The investigation of traumatic lesions of the brachial plexus by electromyography and short latency somatosensory potentials evoked by stimulation of multiple peripheral nerves

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SUMMARY A study of 10 patients with brachial plexus trauma was performed to determine whether the diagnostic accuracy of sensory evoked potentials (SEPs) may be improved by using stimulation of multiple peripheral nerves (median, radial, musculocutaneous and ulnar). In addition, the relative advantages of SEPs and peripheral electrophysiological studies were considered. SEP patterns following most common brachial plexus lesions were predictable. Injuries to the upper trunk affected the musculocutaneous and radial SEPs predominantly. Lower trunk or medial cord lesions primarily affected ulnar SEPs. Diffuse brachial plexus lesions affected SEPs from all stimulation sites. In the majority of cases, the necessary information was obtainable from conventional EMG; however, for lesions involving the upper segments only, SEP techniques were more useful. It is suggested that selective SEPs from appropriate peripheral nerves when interpreted in combination with conventional EMG may add useful additional information.

The accurate localisation of brachial plexus and cervical root injuries is important in the prognostic assessment of these patients and of the potential success of reconstructive surgery. Distinction between an avulsed root and a more distal lesion is important since useful surgical intervention can only be accomplished when the lesion is distal to the dorsal root ganglion. Conventional electromyography with sensory nerve action potentials may assist in this distinction.^{1,2} More recently a number of workers^{3–7} have applied somatosensory evoked potentials (SEPs) for this purpose. All these reports described single nerve stimulation (usually median) and no adequate comparisons were made with conventional electromyographic techniques. Our study was undertaken to try to improve the diagnostic accuracy of SEPs by using stimulation of multiple

peripheral nerves: median (C6-T1), radial (C6), musculocutaneous (C5), and ulnar (C8-T1). In addition, the relative advantages of SEPs and peripheral electrophysiological studies were considered.

Methods

The median, ulnar and superficial radial nerves were stimulated at the wrist on both sides and in two patients the musculocutaneous nerve was stimulated in the forearm. Stimuli were delivered at 2 Hz by a TECA constant voltage isolated nerve stimulator with a pulse duration of 0.1 ms. The stimulus intensity was adjusted to produce a small twitch in the thenar or hypothenar muscles (median and ulnar) or to be three times sensory threshold in the case of superficial radial and musculocutaneous nerves.

Gold disc 9 mm recording electrodes were attached to the skin using Grass electrode paste and tape. Electrodes were placed over Erb's point, the spinous process of the second and seventh cervical vertebrae, and the contralateral somatosensory cortex. These were referred to a common mid-frontal site (Fz). Signals were amplified and averaged by a DISA (model 1500) system with the high and low pass filters set at 2 Hz and 2 kHz for the scalp responses and 20 Hz and 2 kHz for the cervical and Erb's

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point responses. Potentials were averaged during 500 or 1000 stimuli on three or more channels simultaneously. The subjects were studied while lying in a semi-prone position with special attention being paid to patient relaxation by frequent observation of analog signals on an oscilloscope.

The SEPs studied were the three most prominent negative potentials, labelled EP (maximal over the supraclavicular fossa), P/N13 (positivity maximal over the scalp and negativity maximal over the cervical vertebrae) and N19 (maximal over the contralateral somatosensory cortex). Interpeak latencies (IPL) were measured between EP and P/N13 and P/N13 and N19 potentials. Response latencies, determined by an adjustable cursor, were measured from stimulus artefact to the peak negativity of the responses. Amplitudes were measured to the latter from the preceding positivity for EP and from baseline for P/N13 and N19.

Peripheral electrophysiological studies were performed on all patients using a TECA-4 unit and concentric EMG needles. Conventional motor and sensory nerve conduction studies (skin temperature $> 32^{\circ}\text{C}$) were recorded from the median, ulnar and radial nerves. In addition, late responses were obtained from abductor pollicis brevis (C8-T1), abductor digiti minimi (C8-T1) and extensor indicis proprius (C7-8) muscles. Needle EMG including paraspinal muscles was performed in the conventional manner.

Patients

Ten patients (3 F; 7 M) between 17 and 49 years of age were studied. Patients were divided into four groups according to the clinically assessed location of the lesion: *Group 1*—anaesthesia and paralysis of the arm in the distribution of the C5-T1 segments (1 patient); *Group 2*—major involvement of C5-6 segments with minimal involvement of C7-T1 (4 cases); *Group 3*—involvement entirely confined to the C5-6 segments (2 patients); *Group*

4—involvement of C8-T1 segments (3 patients). Results from these limbs were compared to those from a group of 20 control subjects and from the unaffected limb.

Results

(a) Normal somatosensory potentials

Means and standard deviations of amplitude and latency of each potential in the normal subjects are given in table 1. In each individual the left/right amplitude difference for a given potential was expressed as a percentage of the amplitude of the side with the larger response and the left/right latency difference was expressed in absolute terms (ms). Typical traces of short latency SEPs from all nerves are given in fig 1. Median nerve stimulation yielded potentials as described previously.⁸⁻¹¹ With ulnar nerve stimulation a similar SEP pattern was seen except that the amplitudes of all responses were significantly smaller and the EP latency and EP-P/N13 IPL were increased when compared to median nerve stimulation. These latency differences are presumably related to the longer course of the nerve in the arm and the lower level of entry of the C8-T1 roots into the spinal cord. Radial nerve stimulation elicited a pattern of potentials similar to those seen with median and ulnar nerve stimulation; however, the amplitudes of all the responses were even smaller than with ulnar nerve stimulation. The strikingly larger size of the responses from median nerve stimulation is most likely related to the greater number of afferent fibres in that nerve.

(b) Patients

In the single patient in group 1, all SEPs, including

Table 1 Normal SEP studies

	Latency (ms)	Median Amplitude (μV)	Max. (R-L diff)	
	mean $\pm$ SD	mean $\pm$ SD	lat. (ms)	amp (%)
Erbs	9.6 $\pm$ 0.7	5.4 $\pm$ 2.5	0.5	50%
P/N13	13.2 $\pm$ 0.8	2.9 $\pm$ 1.3	0.6	46%
N19	18.9 $\pm$ 1.0	2.8 $\pm$ 1.6	0.9	50%
E-P/N13	3.5 $\pm$ 0.4		0.8	
P/N13-N19	5.8 $\pm$ 0.5		0.5	
<i>Ulnar</i>				
Erbs	10.0 $\pm$ 0.9	2.9 $\pm$ 1.6	0.4	48%
P/N13	13.9 $\pm$ 1.1	1.7 $\pm$ 0.8	0.5	56%
N19	19.3 $\pm$ 1.2	1.8 $\pm$ 1.1	0.6	55%
E-P/N13	4.0 $\pm$ 0.4		0.5	
P/N13-N19	5.3 $\pm$ 0.4		0.6	
<i>Radial</i>				
Erbs	9.5 $\pm$ 0.8	2.8 $\pm$ 1.2	0.5	49%
P/N13	13.5 $\pm$ 1.1	1.4 $\pm$ 0.6	0.6	44%
N19	18.8 $\pm$ 1.0	1.5 $\pm$ 0.8	0.6	54%
E-P/N13	3.9 $\pm$ 0.5		0.5	
P/N13-N19	5.3 $\pm$ 0.5		0.6

Fig 1 Somatosensory evoked potentials simultaneously recorded from four electrode locations with a mid-frontal (Fz) reference following stimulation of the right median, ulnar and radial nerves in a normal subject. The electrodes were located over the contralateral somatosensory cortex (Cc), second cervical vertebrae (Cv2), seventh cervical vertebrae (Cv7) and ipsilateral Erb's point (EP). Two runs (500 trials) are superimposed and the three major potentials EP, P/N13 and N19 are demonstrated.

the EP potential, were absent (fig 2). Clinical examination of this 36-year-old female, who sustained an injury from a sharp object to the neck following a motor vehicle accident, revealed an anaesthetic limb with some movement only in the small muscles of the hand and forearm. No SEPs were obtained following median, ulnar or radial nerve stimulation. Radial and median nerve SNAPs (sensory nerve action potentials) were absent and the ulnar SNAP was of abnormally low amplitude. Compound muscle action potentials could be evoked by stimulation of median, ulnar and radial nerves but they were all of low amplitude. EMG showed no voluntary activity in C5-7 muscles and a low interference pattern in C8-T1 muscles. Paraspinal EMG demonstrated fibrillation potentials from C5 to C8 segments. The absence of potentials at Erb's point placed the pathology distal to the dorsal root ganglion but the presence of active denervation in the paraspinal muscles localised the lesion to the root level. The most severe damage was at the C5-7 level with no apparent functional continuity; in the C8-T1 segments there was some preservation of motor fibres. These conclusions correlated well with myelography and operative findings: C5-7 roots appeared to be in continuity but on stimulation there was no evokable response.

The second group of patients all demonstrated similar evoked potentials. These included absent responses at all levels on stimulating the musculocutaneous and radial nerves, whereas on median and ulnar nerve stimulation there were only minor

changes. This is best exemplified by the SEPs in fig 3. This patient was a 20-year-old male with brachial plexus trauma secondary to a motor cycle accident. Clinical examination revealed no power in C5-6 muscles, mild reduction in power in the muscles innervated by C7-T1 roots and an area of complete anaesthesia over C5-6. Evoked potentials following musculocutaneous and radial nerve stimulation were absent at all levels, including the Erb's point response, suggesting no functional continuity in these segments. With median and ulnar nerve stimulation, the EP and P/N13 potentials were of low amplitude with an increase in EP-P/N13 IPL. The results on conventional EMG corroborated these findings. Motor conduction velocities in the median, ulnar and radial nerves were normal with some increase in the minimal F-wave latencies. The radial SNAP was absent, the median SNAP (digit II) was reduced in amplitude whereas the ulnar SNAP (digit V) was normal. Active denervation was present in all C5-T1 muscles including C5-8 paraspinals; no voluntary units were obtained from C5-6 muscles and a reduced pattern was seen in C7-T1 muscles. The SEP findings suggest a complete lesion of the C5-6 segments of the brachial plexus (upper trunk) and partial lesion of the C7-T1 segments (middle and lower trunks). Loss of the potential at Erb's point suggests the major pathology was distal to the dorsal root ganglion and the presence of paraspinal denervation suggests additional root involvement.

In the two patients in group 3, ulnar nerve studies were normal and two types of abnormalities were

Fig 2 Somatosensory evoked potentials from median and ulnar nerve stimulation in a 36-year-old female with brachial plexus trauma. There were no SEPs recorded with left median or ulnar nerve stimulation at any level. These features suggest extensive (C5-T1) post-ganglionic pathology. The presence of denervation in paraspinal muscles suggest additional root pathology. Two runs (500 trials) are superimposed.

seen in median and radial nerve responses. In the first patient the Erb's point potential was normal, whereas spinal and scalp responses were of low amplitude with an increase in the EP-P/N13 IPL (fig 4). These features suggested C5-6 root pathology. In the second patient the abnormalities showed a similar pattern except that in addition, the Erb's point potentials were of low amplitude or absent (fig 5). Clinical examination of this 17-year-old male involved in a motorcycle accident revealed anaesthesia in the C5-7 dermatomes and no power in the muscles innervated by these segments. The SEP findings (fig 5) suggest pathology of the upper trunk which was confirmed by myelography but as sensory axons were in continuity, the patient was not operated on.

In the last group, major abnormalities were found with ulnar nerve stimulation, minor changes with median nerve stimulation and normal radial studies. Figure 6 illustrates SEPs from a 22-year-old male involved in an industrial accident, with weakness of the small muscles of his right hand and numbness in a C8-T1 distribution. SEPs from the radial nerve were normal, whereas there were clear abnormalities in the median and ulnar studies. On ulnar

Fig 3 Somatosensory evoked potentials from musculocutaneous, radial, ulnar and median nerves in a 20-year-old male with a traction lesion of the brachial plexus. No potentials were evokable with right musculocutaneous or radial nerve stimulation. Right median and ulnar studies showed reduced amplitude of all potentials including EP with an increase in the EP-P/N13 IPL. These features suggest severe pathology, with loss of functional continuity, of the upper trunk (C5-6) and minor pathology, of lower and middle trunks. Two runs (500 trials) are superimposed. The calibration bar represents 1 μ V.

nerve stimulation both the EP and P/N13 potentials were absent but a low amplitude delayed scalp potential was present. Stimulation of the median nerve produced low amplitude potentials at all levels with an increase in the EP-P/N13 IPL. These features were consistent with a medial cord or lower trunk lesion. Even though the digit V SNAP and EP potentials were absent, the presence of a scalp potential suggested continuity of some sensory axons. In one patient in this group the findings were unusual—the clinical features suggested pathology of the C8-T1 segments (wasting of the small muscles of the hand, sensory impairment in the C8-T1 dermatomes) but the SEPs were normal. The EMG showed active and chronic denervation in the small

Fig 4 Somatosensory evoked potentials from stimulation of radial and median nerves in a 32-year-old female with trauma involving the C5-6 roots. The potentials at EP are all normal but with right radial nerve stimulation the EP-P/N13 IPL is increased and the P/N13, N19 amplitudes are reduced. The median SEPs are normal. The preservation of all the potentials suggests a lesion at the C5-6 root level with preservation of axonal continuity. Two runs (500 trials) are superimposed. The calibration bar is 1 μ V.

muscles of the hand and no CMAP were evokable from the median and ulnar nerves; F-waves to these muscles were absent as well. The SNAPs from median, ulnar and radial nerves were all normal and therefore suggestive of C8-T1 root pathology. The SEP findings were surprising in that they were normal at all levels except for some minor asymmetry in the amplitude of the response at Erb's point. The significance of this will be discussed later.

Discussion

The brachial plexus and its associated spinal roots (C5-T1) are particularly prone to traction injury. The extent and location of such lesions are important factors in assessing the prognosis of these patients. Avulsion of dorsal roots proximal to the dorsal root ganglion carries a poor prognosis in comparison with postganglionic lesions which may recover spontaneously when the nerves remain in continuity or are surgically repaired. It is thus important to establish the location of the lesion and the presence of functional continuity as accurately as possible. Conventional electromyography may be of help in this assessment. The presence of SNAPs, providing the lesion occurred more than a week

Fig 5 Somatosensory evoked potentials with median and radial nerve stimulation in a 17-year-old male involved in a motorcycle accident. Left radial nerve studies show an absent EP and P/N13 and a delayed low amplitude N19. Left median nerve stimulation produced low amplitude potentials at all levels with an increased EP-P/N13 IPL. Ulnar SEPs were normal. These features suggest post-ganglionic pathology affecting the upper trunk of the brachial plexus. The presence of an N19 potential suggests axonal continuity. Two runs (500 trials) are superimposed. The calibration bar is 1 μ V.

before, documents continuity between sensory axons and their cell bodies in the dorsal nerve root ganglia¹ and, in association with anaesthesia in the appropriate segments, suggests preganglionic pathology. In addition, the lack of motor units under voluntary control and the presence of features consistent with active denervation, particularly in muscles with nerve supply from spinal roots (paraspinals, serratus anterior), may also help, by assessing functional continuity of the ventral roots, in localisation of the lesion.

Despite the usefulness of peripheral nerve SNAPs in the localisation of plexus pathology, the method is indirect. At an early stage the preservation of SNAPs and the absence of denervation on EMG may be misleading as to the site of the lesion (that is pre- or postganglionic) and as to the presence of axonal continuity. Gilliatt and Hjorth¹² found that motor fibres continued to conduct for 4 or 5 days after peroneal nerve section (baboon) and sensory fibres for an additional 2-3 days. Other workers^{13, 14} demonstrated that these changes are related to the length of the denervated section of nerve. The recording the potentials closer to the site of the lesion (Erb's point and the cervical spine) would

Fig 6 Median and ulnar somatosensory evoked potentials from a 22-year-old male with brachial plexus trauma. Right ulnar nerve stimulation showed absent EP and P/N13 potentials and a delayed low amplitude N19. Median nerve studies showed low amplitude potentials at all levels and an increase in the EP-P/N13 IPL. Radial nerve studies were normal. These features suggest a lesion affecting the lower trunk or medial cord of the brachial plexus with preserved axonal continuity. The normal left side (dotted) is superimposed on the affected side (filled line). Two runs (500 trials) are superimposed.

provide early information on the characteristics of the lesion, that is distal or proximal to the spinal ganglion. In addition the recording of potentials proximal to the site of pathology (cervical spine and somatosensory cortex) may assist in the detection of multiple lesions that are pre- and post-ganglionic and the presence of continuity of sensory axons in the plexus and roots.

Several groups³⁻⁵ effectively combined SCEP (somatosensory cerebral evoked potentials) and SNAPs in the assessment of brachial plexus injuries. However the numbers of patients studied were small and failure of the first two groups to look for a cervical potential made the exclusion of an additional central lesion difficult. More recently Jones⁶ and Jones *et al*⁷ have studied a large series of patients with brachial plexus trauma, recording at three levels (Erb's point, cervical spine, and somatosensory cortex) following stimulation of the median or ulnar nerve at the wrist. They were able to predict accurately the site of lesions in 10 of 16 patients who were explored surgically. Some inaccuracies in these

studies may have been related to the nerve stimulated. Exclusive stimulation of the median nerve reduces the precision of the study since sensory fibres which constitute the afferent volley arise not only from cutaneous fibres innervating the C6-7 segments but also from muscle afferents from C8-T1 innervated muscles.

Our study shows that recording early SEP components following median, radial, ulnar and musculocutaneous nerve stimulation was more accurate in the specific localisation of which particular root, trunk or cord is (are) involved. As shown in fig 7, afferent pathways from the four stimulation sites embrace every major subdivision of the brachial plexus. Musculocutaneous nerve sensory impulses traverse the lateral cord to reach the upper trunk and enter the spinal cord via the C5 level. Radial afferent impulses travel up the posterior cord and upper trunk to reach the C6 root. Ulnar somatosensory impulses enter the medial cord and upper trunk to reach the C8-T1 roots. Median nerve stimulation at the wrist involves a wide range of sensory fibres

Fig 7 Normal anatomy of the brachial plexus illustrating the sensory fibre contribution to the nerves stimulated. SEP patterns with the following common lesions may be predicted: C5-6 roots/Upper Trunk—Abnormal musculocutaneous and radial studies with some changes in median studies. Normal ulnar studies. C8-T1 roots/Lower trunk/medial cord—Abnormal ulnar nerve studies with some changes in median nerve studies. Normal radial, musculocutaneous studies. Posterior cord—Radial nerve studies will produce the only abnormal SEPs. Diffuse Lesions—SEPs from all stimulation sites will be affected.

(C6-7-cutaneous, C8-T1-muscle afferents) which enter via the lateral (cutaneous afferents) and medial cords (muscle afferents) to reach the upper, middle and lower trunks and then enter the C6-T1 segments of the spinal cord. SEP patterns following most common brachial plexus lesions are thus predictable. Injuries to the upper trunk will affect the musculocutaneous and radial SEPs predominantly with some reduction in the amplitude of the median evoked potentials (fig 5), but with normal ulnar SEPs. Lower trunk or medial cord lesions will primarily affect ulnar SEPs with some change in the median SEPs but radial and musculocutaneous SEPs will be unaffected (fig 6). Posterior cord lesions will affect only radial SEPs. With diffuse brachial plexus lesions (the most common) SEPs from all stimulation sites will be affected (figs 2, 3).

Differentiation between pre- and post-ganglionic lesions was possible by recording potentials proximal (P/N13, a potential thought to arise in the dorsal horn or cuneate nucleus and N19, thought to arise

from thalamus or thalamocortical projections) and distal (EP potential, thought to be generated by the brachial plexus) to the dorsal root ganglion. Lesions distal to the dorsal root ganglion resulted in attenuation or loss of the EP potential whereas with proximal lesions, this potential was preserved. Degeneration of motor axons because of a more proximal lesion would have only a minor effect on the amplitude of the brachial plexus potential with submaximal stimulus intensities. This conclusion is supported by the last patient who had very few remaining motor fibres to the small muscles of the hand and no evokable CMAP or F-waves to these muscles but who had only a minor reduction in amplitude of the EP potential from median and ulnar nerve stimulation. P/N13 and N19 potentials were reduced in amplitude or absent with lesions on either side of the dorsal root ganglion. In addition, when they were present there was often an increase in the EP-P/N13 IPL. Comparison of EP to P/N13 amplitudes to determine the presence of pathology affecting the roots and the brachial plexus was considered to be unreliable⁶ and a severe lesion at the post-ganglionic level precluded the diagnosis of additional root avulsion.

With severe axonal loss, the brachial plexus and cervical potentials may be sufficiently dispersed and of such low amplitude that they are not recordable. In this situation the simultaneous recording of scalp potentials allowed the differentiation of a severe but incomplete lesion from a functionally complete transection (figs 5, 6). The cortical evoked potential may still be elicited in the absence of these potentials due to amplification of the ascending volley within the central nervous system¹⁵ and its presence indicates some degree of axonal continuity. This suggests a favourable prognosis without the need for surgical intervention.

Our peripheral electrophysiological results were typical of those found on previous studies^{1 2 16 17} and are shown in table 2. Motor conduction studies were not particularly useful; abnormalities were either mild, such as slight slowing of conduction velocity or reduced amplitude of the compound muscle action potentials or else there was no evokable response. Sensory studies were more useful and correlated well with SEP studies. In patients with root lesions, SNAPs were normal from radial, median (digit II, III) and ulnar (V) nerves, whereas patients with pathology in the plexus distal to the dorsal root ganglion had absent or low amplitude SNAPs when compared to the normal side. In some with severe plexus lesions, peripheral SNAPs were present (although of low amplitude) in the absence of Erb's point or cervical potentials. This may be due to dispersion of the sensory volley such that by the time it

Table 2 Peripheral electrophysiological studies

Patient	Clinical extent of lesion	Nerve conduction									F-waves				Electromyography							
		Sens.			R Mot.			Sens.			Me Mot.			Sens.			U Mot.			Paraspinals	Appendicular	
		Amp.	Amp.	Vel.	Amp.	Amp.	Vel.	Amp.	Amp.	Vel.	Amp.	Amp.	Vel.	Amp.	Amp.	Vel.	Amp.	Amp.	Vel.		Red. Act.	No Act.
1	C5-T1	A	N	N	A	L	N	L	L	N	A	A	N	C5-C8	C8-T1	C5-7						
2	C5-T1 severe	A			A	L	S	L	N	N		P	N	N	C7-T1	C5-6						
3	C5-C7 minor																					
4	C5-T1 severe	L	L	S	L	N	N	L	N	N	P	N	N	N	C7-T1	C5-6						
5	C5-C6	L	L	N	L	N	N	L	N	N	P	N	N		C7-T1	C5-C6						
6	C5-T1 severe																					
7	C5-C6	L	N	N	L	N	N	N	N	N	P	N	N	N		C5-C6						
8	C5-C6	N	N	N	N	N	N	N	N	N	N	N	N	N	C5-C6	N						
9	C8-T1	N			N	A	A	A	L	S		A	P	N	C8-T1							
10	C8-T1				N	L	N	N	L	N		A	A	A	C8-T1							
	C8-T1				N	A	A	N	A	A		A	A	N		C8-T1						

Abbreviations: - R-radial, Me-median, U-ulnar EIP-extensor indices proprius; APB-abductor pollicis brevis; ADM-abductor digiti minimi. N-normal. L-low amplitude; S-slow conduction velocity; A-absent; P-prolonged.

reaches EP and the spinal cord the response is too small to record or to some localized conduction block in addition to axonal loss. Another possible reason for this divergence is that the damaged part of the plexus may be displaced such that the surface electrode at EP may be inappropriately placed.⁶

Studies of late responses provided useful information about the proximal segment of motor fibres. F waves from proximal muscles (brachioradialis (C5-6), extensor indices proprius (C7-8)) and from the small muscles of the hand (abductor pollicis brevis, abductor digiti minimi (C8-T1)) were either absent or were abnormal (increased minimal latencies, minimal-maximal latency difference and poor persistence) if the segments were involved.

All patients had abnormalities with concentric needle EMG in appropriate muscles. Changes typical of neurogenic lesions were seen in these muscles, including fibrillation potentials, polyphasic large-amplitude units and reduced recruitment patterns. Cervical paraspinal EMG was useful in localising the pathology to the roots and was consistent with the findings of Bufalini and Pescatori.¹⁸ In the presence of paraspinal denervation, the lesion is intravertebral because the posterior ramus leaves the spinal nerve just after it exits from the intravertebral foramen. Paraspinal EMG was found to be particularly useful in the detection of multiple lesions at the plexus and root levels where the absence of a SNAP does not preclude the presence of an additional lesion proximal to the dorsal root ganglion (figs 2 and 3). The lack of motor units under voluntary

control in involved muscles suggested Wallerian degeneration of motor axons but was less helpful in analysing what segment of the axons had been severed. There was good correlation between the amplitude of the SNAPs and the severity of denervation on EMG and in the absence of voluntary activity or with single unit activity, peripheral SNAPs were always absent.

In the majority of situations the necessary information was obtainable from conventional EMG (including late responses). However, for lesions involving the upper segments only, SEP techniques were useful as late responses and SNAPs from these segments are less accessible.⁷ Furthermore, by recording proximal to the lesion, taking advantage of the amplifying characteristics of the central nervous system, SEPs provided the most accurate method for assessing axonal continuity which is integral to determining the need for surgical intervention. In patients with pathology at the plexus level the presence of a peripheral SNAP and an Erb's potential (albeit of low amplitude) and the absence of spinal or scalp potentials suggest additional root avulsion. When there is severe postganglionic pathology, with absent SNAP and EP potentials, the diagnosis of additional root pathology is obscured and in such cases myelography is necessary to make the distinction.

We feel that conventional EMG and SEPs, particularly when interpreted in combination, can be of considerable assistance in the precise diagnosis of traumatic lesions of the brachial plexus. This is of

particular importance with regard to prognosis and the possible benefits of reconstructive surgery. It is not our intention to suggest that SEPs from all peripheral nerves should be studied routinely in addition to EMG because the time required to perform these studies would be prohibitive. However, studying SEPs from a mixed nerve with multisegmental composition (such as the median nerve) may be imprecise; selective study using the appropriate nerve containing sensory afferents from the segments which are most severely affected clinically and on EMG (particularly where continuity is in doubt) would provide very useful additional information without being too time-consuming. Furthermore these techniques provide a non-invasive test for the follow-up of patients, particularly after surgical intervention, to assess the progress of nerve regeneration.

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