpz. Sometimes oculars movement and contralateral temporal site (T3, T4) are recorded. To have a high signal quality the electrodes impedance should be lower than 5 Kohm and balanced between the different electrodes

Stimulation

Type :	Laser
Duration :	Depending by pain patient threshold
Intensity :	Depending by pain patient threshold
Rate :	0,1 Hz

Acquisition parameters

Channel number :	1 to 3
High Pass Filter :	0,3 Hz
Low Pass Filter :	70 Hz
Time Base:	1 s
Signal Max:	±200 µV
Gain/Div:	10 µV/div

Average

Average :	30
Gain/Div :	10µV/div

Working modality

As a first step, you need to test the patient pain threshold, then you start the acquisition. Average the trace until you obtain a clear and well defined potential, potential has an amplitude of some µV, so to obtain a good result 30 averages are enough in most of the cases.
Repeat the examination 2 times for each side to verify the coherence of the potentials.
LEP potentials is composed by a negative peak around 120 ms and a positive deflexion around 400 ms.

Cognitive Evoked Potentials

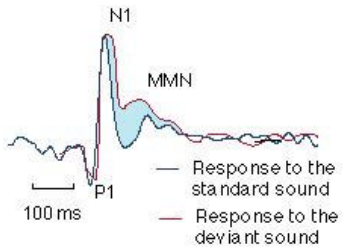
While short latency EP are generated by the «obligatory» nervous pathways (they are also called «exogenous» that means: determined outside the organism), later EP components are sensitive to changes in meaning of stimulus and information processing (for this reason, they are called «endogenous» = determined within the organism). Long latency EP, also called Cognitive Evoked Potentials (ERP), are further divided in two classes:

- Evoked ERP, the most commonly studied, occurring in response to a physical stimulus,
- Emitted ERP occurring in absence of a physical stimulus (i.e. omission of item in a sequence).

Evoked ERP can have both exogenous and endogenous components; emitted usually have only endogenous.
Oddball stimulation paradigm is the most widely used in order to evoke ERP; oddball paradigm propose a sequence of two different stimuli called “frequent” and “rare”. The frequent stimulus is given at a predefined or random rate; the rare stimulus is presented randomly in place of the frequent one (frequent to rate ratio is defined by the stimulation protocol). The rare stimulus can also be a “missed” stimulus, but in this case some problems for synchronization of the average arise. Sometimes the user is asked to perform a “cognitive” task every time a rare stimulation occur (like to count the number of stimulations or to press a button).
Different kind of stimulators are used; frequent and rare stimulation may vary for intensity (i.e. lower and higher volume of acoustic stimulation), position (i.e. left and right hand electrical stimulation), characteristic (i.e. different tone of acoustic stimulation), meaning (i.e. relaxing or tensing pictures). The most widely and documented stimulation used is acoustic.
Two different Evoked Potentials, each following frequent or rare stimulations, are then calculated and analysed.

Mismatch Negativity

The Mismatch Negativity or MMN is a negative ERP component that is recorded between 100-200 ms in response to low-probability deviant sounds in a sequence of standard sound stimuli, when attention is directed elsewhere. The deviance between sounds can be defined by a frequency (pitch) difference or a duration difference. The MMN is considered as the 1st step in the processes leading to conscious detection of differences in auditory context, i.e. the mnemonic comparison of a given stimulus with a previous one which has already build up a trace in memory. The violation of the previously formed memory trace produces the MMN. Recently, it has been demonstrated that not only physical characteristics of the stimulus but also abstract properties can lead to the MMN. MMN has being used to study dyslexia and, since it reflects a preattentive state, it can be also elicited during sleep, moreover, it has been proposed as an index for coma prognosis.
The MMN is best seen in the difference wave between the ERP in response to the standard and deviant sounds.



P300

The classical P300 deflection emerges in a timelocked record as a positivity typically appearing approximately 300 to 400 ms following stimulus presentation. Timing of this component may range widely, however, from 250 ms and extending to 900 ms, with amplitude varying from a minimum of 5 µV to a usual limit of 20 µV for auditory and visual evoked potentials, although amplitudes of up to 40 µV have also been documented. The P300, first described by Sutton, et al., is perhaps the most-studied ERP component in investigations of selective attention and information processing, due partly to its relatively large amplitude and facile elicitation in experimental contexts.
The P300 is typically generated in an auditory 'oddball' protocol in response to attended low-probability (deviant) target stimuli requiring an overt response. Typically the P300 amplitude in response to the low-probability target stimuli will be higher relative to that in response to the standard stimuli. The P300 is considered to be related to the maintenance of working memory when the mental model of the stimulus environment is updated.

Electrode Positions

ERPs can be acquired using 2 up to 32 channels; the most used configuration for clinical purposes employs 3 recording points: Fpz, Cz, Pz, all referring to A1A2 (ground in Fz).

Stimulation

Type :	Many different kind of stimulation are employed; depending on the type of stimulation different stimulators may be used (from the traditional electric stimulator, to the complex paradigm stimulators). The most test are performed by using acoustic tones as described below:
Frequency:	Rare tones having lower frequencies than frequent tones (1000 Hz against 2000 Hz, trapezoidal envelope)
Duration :	50 ms or slightly higher
Intensity :	70 dB HL
Rate :	Random between 0,3 to 0,8 Hz

Acquisition parameters

Channel number :	2 up to 32
High Pass Filter :	0,5 Hz
Low Pass Filter :	100 Hz
Time Base:	500 ms
Signal Max:	±200 µV
Gain/Div:	20 µV/div

Average

Average :	60 per trial (presentation of rare sounds about 15% or 20%), 3 trials per exam
Gain/Div :	10µV/div