The Changing Role of Clinical Neurophysiology in Medicine: A Review of Recent Developments

Lo Yew Long *MMed (Int Med), FAMS*

Department of Neurology, National Neuroscience Institute, SGH Campus

INTRODUCTION

The term "clinical neurophysiology" is believed to have been coined by Eric Kugelberg, a pioneer of clinical electromyography in Sweden.[1] Clinical neurophysiology is the science of functional evaluation of the nervous system. In the last few decades, neurophysiological techniques have increasingly been employed in the diagnosis, treatment, prognosis and research of both neurological and other medical conditions. This article considers the new developments in nerve conduction studies (NCSs), electromyography (EMG), repetitive nerve stimulation (RNS), evoked potentials (EPs) and transcranial magnetic stimulation (TMS).

NERVE CONDUCTION STUDY AND ELECTROMYOGRAPHY

NCS and EMG are routine investigations in the evaluation of neuromuscular disorders. NCS allows for quick characterisation of demyelinating or axonal peripheral nerve disorders, localisation of focal entrapments and assessment of more proximal root lesions with late responses.[2] The use of mixed nerves in NCS has not been extensively explored previously, due mainly to uncertainty over relative contributions of motor and sensory components. However, mixed nerve potentials allow for simultaneous evaluation of these components, which can be useful in various clinical situations. Mixed nerve conduction studies have been shown to be of value in the evaluation of severe axon loss ulnar neuropathy at the elbow when conventional NCS could not adequately localise the site of entrapment.[3] In brachial plexopathy, conventional neurodiagnostic techniques only provide indirect evidence in lesion localisation. The use of mixed nerve potentials over the brachial plexus is a recently described adjunctive method for direct recordings at Erb's point.[4] Side-to-side comparison studies allow for further evaluation of brachial plexus injuries, as well as localisation of rare distal ulnar nerve entrapments.[5]

The technique of sympathetic skin response, which evaluates sudomotor components of the autonomic nervous system, has a role in the diagnosis and follow-up of statin-induced small fibre neuropathy.[6] Neuralgic amyotrophy or brachial neuritis is an acute inflammatory neuropathic disease of the brachial or lumboscral plexi and its nerves. This condition, long thought to be axonal in origin, has been shown, using a high voltage electrical stimulation technique, to evolve from preceeding demyelination.[7] This has subsequently been reproduced in separate studies.[8]

Routine EMG is generally limited to limb musculature studies. Needle EMG sampling aids in localising root lesions, distinguishing neuropathic and myopathic weakness, and assessing the extent of axon loss in nerve lesions. In recent years, the role of EMG has expanded to include sampling of non-limb muscles, including the diaphragm, anal sphincter, facial musculature and larynx. In particular, EMG findings in laryngeal musculature are of value in elucidating the cause of vocal paralysis post-radiotherapy by demonstrating typical changes of EMG myokymia.[9] This EMG finding has also been shown to be helpful in the electrodiagnosis of ptosis in hypothyroidism and radiation-induced neurogenic muscle hypertrophy.[10,11]

Single fibre EMG (SFEMG) is a sensitive technique for measuring defects of neuromuscular transmission.[12] It is particularly useful in the diagnosis of myasthenia gravis and myasthenic syndromes. The measure of 'jitter', a statistical parameter of latency variability in single fibre potentials, can be a sensitive measure of ongoing neurogenic reinnervation after nerve injury. This phenomenon is attributed to uncertain

neuromuscular transmission in newly formed nerve sprouts.[13] Neurophysiological techniques now play larger roles in critical care. NCS and EMG can help distinguish acute inflammatory demyelinating polyneuropathy from critical illness neuropathy and myopathy.[14, 15] Phrenic NCS are also complementary in this situation and, in particular, in the ventilated patient.[16]

REPETITIVE NERVE STIMULATION

This is a simple and well-tolerated method to evaluate neuromuscular transmission defects, most commonly, myasthenia gravis. Although RNS lacks the sensitivity of SFEMG, its main advantages are technical simplicity, comfort and accessibility. Various methods have been incorporated successfully to increase RNS's diagnostic yield, including recording close to the site of maximal weakness and using area calculations of motor responses.[17,18] RNS of the long thoracic nerve may also be useful in assessing patients for possible respiratory compromise.[19]

EVOKED POTENTIALS

The basic categories of EPs — visual, auditory and somatosensory — refer to averaged cortical wave responses recorded from light, sound and nerve stimuli. The characteristics of these responses, when compared with controls, are instrumental in assessing the integrity of their respective neural pathways. EPs are routine in the diagnostic work-up of multiple sclerosis, demyelinating neuropathies, spinal cord disorders and intra-operative monitoring.

Stacked derived-band brainstem auditory EP study techniques have been proven to be of comparable sensitivity in the detection of small acoustic neuromas.[20] The use of auditory EPs and cochlear nerve action potentials have also been expanded to monitoring intracranial and skull base surgery.[21] Somatosensory EPs also play a role in the prognostication of coma after head injury.[22]

The P300 is a large positive wave recorded over the scalp when subjects are presented with auditory stimuli. Its peak latency is a reliable correlate of the speed of information processing. P300 waveform abnormalities are helpful in the electrophysiological evaluation of dementia and differentiation from pseudodementia.[23] Movement-related cortical potentials recorded using back-averaging techniques represent cortical activity in the preparation of movement. Its presence is helpful in the diagnosis of volitional types of movement disorders.[24]

TRANSCRANIAL MAGNETIC STIMULATION

Since its introduction some 15 years ago, TMS of the human brain has made tremendous progress.[25] In principle, TMS consists of a circular coil capable of generating a magnetic field, which in turn produces a current in the motor cortex. A peripheral muscle response, known as a motor EP, can be recorded in the limb muscles. TMS allows for painless assessment of conduction abnormalities in the corticospinal system and has contributed greatly to the understanding and evaluation of multiple sclerosis, motor neuron disease, cervical myelopathy, stroke and movement disorders.[26]

The involvement of central pathways in the Miller Fisher syndrome (MFS), a variant of the Guillain-Barre syndrome, has long been a subject of debate. A recent study documented dynamic resolution of subclinical corticospinal tract conduction abnormalities with clinical resolution using TMS techniques.[27] This has subsequently been reproduced by other studies.[28] Corticobulbar dysfunction has also been demonstrated to occur in this condition using TMS with tongue recordings.[29] These findings corroborate imaging evidence in demonstrating that MFS can manifest as a widespread immunological disorder of the central nervous system.[30]

New methods of TMS have allowed stimulation at the foramen magnum level, enabling more detailed localisation of corticospinal tract conduction defects.[31] Suppression of motor responses with magnetic cerebellar stimulation has been shown to be of value in the diagnosis and follow-up of lesions involving cerebellar connections, in particular the degenarative ataxias.[32] The use of TMS has shifted from diagnostic to therapeutic domains in recent years. Repetitive TMS has been studied in relation to depression, obsessive-compulsive disorders, mania and hallucinations in separate trials with promising results.[33] Repetitive TMS has also contributed to studies of cognitive function and mood.[34]

CONCLUSION

Clinical neurophysiology, with its increasing scope of application, holds a unique position connecting basic research and clinical management of diseases. The future direction of this field is towards the integration of its various techniques with functional neuroimaging,[35] in the search for better understanding of the human nervous system.

REFERENCES

1. Stalberg E. Neurophysiological studies of collateral reinnervation in man. In: Ambler Z, Nevsimalova S, Kandaka Z, Rossini PM, editors. Clinical Neurophysiology at the Beginning of the 21st Century. Amsterdam: Elsevier, 2000;3-8.
2. Kimura J. Clinical value and limitations of F wave determination. A comment. Muscle Nerve 1978; 1:250-1.
3. Lo YL, Dan YF, Lee MP, Ratnagopal P. Segmental mixed nerve conduction studies in ulnar neuropathy. J Clin Neurophysiol 2001; 18:456-9.
4. See SJ, Lo YL. Mixed nerve potentials in brachial plexopathy. Clin Neurol Neurosurg 2002; 104:16-9.
5. Lo YL, Ratnagopal P, Leoh TH, Dan YF, Lee MP, Yong FC. Clinical and electrophysiological aspects of distal ulnar neuropathy. Acta Neurol Scand 2002; 105:390-4.
6. Lo YL, Leoh TH, Loh LM, Tan CE. Statin therapy and small fibre neuropathy: a serial electrophysiological study. J Neurol Sci 2002 (in press).
7. Lo YL, Mills KR. Motor root conduction in neuralgic amyotrophy: evidence of proximal conduction block. J Neurol Neurosurg Psychiatry 1999; 66:586-90.
8. Watson BV, Nocolle MW, Brown JD. Conduction block in neuralgic amyotrophy. Muscle Nerve 2001; 24:559-63.
9. Lau DPC, Lo YL, Wee J, Tan NG, Low WK. Vocal fold paralysis following radiotherapy for nasopharyngeal carcinoma. Laryngeal electromyographic findings. J Voice 2002 (in press).
10. Lo YL, Ho SC, Koh LK, Khoo DH. EMG myokymia as a cause of ptosis in hypothyroidism. Eur J Neurol 2003; 10:87-90.
11. Gorkhaly MA, Lo YL. Segmental neurogenic hypertrophy associated with radiation injury. Clin Neurol Neurosurg 2002; 105:32-4.
12. Sanders DB, Stalberg E. AAEM minimonograph #25: single-fibre electromyography. Muscle Nerve 1996; 19:1069-83.
13. Stalberg E, Trontelj JV. Single Fibre Electromyography: Studies in Healthy and Diseased Muscle. New York: Raven Press, 1994.
14. Chen R. Electrophysiological studies in the critical care unit: investigating polyneuropathies. Can J Neurio Sci 1998; 25:32-5.
15. Rich MM, Teener JW, Raps EC, Schotland DL, Bird SJ. Muscle is electrically inexcitable in acute quadriplegic myopathy. Neurology 1996; 46:731-6.
16. Bolton CF. Clinical neurophysiology of the respiratory system. Muscle Nerve 1993; 16:809-18.
17. Lo YL, Leoh TH, Tan TE, Foo ML, Dan YF, Ratnagopal P. Repetitive hypoglossal nerve stimulation in myasthenia gravis. Clin Neurophysiol 2002; 113:1227-30.
18. Lo YL, Dan YF, Leoh TH, Tan YE, Ratnagopal P. Decremental area responses in repetitive nerve stimulation. Muscle Nerve 2002 (in press).
19. Lo YL, Leoh TH, Dan YF, Tan YE, Nurjannah S, Ratnagopal P. Repetitive stimulation of the long thoracic nerve in myasthenia gravis: clinical and electrophysiological correlations. J Neurol Neurosurg Psychiatry 2003; 74:379-81.
20. Don M, Masuda A, Nelson R, Brackmann D. Successful detection of small acoustic tumours using the stacked derived-band auditory brainstem response amplitude. Am J Otol 1997; 18:608-21.
21. Jackson LE, Roberson JB Jr. Acoustic neuroma surgery: use of cochlear nerve action potential monitoring for hearing preservation. Am J Otol 2000; 21:249-59.
22. Facco E, Munari M, Baratto F, Behr AU, Giron GP. Multimodality evoked potentials (auditory, somatosensory and motor) in coma. Neurophysiol Clin 1993; 23:237-58.
23. Goodin DS, Aminoff MJ. Electrophysiological differences between demented and non-demented patients with Parkinson's disease. Ann Neurol 1987; 21:90-4.
24. Shibasaki H. Movement-related cortical potentials. In: Halliday A, editor. Evoked Potentials in Clinical Testing. Edinburgh: Churchill Livingstone, 1993:523-37.
25. Barker AT, Jalinous R, Freeston IL. Non-invasive magnetic stimulation of human motor cortex. Lancet 1985, 1:1106-7.
26. Van der Linden C, Bruggeman R, Goldman WH. Alterations of motor evoked potentials by thalamotomy. Electromyogr Clin Neurophysiol 1993; 33:329-34.
27. Lo YL, Ratnagopal P. Transcranial magnetic stimulation studies in the Miller Fisher syndrome: evidence of corticospinal tract abnormality. J Neurol Neurosurg Psychiatry 2001; 71:210-4.
28. Oshima Y, Mitsui T, Endo I, Umaki Y, Matsumoto T. Corticospinal tract involvement in a variant of Guillain-Barre syndrome. Eur Neurol 2001; 46:39-42.
29. Lo YL, Ratnagopal P. Corticobulbar dysfunction in the Miller Fisher syndrome. Clin Neurol Neurosurg 2002 (in press)
30. Lo YL, Chan LL, Lim PAC, Wong MC. Sulcal MRI abnormalities in the Guillain-Barre syndrome. J Neurol Neurosurg Psychiatry 2002; 73:92-3.
31. Ugawa Y, Uesaka Y, Terao Y, Hanajima R, Kanazawa I. Magnetic stimulation of corticospinal pathways at the foramen magnum level in humans. Ann Neurol 1994; 360:618-24.
32. Ugawa Y, Terao Y, Hanajima R, Sakai K, Furubayashi T, Machii K, et al. Magnetic stimulation over the cerebellum in patients with ataxia. Electroenceph Clin Neurophysiol 1997; 104:457-8.
33. Pascual Leone A, Rubio B, Pallardo F, Catala MD. Rapid-rate transcranial magnetic stimulation of left dorsolateral prefrontal cortex in drug-resistent depression. Lancet 1996; 348:233-7.
34. George MS, Wassermann EM, Williams WA. Changes in mood and hormonal levels after rapid-rate transcranial magnetic stimulation (rTMS) of the prefrontal cortex. J Neuropsychiatry Clin Neurosci 1996; 8:172-80.
35. Walsh V, Cowey A. Transcranial magnetic stimulation and cognitive neuroscience. Nat Rev Neurosci 2000; 1:73-80.