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CONTENTS

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ORIGINAL ARTICLES

- | | |
|---|---|
| Neoplasms involving the spinal cord in Zimbabweans: an analysis of 262 cases | PI Garrido, S Laher-Mooncey, NL Murphree, N Jonker, LF Levy, S Makarawo 201 |
| Termination of pregnancy using extra-amniotic prostaglandin F _{2α} – experience in a peripheral hospital | A Krolkowski, KA Janowski, JV Larsen 204 |
| Epidemiological study of drug use in urban and rural secondary schools in Zimbabwe | SW Acuda, AH Eide 207 |
| A comparison of three types of "M" traps for sampling tsetse fly (Diptera: Glossinidae) populations at South Luangwa Game Management Area, Zambia | MM Ziba, M Mukunyandela, S Siziya, JS Chipipa, L Mwanza 212 |
| Increased susceptibility of erythrocyte membrane lipids to peroxidation in sickle cell disease | EU Essien 217 |

CASE REPORTS

- | | |
|---|--|
| Intracranial Burkitt's lymphoma with extension into orbital spaces resulting in bilateral blindness | K Ramesh, LD Gahukambele, DB Gahukambele ... 220 |
| Munchausen syndrome by proxy – a case report and review of literature | OA Oyelami, AM Alhaj, IK Airede 222 |
| Hypothyroxinemia in Acquired Immune Deficiency Syndrome (AIDS) | CC Ezeala, E Chukwurah 226 |

REVIEW ARTICLES

- | | |
|--|--------------------------------------|
| Advances in electrodiagnosis in Zimbabwe. Part II: "Evoked Potentials" | O Parry, LF Levy, J Mielke 229 |
|--|--------------------------------------|

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and electromyography. This paper (Part II) will review the physiological basis of "Evoked Potentials" and their clinical applications.

INTRODUCTION

Cathode ray oscilloscopes incorporating averaging computers were developed about 20 years ago and this led to the ability to record brain potentials (0.5—5uV) with silver disc electrodes placed over appropriate areas of the scalp. These potentials are referred to as "evoked" potentials since, unlike the potentials recorded on an encephalogram (EEG), they are evoked only by stimulating either the somatosensory (ie large myelinated afferents subserving touch), visual or auditory pathways. Depending on which sensory pathway is being stimulated there are three types of evoked potentials:

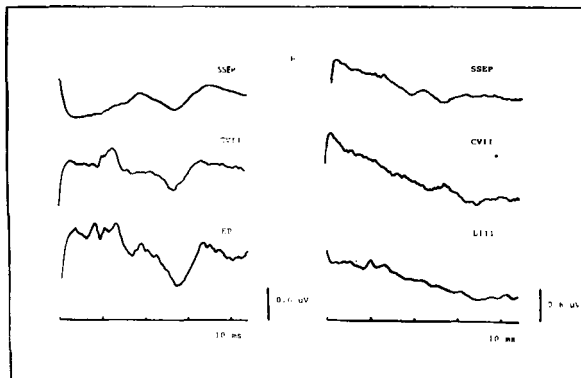
1. Somatosensory (SEP)
2. Visual (VEP)
3. Brain Stem Auditory (BSAEP)

A brief review of each type will be given.

Somatosensory Evoked Potentials (SEPs).

SEPs can be evoked by stimulating with a pair of electrodes peripheral nerves in either the upper limb (ie median or ulnar) or lower limb (posterior tibial nerve).

Figure 1: A shows evoked potentials recorded from the somatosensory cortex (SSEP), CVII vertebra and Erb's Point in response to stimulation of the median nerve at the wrists. B shows evoked responses recorded from the somatosensory cortex, CVII vertebra and LIII vertebra in response to stimulation of tibial nerve at the popliteal fossa. Calibration marks are indicated. Note the latency to onset of the various peaks and the shape of the waveform.



REVIEW ARTICLES

Advances in electrodiagnosis in Zimbabwe Part II: "Evoked Potentials"

O PARRY,¹ L F LEVY², J MIELKE³

SUMMARY

This paper is a short review of the electrodiagnostic technique of "evoked potentials", a technique recently introduced to Zimbabwe. The types of evoked potentials recorded, the method of recording and their clinical applications are discussed. Abnormal evoked potentials from a variety of neurological disorders are illustrated.

"Advances in electrodiagnosis in Zimbabwe" Part I discussed peripheral nerve conduction measurements

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Evoked potentials can be recorded not only for the appropriate area overlying the somatosensory cortex (SSEP) but also from other locations along the ascending somatosensory pathways. This includes the seventh cervical vertebrae (CVII) and the brachial plexus (Erb's point — EP) following upper limb stimulation; and the first (LI) or third (LIII) lumbar vertebrae following lower limb stimulation. Figure I shows the characteristic waveforms generated at each of these locations in response to median nerve (A) and posterior tibial nerve (B) stimulation. Parameters of note are the latencies to each clearly defined peak, amplitudes of the peaks and the shape of the waveform.

Clinical Applications.

Generally abnormal SEPs are due to disorders of proprioception, vibration and stereognosis. However disorders affecting only pain and temperature sensation give normal SEPs. This is because electrical stimulation of the peripheral nerves stimulate almost exclusively the large diameter myelinated afferents and not the smaller pain and temperature afferents.

SEPs are an useful adjunct in the diagnosis of the following conditions:

Peripheral Nerve Lesions: A peripheral nerve lesion usually involves sensory and motor nerves. It is useful to know if the lesion is complete or not, since the latter obviously has a better prognosis. This could be done by recording sensory nerve action potentials (SNAP). However SNAPs are small in amplitude and may be difficult to record particularly if the nerve is damaged but if one could record an SSEP in response to sensory nerve stimulation then this would demonstrate conclusively that the lesion was incomplete.

Peripherals Neuropathies: In some peripheral neuropathies the proximal segment of the nerve may be affected to a much greater extent than the distal segments. This is sometimes encountered in the early stages of the Guillain Barre syndrome. The proximal segments of motor nerves are tested by recording the F wave. This is produced by stimulating the distal end of a motor nerve. The action potentials travel antidromically towards the motoneurons where they are bounced back off the motoneurone and travel orthodromically down the motor nerve fibres to cause the muscle to contract. This delayed contraction is picked up as the F wave. In sensory nerves this could be tested by recording the SSEP. This test would be particularly useful if the distal sensory conduction velocity was normal.

Brachial Plexus Injuries and Cervical Root Trauma: The brachial and associated spinal roots (C5-T1) are particularly susceptible to injury. It is important to locate the site of the lesion since this will have a bearing on the prognosis: root avulsion has a poor prognosis whereas a plexus injury may be amenable to surgery and recovery may occur. This can be done by comparing the amplitudes of the EP potential and CVII potentials. An appreciable reduction in CVII but a relatively normal EP potential suggests root avulsion whereas a reduction in EP and CVII potential is indicative of a plexus injury. The latter does not, however, preclude a root avulsion in addition to the plexus injury.

Spinal Cord Trauma: In complete traumatic lesions of the spinal cord SSEPs cannot be recorded. Occasionally SSEPs have been recorded in patients who clinically appear to have a complete lesion. Obviously the presence of an SSEP indicates that the lesion is not complete and some residual spinal function may still persist. Thus SSEPs can distinguish between a completely transected cord and a severely injured cord. Serial SSEP recordings in incomplete lesions have proved to be a useful prognostic indicator since a progressive normalisation of the SSEP occurs before there is clinical evidence of improvement.

Intra-operative Monitoring: Since SEPs are not significantly affected by general anesthetics the recording of SEPs (CVII and SSEP) has proved a useful means of monitoring the integrity of the spinal cord during surgery; the aim of which is to detect damage to the cord at an early state so that corrective measures could be instituted in order to avoid permanent damage. This technique is widely used during operations to correct scoliosis.

Visual Evoked Potentials (EVPs).

The visual evoked potential is recorded from the scalp overlying in occipital cortex in response to stimulation of the visual system by using a checkerboard whose pattern reverses at a controlled rate. The VEP in healthy individuals has a clearly defined waveform characterised by three peaks with approximate latencies of 75, 100 and 145 ms (ie the N75, P100 and N145 peaks — see Figure IIA). The P100 is believed to be generated in the striate and prestriate cortex. It is abnormalities of the P100 waveform in terms of latencies and amplitudes that are clinically relevant.

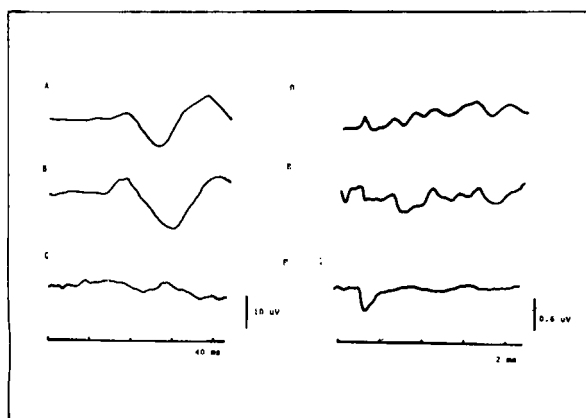
Clinical Applications.

VEP testing provides the most sensitive means of detecting subclinical lesions of the optic nerve.

Optic Neuritis: About 90 pc of patients presenting with a clear history of optic neuritis have abnormal VEPs usually manifested as a prolonged latency of the P100 component and a reduced amplitude. In some cases (illustrated in Figure IIC) the wave is completely absent. The abnormalities appear to be present whatever the time interval since the clinical episode of optic neuritis and may even be present 15 years later.¹

Compressive lesions of the anterior visual pathways also produce abnormalities of VEPs. In one study² of 19 patients with compression of the optic nerve, chiasm or optic radiation abnormalities were found in 18 cases even when there were no signs of clinical impairment.

Figure II: Evoked potentials in various clinical conditions are illustrated and compared with normal responses. A is the visual evoked potential from a healthy individual. B and C are visual evoked potentials from a multiple sclerosis patient (note the delayed P100 waveform) and a patient with optic neuritis respectively. D is a normal brain stem auditory evoked potential whereas E is the BSAEP from an MS patient. Note the abnormal waveform. F is the BSAEP from a "deaf mute". Note the absence of waves.



Brain Stem Auditory Evoked Potentials (BSAEPs)

BSAEPs are recorded from the vertex of the scalp in response to monaural click stimulation. The typical BSAEP consists of a series of waves (I to VII) all occurring within 10 ms. Each wave is believed to represent activity in a particular part of the auditory pathway: wave I—the auditory nerve near the cochlea; wave II— cochlea nucleus; wave III — the superior

olivary complex; wave IV — the lateral lemniscus; wave V — the inferior colliculus. It is speculated that wave VI is generated in the medial geniculate and wave VII in the auditory radiations.³

Wave V is the most prominent component and the most reliable inter-individually. Waves VI and VII are unreliable and have no clinical use. The most sensitive parameter used to detect abnormalities is the interpeak latencies (IPL). The BSAEP from a normal individual is illustrated in Figure 2D.

Clinical Applications.

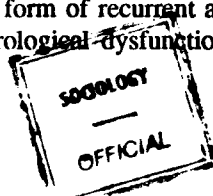
BSAEPs provide a sensitive tool for assessing the brain stem auditory tracts. Abnormal BSAEPs could be due to any disorder that directly or indirectly affects these tracts. The interpeak latency is not affected by peripheral hearing disorders. Conversely, gross BSAEP abnormalities are often accompanied by completely normal behavioural hearing parameters (as seen in patients with MS and pontine gliomas). However, these patients usually show abnormal auditory localisation and interaural time discrimination. These results suggest that BSAEP waveforms are most closely related to the non hearing functions of the auditory system. Diseases in the peripheral vestibular system (e.g. Meniere's disease) do not appear to affect BSAEPs.

Acoustic Neuromas: BSAEPs are the most sensitive test when acoustic neuromas are suspected since they may be abnormal when routine audiological tests and CT scans are normal. The I— III inter peak latency is the most sensitive indicator together with the inter ear difference in this parameter.

Miscellaneous: Conventional behavioural hearing tests are difficult to perform reliably in infants and psychiatrically disturbed individuals. The presence of BSAEPs in these cases implies that the auditory tract is functional. Figure IIF illustrates the BSAEP recorded from a woman who appeared to be a deaf mute but whose previous history was unknown. The absence of waves confirmed that deafness was due to non functional auditory pathways and not to a psychiatric disorder.

In the following clinical situations the three types of evoked potentials are used in conjunction with each other to aid diagnosis.

Multiple Sclerosis: In multiple sclerosis (MS) demyelination of central pathways occurs. The disease presents in the form of recurrent attacks of focal or multifocal neurological dysfunction. Attacks occur,



remit and recur, in a seemingly random fashion over many years. The clinical picture is determined by the location of the foci of demyelination within the CNS. Classic features include nystagmus, impaired vision, dysarthria, decreased perception of vibration and position sense, ataxia, intention tremor, weakness or paralysis of one or more limbs, spasticity and bladder dysfunction. It is a difficult disease to diagnose conclusively. Nowadays certain criteria must be satisfied before a definite diagnosis can be made. There should be a history of at least two episodes of neurological deficit and objective clinical signs of lesions at more than one site within the nervous system. Demonstration of a second lesion by laboratory tests together with one objective clinical lesion also fulfills the criteria. A suitable laboratory test is the demonstration of an abnormal evoked potential be it somatosensory, visual or auditory.

Several evoked potential studies have been carried out in MS patients. In one study abnormal lower limb SEPs were found in 76 pc and abnormal upperlimb SEPs in 58 pc of MS patients.⁴ Every type of abnormality has been encountered ranging from delayed waveforms (see Figure IIB) to a complete absence of waves. The incidence of VEP abnormalities in MS ranges from 47 pc to 96 pc⁵ and is manifested as a prolongation of the P100 latency or interocular differences. The VEP in an MS patient is illustrated in Figure IIB. Note the prolongation of the P100 waveform. BSAEP abnormalities have been found in almost half of MS patients and are manifested mainly as a decrease in wave V amplitude or an increase in III-V interpeak latency.⁶

What is of particular interest from these studies is that a particular evoked potential may show abnormality even in the absence of sensory dysfunction, ie the abnormality precedes the clinical signs. Evoked potential testing is therefore particularly useful for identifying unsuspected CNS lesions in any of the three sensory pathways. As mentioned earlier the objective demonstration of lesions is of tremendous benefit in the early diagnosis of this disorder. Indeed the pooled results⁷ of many studies show that 97 pc of patients diagnosed as MS "definites" had abnormalities of at least one evoked potential. In the "probable" MS group 86 pc had abnormalities and in the "possible" group abnormalities were encountered in 63 pc of patients.⁷

Coma: Several studies have been carried out to ascertain the effects of coma (of all aetiologies) on SEPs and BSAEPs.^{8,9} The pooled results show that no

clear correlation exists between the extent of the evoked potential abnormality and the clinical outcome.¹⁰ In fact SEPs in comatose patients have proved more accurate in the prognosis of no recovery or poor recovery than for a favourable outcome since no patient with absent bilateral SEPs had a good outcome. There does however, appear to be a better correlation between SEPs and clinical outcome in patients with coma secondary to head injury.¹¹ The use of BSAEPs to assess brain stem integrity in comatose patients is limited to some extent by the anatomical specificity of the test since BSAEPs can be completely normal in patients paralyzed from brain stem infarction provided the auditory tracts are still functional. Thus BSAEPs cannot indicate that the entire brain stem is fully functional.

Brain Death: SEPs and BSAEPs have been recorded in brain dead patients in order to confirm the clinical diagnosis of brain death. Erb's Potential is present in all brain dead patients and many patients showed a preservation of the CVII potential. However, a complete absence of the SSEP indicates there is no rostral conduction of the signal from the upper levels of the spinal cord to the higher centres thus indicating that the brain stem is no longer functional. Just as Erb's Potential is present in brain dead patients so is wave I of the BSAEP which is generated in the auditory nerve. The absence of subsequent waves indicates lack of function in the auditory pathways. However, without the presence of wave I no inferences can be drawn since the integrity of the peripheral apparatus for hearing may be in doubt.

Conclusion: Evoked potential recordings when used in conjunction with other tests have an important part to play in the diagnosis of various neurological disorders. A few clinical situations have been described where they are invaluable. Their major advantage is that they are non invasive and relatively very cheap.

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