

Technology in neurology

Overlapping areas of diagnosis and treatment are supported by developments in neurological technology.



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Promising developments in clinical neurophysiology over the last 10 years have been largely eclipsed by the dramatic evolution of magnetic resonance imaging (MRI). One exception has been encephalography (video EEG) monitoring and, of course, research in clinical neurophysiology knows no bounds.

Neurosurgery has had major developments and some of these areas have involved neurophysiological co-operation such as neurophysiological sampling and stimulation in extrapyramidal movement disorders, especially Parkinson's disease.

Overall, as in the rest of medical technology, digitisation and computerisation have gradually replaced all analogue systems and as the industry matured, many proprietary systems have migrated to commercial standards, particularly versions of the Windows operating systems.

This development in technology has had tangible benefits in overlap with office software, ease of handling large amounts of data and increasing confidence in improved reliability and manipulation of signals. However, this technological benefit is a double-edged sword and apart from the more familiar problems common to many small computer systems, digital systems are capable of distorting or hiding signals without the unwary operator being aware of this. An example would be suspicious looking 'sharp waves' (potentially epileptogenic) on the EEG, which are the result of a noisy (bad) signal unwittingly being filtered by innocuous sounding switches ('muscle filters'). Despite the advanced technology, basic principles of a clean source of signal are still essential.

Neurophysiological studies have not been exclusive to neurology and with important developments in cardiology and anaes-

thetics, there is greater overlap in some of the technology underlying these fields. At the same time, there has been a move to train clinical technologists who are capable of moving between even more disparate fields such as renal (dialysis) to respiratory (lung functions) to neurology. Unfortunately, the numbers of clinical technologists' posts, and hence members, have dropped significantly and such developments may be more necessary than originally planned. The training centres for clinical technology have also been drastically reduced, further hampering new recruits.

NEUROPHYSIOLOGY SUBGROUPS

The standard subdivisions of neurophysiology are largely unchanged with the two major groups being nerve and muscle investigation (electromyography (EMG)) and cerebral or brain wave study (electroencephalography (EEG)). Straddling these two are evoked potentials (EP), mainly reactive cerebral signals elicited by stimulation. Although these are often cerebral signals, the equipment overlaps more readily with the EMG type of apparatus and thus commercial EP devices are typically modified and extended EMG machines.

The basic model of signal amplification and presentation on a screen is unchanged. However, along with the development of computers, electronics have improved to provide cleaner, brighter signals and systems for checking, with relatively smaller increases in costs. Despite this and utilising standard computers and software, the low volumes and rand/dollar or yen rate have kept equipment prices high.

Electromyography

EMG actually includes two complementary sections: nerve conduction studies (NCS) and EMG itself. The former is a process of eliciting and measuring how well nerves conduct and the latter is a look at the pattern of muscle (and therefore indirectly motor nerves, or directly muscles) activity from inside the muscle with needle electrodes. This needle electrode examination (NEE) is the standard procedure, despite its painful nature. ('Surface electrode' EMG i.e. stick-on electrodes on the skin are of limited use in defining most problems.)

These studies are highly operator dependent and laboratory techniques and standards dictate the confidence levels with which reports may be interpreted. Digital signals are by nature modified and 'virtual', and therefore greater care needs to be taken when signals may be unwittingly filtered or altered.

The modern EMG device has greater automation and manipulation of signals and, if used judiciously, should produce a more objective report. Thus EMG signals can be more readily quantified in terms of the characteristics of the wave form.

A new area of neurophysiology has developed with the surgical treatment of Parkinson's disease.

Carpal tunnel syndrome remains the most common and robust nerve compression syndrome and is easily demonstrated by most systems with NCS. In contrast, the tarsal tunnel or post interosseus

compressions are more uncommon and much more difficult to document electrically.

Peripheral neuropathies with axonal damage and radiculopathies require EMG (NEE) to confirm the findings.

Clinically, demyelinating polyneuropathies remain the province of NCS. Both HIV-associated and idiopathic, chronic (and acute with the former) inflammatory demyelinating polyradiculo-neuropathies (CIDP) appear to be more commonly diagnosed these days and with appropriate therapies available, nerve conduction findings of demyelination need to be reliable. Unfortunately, NCS are operator dependent and technique and experience determine reliability. Newer techniques include more widespread proximal testing, i.e. closer to the spinal cord, to diagnose a rarer but also treatable condition called multifocal motor neuropathy. The differential diagnosis of this includes motor neurone disease.

Electroencephalography

For years standard EEG machines were fixed to 8 or 16 channels, mainly limited by the size and costs of paper and the writing instruments. The advent of digital EEGs pushed this up to 32 and 64 channels (and indeed 128) without a commensurate increase in size or cost. This has been particularly useful in the detailed localisation of epileptic foci in patients being investigated for possible epileptic surgery. Such signals are also sourced directly from the brain using subdural electrode strips or grids. Some centres used intracerebral probe electrodes, but this is less common today.

However, this increase in signal handling also demands an increase in signal integrity. As with EMG, digital signals are by nature modi-

fied and 'virtual', and therefore greater care needs to be taken when signals may be unwittingly filtered or altered (Fig. 1).

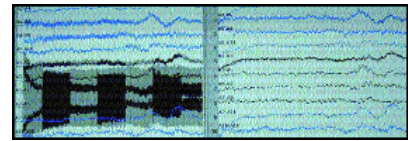


Fig. 1. Digital EEG signal. Left: raw data showing severe artefact. Right: same signal after being filtered.

Video EEG monitoring and epilepsy surgery started off in one or two centres in Canada but is now done in most large cities of the world. In South Africa, it is available in private practices in the largest cities but only in very few (if not only one) public sector hospitals. The technology of video EEG started off in specialist systems but is now available in off-the-shelf units. It combines simultaneous video imaging of the patient while the EEG is being recorded (from the scalp or subdural area). In most cases this involves harnessing the patient with long leads to the machine, allowing limited movement from the bed/chairs, for 24 hours per day over 1 or more weeks (Fig. 2). The logistics of performing this, associated with the integrity of the signal and the planning and calculation of best sampling, are not insignificant. The cost is commensurate with the intensive monitoring and technology, but the potential rewards in carefully chosen cases continue to drive the service. Statistically, many potentially treatable cases exist in the local epileptic population. In contrast, incorrect surgical decisions can be disastrous.

A significant offshoot of epilepsy surgery is pseudoseizures (or non-epileptic attacks). These cover a wide spectrum of presentations and the complex ones may need the intense scrutiny of video EEG. Pseudoseizures carry a real mor-

MAIN TOPIC

bility and are considered as important to the patient as any other major illness. A confident early diagnosis therefore is in the interests of all, from the patient to the people around the patient, to the medical funders.

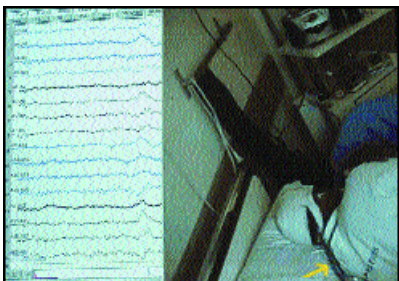


Fig. 2. Video EEG monitoring with a 'split screen' (or windows or two screens). Arrow indicates wires connecting patient to machine.

Ambulatory EEGs have not been as well received, and telemetry is also considered suboptimal on a broad scale mainly due to limitations of the system and the conditions under which it operates to produce clear reliable signals at reasonable cost. However, the wave of radio (wireless) LAN networks now sweeping the PC industry (Bluetooth, Wi-Fi and its derivatives) is likely to see a resurgence of this type of device in the near future.

Another area of EEG, which has matured, is **polysomnography**. This straddles respiratory, neurology and some other specialist areas. The signals are mixed EEG, eye movement and respiratory parameters run at a slower speed of data capture but typically for about 8 hours at night. A variety of additional signals can be added, as well as video monitoring for patients who may have strange events during their sleep. These would include people who 'act out their dreams' — often with unintentional or misdirected violence. This condition is known as REM behaviour disorder (RBD) and is likely to be undiagnosed for many years

unless the clinician is familiar with it.

Sleep centres and studies are available in the larger centres in South Africa. However, although the indications are diverse, many insomniacs can be managed without such studies. Underrated and less often used are **sleep studies for epilepsy**. These are not really polysomnograms but true EEGs done while the patient is sleeping for longer periods of time at slow EEG detail. The yield in 'difficult-to-diagnose' epileptics is significant and may provide an answer at much lower cost than video EEG monitoring, which is dependent on relatively frequent attacks.

EVOKED POTENTIALS

EP usage did not mature as expected, mainly as MRI brain scans became the superlative evaluator of brain and spinal cord damage. Even in multiple sclerosis, where somatosensory evoked potentials (SSEP) were briefly a defining test, they now have been fully eclipsed by MRI. Only visual evoked potentials (VEP) are still independently useful in MS evaluation. In First World areas, particularly the USA, SSEP may be used to assist prognosticating in severely brain-damaged patients in coma.

Brainstem auditory evoked potentials (BAEPs) had an even briefer period of use in the diagnosis of acoustic neuromas, before they were displaced by the MRI. They do still play an important role in some auditory assessments. Apart from VEPs, EPs now only have a limited role to play in the assessment of patients for clinical neurology.

STIMULATORS

Apart from measuring spontaneous or voluntary electrophysiological signals, there are many ways to

stimulate the nervous system for testing or treatment. The commonest is the stimulation necessary to perform nerve conduction tests such as in EMG or NCS.

EPs are analogous ways of assessing central sensory conduction by stimulating the peripheral organ (nerve/SSEP, eye/VEP, ear/BAEP). It is also possible to measure central conduction time by stimulating the brain with a magnetic field pulse and picking up the response along the course of the spine or at the muscle. Again, this development has been less useful than MRI of central pathways, even though it may be complementary.

Carpal tunnel syndrome remains the most common and robust nerve compression syndrome and is easily demonstrated by most systems with NCS.

Longer term stimulators have been around for many years in the form of pain controllers. Such transcutaneous electrical nerve stimulation (TENS) devices attach to the external body and suppress chronic neurogenic pain, but have been in recent times commercialised to include many more pain conditions including labour pains. However, the data and need for some of these should be scrutinised. Similar devices are sold as auto-exercisers and weight reducers although a medical use may be in chronic rehabilitation of paralysed muscles.

There are special, internal, programmable pacemakers not only for the heart, but also for the

phrenic nerve (in paralysis of respiration), for the vagus nerve (to reduce the frequency of intractable seizures) and for stimulating the basal ganglia in Parkinson's disease ('deep brain stimulation').

Apart from measuring spontaneous or voluntary electrophysiological signals, there are many ways to stimulate the nervous system for testing or treatment.

The vagal nerve stimulator is available in SA but use is reserved for patients with many intractable seizures who accept they are unlikely to be seizure free, but need to reduce the overall number of seizures.

RECORDING AND STIMULATING IN PARKINSON'S DISEASE

A new area of neurophysiology has developed with the surgical treatment of Parkinson's disease. The original co-ordinates for electrically destroying a small target in the basal ganglia were largely obtained by MRI 3D calculations with electrical stimulation used as a check for the wrong area (bright lights in the visual fields indicated a probable significant field defect and motor symptoms a likely hemiparesis). However, soon after this, neurophysiologists studied the signals coming from different parts of the brain, through which the probe was passing. They were thus able to confirm, by the nature of the signals, what type of tissue the tip

of the probe was in. This is a slow, meticulous process (typically 5 hours) and is not practised universally and probably not locally. The debate as to which method is the most effective, in terms of accuracy of localisation, has not been finally settled although the sampling method, without side-effects, is probably more desirable. Once the tip is in the correct place (e.g. the inner globus pallidus, millimeters away from the internal capsule and visual fibres) the area is destroyed by the probe (heat) (Fig. 3).

A further refinement, pioneered by the French, was not to destroy the area permanently but to stimulate it electrically. This had the advantage that the stimulator can be turned off and even repositioned. Also the stimulator's settings could be adjusted remotely from outside the body. Exactly how this stimulation works isn't clear, although it most likely renders the area inactive rather than stimulating it.

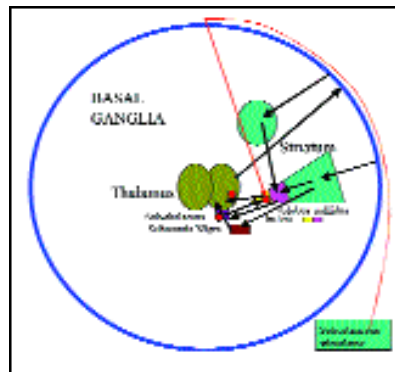


Fig. 3. Red spots: target areas for deep brain stimulation (not to scale).

Originally, the rather minute area of the subthalamic nucleus was targeted but subsequently a variety of sites have been used. Thalamic sites were also found useful in involuntary movement disorders such as tremors. The other advantage was the tolerability of stimulating the side opposite to a previously surgically ablated side — surgical ablation to one side of the

brain was reasonable, but bilateral lesions had an unacceptable morbidity rate. Patients who had been operated on one side and needed more treatment later could still have a stimulator implanted on the opposite side. Even better, they could have bilateral stimulators. Target areas are shown as small red circles in Fig. 3, which has a stimulation probe in the globus pallidus interna.

IN A NUTSHELL

Neurophysiology can conveniently be divided into two broad groups:

- Electrical signal sampling and measurement (spontaneous or evoked) such as in EMG (NEE) in the periphery, or EEG, EPs and basal ganglia centrally
- Stimulation and evoking techniques such as in NCS, EPs, and a variety of treatment types.

Often the two are combined as in NCS and EPs or EEG mapping for epilepsy surgery.

Both areas have improved and been applied to very specific targets, with good clinical success in highly specialised centres.

Neurophysiology has advanced in specific areas:

- video EEG monitoring as in epilepsy surgery and pseudo-seizures
- stimulation of various parts of the nervous system, such as the vagal nerve and basal ganglia.

Some conditions are now better recognised, e.g. chronic inflammatory demyelinating polyradiculoneuropathy and mixed motor neuropathy.

The skill and experience of the operators/clinicians determines the quality of the work.