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Evidence Check

New and emerging technologies in neurophysiology and operating theatres

An **Evidence Check** rapid review brokered by the Sax Institute for the NSW Ministry of Health. January 2018

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Contents

Glossary

ABRET	American Board of Registration of Electroencephalographic and Evoked Potential Technologists
ACNS	American Clinical Neurophysiology Society
ADHD	Attention deficit/hyperactivity disorder
ANSA	Applied Neuroscience Society of Australia
ALS	Amyotrophic lateral sclerosis Neuroscience Society of Australasia
BCIA	Biofeedback Certification International Alliance
CEA	Carotid endarterectomy
CNAP	Continuous non-invasive arterial pressure
CT	Computed tomography
ECG	Electrocardiography
EDM	Esophageal Doppler monitor
EEG	Electroencephalography
EMG	Electromyography
EP	Evoked potentials
FDA	Food and drug administration
GDFT	Goal-directed fluid therapy
HMD	Head-mounted displays
HIT	Head impulse test
ICU	Intensive Care Unit
IFCN	International Federation of Clinical Neurophysiology
IONM	Intraoperative neurophysiological monitoring
IONM-P	Intraoperative Neurophysiological Monitoring Supervising Professional
IONM-T	Intraoperative Neurophysiological Monitoring Technologist
ISNR	International Society for Neurofeedback and Research
IT	Information technology
MRI	Magnetic resonance imaging
MRN	Magnetic resonance neurography
MS	Multiple sclerosis
MUNIX	Motor Unit Number Index
NCS	Nerve-conduction studies
NHMRC	National Health and Medical Research Council
NIBS	Non-invasive brain stimulation
NICE	National Institute for Health and Care Excellence (UK)
NIRS	Near infra-red spectroscopy
OSA	Obstructive sleep apnoea
OSET	International) Organisation of Societies for Electrophysiological Technology

PA(A)	Physicians' Assistant (Anaesthesia)
PSG	Polysomnography
PTSD	Post-traumatic stress disorder
QEEG	Quantitative EEG
rTMS	Repetitive transcranial magnetic stimulation
tDCS	Transcranial direct current stimulation
STARTTS	NSW Service for the Treatment and Rehabilitation of Torture and Trauma Survivors
TGA	Therapeutic Goods Administration
VEMP	Vestibular evoked myogenic potentials
vHIT	Video-assisted head impulse test(A) - Physicians' Assistant (Anaesthesia)
PSG	Polysomnography

Executive summary

Background / Purpose of the review

The medical technician workforce provides support to medical professionals in various ways and settings, such as operating medical equipment, performing and assisting with patient assessments or other tests. It is recognised that, over the next decade or so, changes in technological advancements will have an impact on the way these workforces operate and the types of skills they need. This review focuses specifically on the current and emerging science, technology and procedural issues relevant to medical technicians working within two fields which are rapidly advancing; neurophysiology and operating theatres.

Review questions

This review aimed to address the following questions:

1. What evidence is there of new and emerging technologies in the two focus areas of neurophysiology and operating theatres that are currently, or likely to be, adopted in private as well as public practice over the coming 5–10 years?
2. What are the new and existing specialised skills required for the effective and safe uptake of the technologies identified in question one?

Summary of methods

This review used a rapid review methodology. Both the peer reviewed and grey literature were systematically searched to answer the review questions. Consultation with relevant experts, in both clinical practice and the medical technology industry, was also informally undertaken to aid the search process or interpretate evidence.

Key findings

This review confirms the medical technician workforce landscape is changing rapidly, and that future technological developments will continue to alter the nature of patient care, and the duties and skills required of clinical and technical staff. In both operating theatres and neurophysiology (a field focused on assessments of the nervous system) several technological advancements appear set to influence clinical practice. These will change the way monitoring, assessment, diagnosis and treatment take place, and will require a workforce that is adept in programming, operating and interpreting results from the associated technologies.

Q1. New and emerging technologies

In neurophysiology, strong evidence from various studies and an international consensus statement suggests emerging brain monitoring technologies will enable long term monitoring of critically ill patients to become more routine practice. This particularly applies to electroencephalography (EEG) monitoring. Such technologies will be useful in intensive care units (ICUs) to improve early detection of secondary brain abnormalities such as seizures or strokes. In addition, these technologies are becoming increasingly compact and mobile which will enable their use for long term monitoring outside of acute care settings (for example, detection of epileptic seizures). Sleep testing technologies, which monitor EEG and other body functions (polysomnography), are also becoming more portable, making home testing and diagnosis of conditions such as sleep apnoea more accessible.

There is also evidence suggesting that EEG can be used for other purposes such as for neurofeedback training, where patients are given immediate feedback about their own brain activity as recorded by an EEG. From this, patients can learn which brain patterns are healthy or 'optimal' (for example, associated with focused attention) and which are 'sub-optimal' (for example, associated with mind-wandering), and then learn techniques to regulate them. There is strong evidence to suggest this is an effective therapy for attention deficit/hyperactivity disorder (ADHD) and growing evidence to suggest it may be useful therapy for other conditions such as post-traumatic stress disorder.

Advancements in technologies that involve electrical or magnetic stimulation of the brain or nervous system to alter their function to treat certain conditions (neuromodulation) are also on the horizon. Of particular interest are non-invasive brain stimulation techniques for treatment of clinical disorders. Repetitive transcranial magnetic stimulation (rTMS) is the most established technology and there is strong evidence for its therapeutic effects for depression and neuropathic pain. Such treatments are currently emerging in Australia.

The future of clinical assessment for conditions such as peripheral neuropathies, motor unit function or vestibular disorders is also likely to change as emerging techniques are adopted. Novel methods of nerve conduction assessment, measuring muscle responses to nerve stimulation and vestibular system tests are all likely to be widely adopted within the next 10 years. This will improve assessment of certain conditions and also facilitate new insights, particularly in relation to lesser understood conditions.

In operating theatres, advances in technologies are likely to improve and/or automate the way in which patients are monitored, and anaesthetics, gases and fluids are administered during surgery. Advances in intraoperative neurophysiological monitoring will enable monitoring of neural structures within the brain, spinal cord and peripheral nerves during a procedure to minimise risk of damaging them. This technology is currently used in other countries, such as the United States, and is becoming emerging practice in Australia. The use of decision support technologies — which, for example, can facilitate clinical decision-making by providing enhanced visual displays of important clinical information — is also likely to become more widespread over the coming years.

Non-invasive haemodynamic monitoring technology, to guide fluid management during surgery, appears to be a viable alternative to more invasive techniques. At least one device is commercially available. Based on the results of further trials, such devices may be more widely adopted over the next decade.

There is increasing evidence that near infra-red spectroscopy (**NIRS**) monitoring of brain oxygenation status has clinical benefits in a variety of surgical settings. It appears feasible that NIRS monitoring will be more widely adopted in these settings over the next decade.

Q2. Skills to support new and emerging technologies

Emerging technologies such as those summarised above will increase the level of skill and training required of technicians working in these areas. In addition, some technologies are likely to result in an expanded scope of practice for technicians, particularly those working at more advanced levels.

In neurophysiology, as long-term EEG monitoring becomes more widespread, increased demand for EEG technicians will follow. Emerging EEG technologies generate alerts about suspected abnormal patterns (such as seizures), and experienced technicians will be required to interpret the alerts and make decisions about whether referral to a specialist is required. For example, if seizures are suspected by the technician and then confirmed by the neurologist, anti-epileptic drugs could be administered more promptly. Advanced technicians would also be involved in development of EEG policies and procedures, and provision of EEG-related supervision and training of less experienced EEG technicians and staff.

As neurofeedback training becomes more widely used, an appropriate strategy would be to have EEG technicians routinely involved in the set-up and operation of neurofeedback sessions with patients (for example, ADHD or mental health conditions). This should occur under the general supervision of a qualified neurofeedback practitioner (typically a psychologist or psychiatrist). For these roles, technicians would require brief specialised training and certification in neurofeedback techniques, protocols and software interfaces.

Currently there is no category of technician specific to non-invasive brain stimulation (**NIBS**) techniques such as transcranial magnetic stimulation. Such a category may be created over the next decade or NIBS may develop within an enhanced scope of an existing medical technician category. Of these, the neurophysiology technician category appears best suited to NIBS methods. Those applying NIBS treatments will need in-depth knowledge of neurobiology and the appropriate safety aspects of the NIBS modalities, and specialised training and certification will be warranted.

Depending on their workplace, in the future some neurophysiology technicians will also require one or more emerging assessment techniques such as:

- Magnetic root motor stimulation or evoked potentials (similar to EEG, but measuring responses to specific stimuli, such as visual)
- Motor unit assessments (for example, motor unit number index),
- Mobile (EEG) monitoring of outpatients, and/or
- Vestibular tests (for example, the video-assisted head impulse test).

In operating theatres, technical aspects of intraoperative neurophysiological monitoring should be performed by experienced neurophysiology technicians. Such aspects will include placement of electrodes or stimulating devices, acquisition of high quality data, troubleshooting problems and providing descriptions of the data. These technicians should also be trained in various aspects specific to operating theatres, including peri-operative procedures, safety, and surgical or anaesthetic techniques or practices. Operating theatre technicians and anaesthetic technicians will require skills relating to emerging technologies, such as anaesthetic devices for automated control of gas concentrations, haemodynamic monitoring technology to guide fluid management, NIRS monitoring of cerebral oxygenation, image-guidance techniques and 'decision support' tools which facilitate decision-making (for example, by enhanced display of patient information).

Discussion

The findings of this report have important implications for technicians, including their skills, responsibilities, education and training. These factors will need to evolve and expand over the next decade in parallel with clinical adoption of various technologies and techniques. Clearly it will be increasingly important for future technicians to be competent in:

- Operation, maintenance, updating, trouble-shooting and/or programming of technologies (such as patient monitors, automated data analysis systems and mobile monitoring systems)

- Inspecting and integrating data from various modalities or devices (for example, EEG, video, imaging) and identifying specific signals or patterns (for example, seizures on EEG)
- Responding to alerts or alarms generated automatically by monitoring technologies
- Data management, including storage, back-up and retrieval of data
- Processing or analyses of data, or some interpretation of data and associated decision-making, in certain situations.

Such duties will become increasingly valuable as new technologies result in greater amounts of data being gathered from patients. Some experienced technicians will effectively be informed mediators between patient data as captured by technology and other clinical staff, including medical specialists. It is also critical that technicians recognise any limitations of specific technologies and use them appropriately.

Future technicians will require more education and training on topics related to emerging technologies and techniques, including data management and others listed above. The education prerequisites of technicians will evolve over the next decade requiring technicians working in these emerging areas to undertake further appropriate training and certification.

Conclusion

In neurophysiology and operating theatres, several emerging technologies are likely to be adopted in clinical practice over the next decade. These include long term brain monitoring systems, intra-operative monitoring, non-invasive brain stimulation treatment and anaesthetic delivery systems.

Portable and wearable technologies are beginning to enable mobile monitoring, outside acute hospital settings. These technologies are assisting mobile or home-based monitoring for disorders such as epilepsy and sleep apnoea.

In parallel with the adoption of new technologies, the skills, responsibilities, education and training of technicians will also need to develop. Although some of these technologies perform automated processing of patient data, technicians will be required to read and interpret data or results, and make decisions about whether referral to a specialist clinician or other action is required.

Future technicians will need to be proficient in operating and programming technologies as well as managing and interpreting data. They will also need further training, and perhaps certification, in relation to various technical and safety matters.

As the forecasts and recommendations of this Evidence Check are realised, technicians working in neurophysiology or operating theatres will interact with more sophisticated technologies as well as with patients and other healthcare professionals. Some technicians should become essential facilitators between technologies, patients and clinicians. Technicians in these areas will, therefore, become increasingly vital members of multi-disciplinary clinical teams delivering quality healthcare to patients.

Background

The NSW Ministry of Health undertakes horizons scanning on targeted workforces, including new and emerging technologies and skills requirements. This rapid review will inform current work focussed around medical technicians in areas where technology is rapidly advancing: neurophysiology and operating theatres.

The medical technician workforce provides support to medical professionals in a variety of ways such as operating medical equipment in emergency rooms and operating theatres, performing and assisting with laboratory tests, and filling prescriptions in pharmacies. For this review, several less well documented sub-groups of medical technicians listed under ANSZCO codes as NEC (not elsewhere classified) are of interest — Neurophysiology technicians, Electroencephalographic Technicians, Sleep Technicians, Anaesthetic Technicians & Operating Theatre Technicians.

This Evidence Check is intended as a scoping review of evidence regarding technological advancements in these fields that are currently entering common practice, or are likely to be adopted in private or public practice. The focus of the review is on both the technologies and the specialised workforce skills required for the safe and efficient use of these technologies in practice. This rapid review seeks to highlight technological and procedural issues related to these workforces and provide insight into supply and demand drivers that may influence these workforces in future.

Methods

Peer reviewed literature

Various distinct searches of the PubMed database were conducted in August 2017. Searches were limited to literature published from January 2010 to August 2017 from OECD nations. Separate searches were performed for new or emerging technologies in each of the following areas:

- Neurophysiology
- Electroencephalography
- Nerve conduction studies
- Vestibular system assessments
- Sleep studies and assessments
- Evoked Potentials
- Electromyography
- Actigraphy
- Operating theatres
- Anaesthetics
- Surgery

The sets of specific search terms for each of the above searches are listed in Appendix B.
In addition, the contents of all issues of *Clinical Neurophysiology* (official journal of the International Federation of Clinical Neurophysiology) since January 2014 were searched.

The following experts were also consulted for specific advice:

- Dr Andrew Wong (Director of Neurology and Stroke, Royal Brisbane & Women's Hospital)
- Dr David Highton (Anaesthetist, Prince Alexandra Hospital, Brisbane)
- Mr Fred Tremayne (Director of Neurophysiology, Royal Brisbane & Women's Hospital)
- Mr Marnix van Bruggen (Territory Manager — Neurophysiology, LifeHealthcare)
- Dr Rob Henderson (Neurologist, The Wesley Hospital; Royal Brisbane & Women's Hospital)
- Ms Alice Pender (Audiologist, Royal Brisbane & Women's Hospital)
- Dr Fiona Robertson (Surgical Assistant, Mater Hospital, Brisbane)
- Dr Peter Devadason (Psychiatrist, Private practice & The Prince Charles Hospital, Brisbane)

Included studies

Three hundred and sixty-nine peer-reviewed publications were identified by the PubMed searches specified above. Sixty-two peer-reviewed publications were selected for inclusion in the review.

Evidence grading

A comprehensive assessment of the quality of included evidence was not undertaken in this review. However, in some instances, an indication of the level of evidence, as per the Evidence Hierarchy of the National Health and Medical Research Council (**NHMRC**) is provided as an indicator. The Evidence Hierarchy is outlined in the table below.

Level of Evidence	Study Design
I	A systematic review of Level II studies
II	A randomised controlled trial
III-**1**	A pseudo-randomised controlled trial (i.e., alternate allocation or some other method)
III-**2**	A comparative study with concurrent controls (i.e., non-randomised experimental trials, cohort studies, case-control studies, interrupted time series studies with a control group)
III-**3**	A comparative study without concurrent controls (i.e., historical control study, two or more single arm studies, interrupted time series studies without a parallel control group)
IV	Case series with either post-test or pre-test/post-test outcomes

Grey literature

Grey literature was searched for reports, guidelines, consensus and position statements, or opinion pieces from relevant stakeholder groups, organisations and agencies. In addition to standard search engines, targeted searches were conducted of relevant organisations' websites, futurists' websites or blogs, and the websites of medical device technology companies. A complete list is provided in Appendix C.

In addition, the websites of various commercial organisations were consulted, as outlined in Appendix D.

Findings

The findings to the two review questions are presented in the two sections below. The first section introduces and describes the new and emerging technologies that are likely to impact technician work forces working in neurophysiology and in operating theatres over the coming decade. The second section focuses on outlining the skills technicians will require to support these new and emerging technologies.

1. New and emerging technologies

1.1 New technologies in neurophysiology

Clinical neurophysiology is defined as: "*a medical specialty, or sub-speciality, concerned with function and dysfunction of the nervous system, caused by disorders of brain, spinal cord, peripheral nerve and muscle, using physiological and imaging techniques to measure nervous system activity. When interpreted in relation to the clinical presentation of patients, data from these techniques can either diagnose, or assist in the diagnosis of, neurological conditions and quantify, monitor and follow progression of such conditions. Clinical Neurophysiology also encompasses physiological methods for therapy of neurological and psychiatric disorders*" (the International Federation of Clinical Neurophysiology[1]).

Clinical neurophysiology employs a wide range of assessment techniques and technologies, including: electroencephalography, evoked potentials, electromyography, nerve conduction studies, intraoperative monitoring, polysomnography and other sleep technology, quantitative neurophysiological methods, brain stimulation and related areas.[2] These technologies and techniques are discussed in detail in this report.

It is also noteworthy that clinicial neurophysiology is an autonomous medical specialty in various European nations and the UK, whereas in the US clinical neurophysiology is a sub-specialty of either neurology or psychiatry. In Australia, there is no clinical neurophysiology specialty or sub-specialty and most assessments, such as those listed above, generally fall within the scope of neurologists (except specialists trained overseas in clinical neurophysiology now practising in Australia).

Various new technologies and techniques are emerging in clinical neurophysiology practice, and these are discussed in detail in the following sections.

1.1.1 Electroencephalography (EEG)

Electroencephalography **(EEG)** assesses brain function by monitoring the electrical activity of the brain ('brain waves'), using electrodes placed at various specific locations on the scalp. EEG is non-invasive, widely available and relatively inexpensive. A standard clinical EEG generally involves recording brain activity for at least 20–30 minutes.

EEG is the gold-standard technique for detecting seizures and thus is commonly used as a diagnostic test for epilepsy.[3] EEG is also used to facilitate clinical diagnoses for symptoms including fainting, fits or other unusual spells. Importantly, EEG can detect seizures which are not associated with any obvious clinical, behavioural or motor symptoms (these are known as subclinical or non-convulsive seizures). These types of seizures cannot be detected without EEG.

EEG is also used to guide decision-making about brain surgery in treatment-resistant epilepsy. In this case, EEG monitoring is performed for several days prior to surgery, either using many electrodes on the scalp, or electrodes can be temporarily implanted directly on the brain surface. EEG patterns from the differing electrodes are used to help specialists decide which brain areas to operate on.

EEG monitoring can also inform important clinical decisions in neurocritical conditions such as coma, brain injury or (suspected) brain death. As outlined below, technological developments are advancing the scope and clinical applications of EEG monitoring.

The following sections summarise technological developments that are leading to EEG monitoring being used more widely, including in new applications. These include hardware developments that are making EEG systems more portable and software developments that are assisting analysis and interpretation of EEG signals. Additionally, recent studies indicate that EEG monitoring is useful in various clinical conditions which have not routinely had such monitoring in the past.

EEG hardware: Electrodes, headsets, amplifiers & mobile EEG

Over the past decade there have been advances in EEG electrode (or sensor) technologies. Some of these advances are leading to new technologies which should be implemented into clinical practice within the next 10 years. These developments have produced smaller EEG devices and wearable headsets containing EEG electrodes. These are enabling EEG monitoring to be done outside the conventional hospital environment.

Conventional clinical EEG involves individual, small metal electrodes that are attached to the scalp using a thick paste. This paste acts as both an adhesive and a conducting medium for electrical impulses (originating in the brain) to be transmitted from the scalp to the electrodes. These are 'wired' electrodes; a thin cable or lead connects each electrode to the EEG monitoring system. However, research and development activities have resulted in 'dry' electrodes which do not require the use of paste or gel, and wireless systems which do not require leads. For example, a university-industry collaborative study reports that there is evidence that "*EEG data recorded from the wireless dry electrode system is comparable to data recorded from a conventional system*".[4]

Various companies have developed headsets which contain EEG sensors. These can be worn on the head (for example, like a pair of headphones). They also have wireless capability, removing the need for cables. These headsets essentially are wearable EEG devices. Companies with EEG headsets on the market currently include Emotiv (EPOC+ headset[5]), NeuroSky (MindWave[6]), InterAxon (Muse[7]) and NeuroTherapeutics (Versus[8]).

While these EEG headsets are currently used for gaming, relaxation or neurofeedback (see below) rather than clinical applications, it appears that with further technological developments they may be used in clinical applications in future.[9] The EEG headsets would need to maintain adequate impulse-conducting contact between the scalp and sensors over long periods before clinical application is possible (see below). In addition, such devices would require regulatory approval from the Therapeutic Goods Administration (TGA) in Australia before they could be used in clinical settings. Once approved, devices are entered on the Australian Register of Therapeutic Goods.[10]

EEG amplifiers have also become increasingly small and portable over the past two decades, and many are now mobile. This technological evolution is very similar to the evolution from bulky desktop computers in the 1980s and 1990s to tablets and smartphones over the past decade. Examples of mobile EEG products are Mobita (BioPac Systems Inc[11]) and eego sports (ANT Neuro[12]). To date, such systems have commonly used with conventional 'wired' EEG electrodes, although in some non-clinical applications they may be used with EEG headsets. These technologies constitute mHealth (mobile health) solutions for EEG.[9]

One clinical application for which mobile EEG technology is well suited is long term monitoring of (suspected) epileptic patients. This is commonly performed to detect seizures, diagnose epilepsy and help inform treatment plans. The monitoring period may last up to several days. Mobile EEG systems enable the patient to remain mobile rather than bed-bound, and at home rather than in hospital during monitoring. EEG monitoring outside the hospital setting is beginning to be used for clinical purposes.

A study in the Netherlands found that 30% (33/109) of neurologists reported that home EEG recordings were used by their hospital. It also reported that the majority of neurologists believed that mobile EEG can have additional monitoring value after initial epilepsy diagnoses.[9] The authors noted that poor electrode contacts and EEG signal quality, and limited recording times (due to battery life) had been significant technical challenges. However, they also stated that these challenges were being addressed by ongoing research and development.[9]

It is likely that home EEG monitoring for disorders such as epilepsy will become more common over the next decade. The same applies for testing for sleep disorders (discussed below in Section 1.1.6). These developments will evidently lead to an increase in the amount of EEG monitoring performed over the coming decade.

Continuous EEG monitoring of critical care patients

This section summarises evidence that long-term EEG monitoring will become more common and performed for additional neurological conditions over the next 10 years.

Strong evidence from many clinical studies indicates that EEG monitoring can provide useful information in neurocritical conditions such as traumatic brain injury or coma. This information about abnormal brain activity can assist medical specialists to make treatment decisions. This is supported by two consensus statements recently published by the Critical Care Continuous EEG Task Force of the American Clinical Neurophysiology Society.[13, 14] These and other experts propose that 'continuous' EEG recording (lasting for hours or days) "has an important role in detection of secondary injuries such as seizures and ischemia in critically ill adults and children".[13] Secondary brain injuries can result in brain damage and deficits if they are not detected and treated promptly. For example, conditions such as traumatic brain injury can trigger seizures while conditions such as brain haemorrhages can lead to critical reduction in blood flow to the brain ('ischaemia'). Both of these events can cause further brain damage and lead to deficits such as inability to walk or talk. Continuous EEG monitoring enables prompt detection and treatment, minimising the risk of long-lasting deficits.

Over the next decade, continuous EEG monitoring should become more routine practice for neurocritical conditions including traumatic brain injury, brain haemorrhage and severe stroke.[14] In addition, technological advances (described below) will facilitate this form of brain monitoring by aiding more detailed review of long term EEG (and simultaneous video footage of the patient). This is superior to the current practice of intermittent review. These technologies include software and hardware which enable real-time EEG signal processing and instantaneous bedside display of 'quantitative EEG trends' in addition to the conventional EEG patterns.

Quantitative EEG and trends

Advances in EEG monitoring software are facilitating the analysis and detection of abnormal EEG patterns. Quantitative EEG (**QEEG**) provides measures of brain function similar to measures such as blood pressure or temperature. These QEEG measures are computed from the standard EEG signals but can be more objective and easy to monitor over time. Therefore, QEEG monitoring can supplement the traditional visual inspection of EEG signals, which can be more subjective. It also can more readily display fluctuations or trends in brain activity which can occur over several hours or more. Therefore, QEEG can assist the detection of important changes, such as worsening brain activity.

Some current clinical EEG systems automatically compute and display QEEG trends. This function is becoming more widespread as new EEG systems are released. Particular patterns in the displayed QEEG trends can alert clinical staff to review specific segments of EEG signals. This can assist the detection of seizures or other brain abnormalities. Reviewing both QEEG trends and the conventional EEG can expedite and improve the detection of abnormal patterns in neurocritical patients and help the effectiveness of treatments.[14]

Computer-assisted EEG analysis

Other types of emerging software are showing potential to aid the analysis of EEG patterns or even to provide an automatic summary report on EEG. Studies in stroke and other patients indicate that computer-assisted EEG/QEEG systems can assist recognition of particular EEG abnormal patterns by non-expert clinical staff[15, 16] as well as improve the efficiency and consistency of EEG interpretations.[17] A study by Lodder et al. (2014) evaluated an automated EEG analysis system by comparing the assessments of ten EEG experts against those generated by computer, concluding that the computer assisted assessments were accurate.[17]

Another group has developed and assessed a computer-assisted system which automatically generates summary EEG reports.[18] The computer reports were found to be consistent with the reports by qualified clinicians, showing that it can be a useful tool to aid EEG assessments by clinicians.[18]

As 'smarter' EEG monitors such as these are utilised in clinical practice, specialised EEG technicians could identify particular abnormal patterns. They would be the first responders to computer-generated alerts and have the responsibility to take further action as appropriate. This may include escalating a query to a more experienced clinician (for example, a neurologist) for detailed assessment. These factors are discussed further below (under Question 2, which focuses on skills).

It is important to note that the interpretation of EEG signals by an experienced clinician (for example, an advanced EEG technician or neurologist) remains vital. That is, the ultimate responsibility for diagnoses should remain with the medical specialist rather than the technology. Emerging EEG technologies, such as those discussed in this section, should be used to *facilitate* detection of abnormal brain patterns by clinicians.[17]

This and the preceding section demonstrate that emerging technologies are likely to assist detection or analysis of EEG signals in the future. However, interpretation by technicians and clinicians will remain important.

Future clinical applications

There are several other clinical conditions and situations in which EEG/QEEG monitoring seems likely to be used in future clinical assessments. These include:

- Post-neurosurgery, encephalopathy, coma or stroke patients[13, 14, 19]
- Monitoring during vascular surgery for early warning of reduced brain perfusion[20] and
- Monitoring responses to therapy or level of sedation.[13, 14, 19, 21, 22]

EEG/QEEG seems particularly useful for guiding predictions about which patients will recover well and which will not. For example, a recent study analysed QEEG measures from 283 comatose patients assessed during the first three days after cardiac arrest. The QEEG measures were compared to patient outcome assessments performed six months later. The authors reported that a QEEG measure "*provides unequalled prognostic value … and enables bedside EEG interpretation of (by) unexperienced readers*".[23] This study provides more evidence that QEEG monitoring can assist clinical decision-making. Firm evidence such as this indicates that QEEG monitoring technologies should become more common (for example, in ICUs) over the next decade.

In recent years further work has been undertaken in developing technologies to facilitate detection of seizures using QEEG methods. Seziures can be caused by epilepsy or other conditions, such as asphyxiation by the umbilical cord at birth. Some seizure-detection technologies are already available commercially. One example is a software package called "*RecogniZe*".[24]

The clinical usage of 'early alert' technologies such as RecogniZe in hospitals is likely to increase over the next decade. These technologies can automatically alert staff, such as EEG technicians, about the incidence of suspected seizures (or other abnormal patterns). These alerts prompt technicians to conduct closer data review in the first instance. In this way, they can expedite further action as appropriate, such as calling a neurologist for assessment and treatment with anti-epileptic medication. In summary, this technology has genuine potential to improve the detection and treatment of seizures.

Finally, telemedicine technologies are opening up new possibilities for remote EEG assessments and/or diagnoses. For example, EEG data can be viewed remotely over a secure internet connection or even on a smartphone[25], enabling a neurologist or clinical neurophysiologist to inspect and interpret EEG remotely. This technology allows a medical specialist in a capital city to remotely assess a patient in a regional or rural hospital.

Evidence summarised throughout section 1.1.1 indicates that, over the next decade, EEG monitoring will generally become more widespread, and applied to additional clinical conditions and in new settings.

1.1.2 Nerve-conduction studies

This section discusses new technologies and techniques which appear likely to be used to augment conventional nerve conduction studies in the future. Nerve-conduction studies **(NCS)** are diagnostic tests used to assess motor or sensory nerves. NCS test the function (impulse conduction) of these nerves. They are commonly used to diagnose suspected cases of neuropathy (disease or damage in peripheral nerves).

NCS generally involve electrical stimulation of nerves and measurement of responses, either in nerves (sensory) or muscles (motor). Recent evidence indicates that a technique involving 'magnetic-motor-root stimulation', which involves stimulation of spinal nerves using a magnetic coil, may be useful for specific clinical assessments. This will be useful for detecting abnormalities of the proximal peripheral nerves and evaluating the abnormal conduction of the corticospinal tract more precisely.

This technique seems specifically useful for conditions affecting the proximal peripheral nerves (those in regions not far from the spine) which are frequently affected by peripheral neuropathies. On the other hand, conventional NCS are 'insufficient for detecting' neuropathies in these nerves[26] although NCS can still provide useful information (see below). A review article concludes: "*These stimulation methods are expected* *to make a breakthrough in the diagnosis, pathophysiology and judgement of therapeutic efficacy, especially when combined with other neurophysiological techniques such as NCS*".[26]

Over the past 15 years other techniques have entered clinical practice, generally used together with conventional NCS. A very recent review highlights that magnetic resonance neurography (**MRN**) and ultrasonography are increasingly used in diagnoses of peripheral neuropathies.[27] MRN and ultrasonography can localise areas of nerve damage. This information can complement results from conventional NCS which provides functional (physiological) assessments rather than static (anatomical) images. That is, the combination of conventional and new technologies can provide a more complete picture to guide clinical assessments.

Emerging technologies such as magnetic-motor-root stimulation and MRN are proposed to be most effective when used together with conventional NCS. So as these new technologies enter clinical practice, there will be a need to integrate results from these with those from NCS. This will probably fall within the scope of practice of future technicians, as discussed later in this report.

1.1.3 Evoked potentials

Some evoked potential techniques may prove useful for assessments of nerve damage, although further studies are needed before broader implementation would be considered. Evoked potentials (**EPs**) measure nervous system responses to specific stimuli, such as visual or auditory stimuli. They are used to assess specific functions of the nervous system. In some cases, EPs are recorded with EEG electrodes placed on the scalp. Some published evidence indicates that specific EP techniques may be useful in clinical assessments of small-fibre neuropathies (nerve abnormalities affecting thin nerves). A recent review article summarises evidence that specific EP techniques may in future be useful in clinical assessments of neuropathies affecting small-fibre nerves in pain pathways of the nervous system.[27] These EP techniques involve stimulation of the skin with electrical impulses, laser or heat. Those involving electrical skin stimulation (pain-related EPs) appear most promising at present but further studies are needed before broader clinical uptake could be proposed [27]. Conventional NCS are of minimal value for assessing small-fibre neuropathies[27] so, EPs could be especially useful in this clinical application.

Other EP techniques used in relation to intra-operative neurophysiological monitoring are also mentioned below.

1.1.4 Electromyography and motor unit assessments

At least one emerging motor (movement) assessment technique seems quite likely to be adopted in clinical practice over the next decade. Physiological assessment of nerves involved in movement is vital in diseases such as amyotrophic lateral sclerosis (**ALS**, also known as motor neurone disease), particularly given that it is not feasible to biopsy motor neurons. These are known as motor unit assessments. Motor units are made up of motor neurons (nerves which stimulate muscles to move) originating in the spinal cord and the muscle fibres (for example, in the legs) to which which they are connected.

Motor unit assessments could be used to assess severity of diseases such as ALS. They could also provide very valuable measures for clinical trials. Some techniques developed in recent years estimate the numbers of functional (unaffected) motor units. This can be done by stimulating the relevant nerve (for example, in the arm) and assessing muscle responses using electromyography (**EMG**). EMG assess muscle activity using electrodes placed on the skin overlying specific muscles.

Currently there are two validated motor unit assessment methods in common usage in clinical research studies. These are the Motor Unit Number Index (**MUNIX**) method, used chiefly in Europe and Asia, and the multipoint incremental method, which is more routinely used in North America.[28] Of these the MUNIX is more commonly used in Australia. In a review article, Henderson and McCombe conclude that "*the need for an objective measure for the assessment of motor units remains tantalizingly close but unfulfilled in 2016*".[28]

Recently Neuwirth et al.[29] analysed MUNIX measures assessed from 49 ALS patients at different times (across three international centres). This study proposed that MUNIX is "*a good biomarker candidate for disease progression and possibly … pharmacodynamics response in early phase II clinical ALS trials*".

Although there currently is only Level III evidence (per the NHMRC framework) and further methodological improvements seem to be required[28], these motor assessment methods are being used clinically in some centres. Henderson and McCombe note that "the MUNIX method is the method used in most centers across the globe, with 39 publications in the last three years and is probably the most widely accepted method for assessing motor units".[28] Although this test does not appear to be used in clinical practice in Australia as yet, this may occur over the next decade, probably in clinical trials in the first instance.

1.1.5 *Vestibular testing*

Two types of vestibular system tests appear likely to be used more widely over the coming 5–10 years. The vestibular system, located in the inner ear, helps maintain balance, posture and associated functions. Vestibular disorders result in symptoms such as vertigo and imbalance. In recent years new tests of the vestibular system (described below) have provided clinicans with many new insights into vestibular disorders.[30, 31]

Vestibular evoked myogenic potentials **(VEMP)** are measurements of head and neck muscle responses to sound or other stimuli. These responses are measured using EMG. For example, cervical VEMPs are measured on the sternocleidomastoid muscle (of the neck) in response to sounds (such as clicks). VEMPs are routinely used to assess the function of the vestibular system.[32]

As stated in a recent review article "*VEMPs can be easily performed by well trained neurophysiological technicians, are well tolerated by patients, and therefore readily applicable in the outpatient clinic*".[31] Clinically, VEMPs are predominantly utilised for diagnoses or assessments of:

- Peripheral neurovestibular disorders
- Ménière's disease
- Vestibular neuritis
- Otosclerosis.

International guidelines for cervical VEMP assessments in both research and clinical testing have been published in recent years.[33]

A recent review article presents evidence that VEMPs can also be diagnoses or assessments of disorders of the *central* nervous system. These disorders affect the brain and spinal cord (rather than peripheral nerves) and include multiple sclerosis (MS), Parkinson's disease, stroke and migraine.[31] The review reports that the current evidence includes case series (Level IV) or case-control studies (Level III evidence [NHMRC]). It also reports that the most promising evidence exists for VEMP assessments of MS, certain types of tumour and stroke. In relation to MS the authors reported: "*in our clinic VEMPs are used in these patients as a complementary diagnostic tool when the cerebral MRI is not explanatory*".[31]

The review proposes that "*the primary indication for VEMP testing should be in patients whose neurovestibular complaints cannot be reliably localized to the central or peripheral neurovestibular system* *clinically, neither with (video) nystagmography nor with brain MRI. Also VEMP testing can help in confirming central nervous system involvement in patients with vestibular complaints with normal brain MRI*".[31] However, further studies are required to achieve Level I or II evidence.

The head impulse test (HIT) of the vestibular system assesses reflex eye movement responses triggered by head movements. These reflexes are required to maintain good vision and balance. In recent years, the HIT has become the most important test for differentiating central versus peripheral vestibular disorders.[30] It is especially useful when traditional neurological deficits are subtle or absent.[30]

Within the past decade, video-assisted HIT (**vHIT**) methods have advanced this form of assessment. The review article states that in "many dizzy clinics around the world, video Head Impulse Testing has supplanted caloric testing as the initial and in some cases the final test of choice in patients with suspected vestibular disorders".[30] ('Dizzy clinics' assess and treat patients with vertigo and associated vestibular symptoms and disorders).

The vHIT is non-invasive and uses portable technology. As a result of increasing clinical usage of this test in recent years, together with VEMP testing in some specific cases, new patterns of vestibular disorders or syndromes are becoming apparent to clinicians.[30]

Overall, it appears that clinical adoption of VEMP and vHIT tests will increase over the next decade. They may be especially used to assess new disorders and conditions, some of which may only be recognised due to technological and methodological advancements made in recent years. Further strengthening of the evidence base and further technological development should help lead to wider clinical usage in the future.

1.1.6 Sleep testing

Portable monitoring devices are enabling sleep testing to become more widespread and to be used outside of traditional clinical environments. Polysomnography (**PSG**) is a multi-modality sleep test (or sleep study) paradigm method used to investigate sleep and sleep disorders. It involves the simultaneous testing of various body functions and is commonly used to diagnose conditions such as obstructive sleep apnoea (**OSA**). PSG involves measurement of:

- EEG
- EMG
- Electrocardiography (ECG)
- Electrooculography (eye movements)
- Respiratory effort
- Snoring
- Pulse oximetry.

PSG can assess the time spent sleeping, sleep latency (time to get to sleep) and amounts of time spent in various sleep stages.

Traditionally. sleep testing has required people to undertake an overnight stay at a sleep centre (or 'sleep laboratory') in a hospital or private practice. However, in recent years home sleep testing using portable devices has become relatively commonplace for initial screening for OSA. In a position paper the Canadian Sleep Society and Canadian Thoracic Society endorsed the use of portable monitoring for diagnosis of sleep apnoea in certain circumstances.[34] In addition, current clinical practice guidelines of the American Academy of Sleep Medicine include a recommendation that: "*polysomnography, or home sleep apnoea testing with a technically adequate device, be used for the diagnosis of OSA in uncomplicated adult patients presenting with*

signs and symptoms that indicate an increased risk of moderate to severe OSA".[35] There is no analogous body for sleep medicine in Australia. The Australasian Sleep Association (ASA) represents "*clinicians, scientists and researchers in the broad area of sleep*", and does not have published, clinical practice guidelines.
Home testing for OSA has become commonplace in recent years. In Australia, various organisations such as Healthy Sleep Solutions[36] provide home sleep testing services and equipment.

Actigraphs are wearable devices that use accelerometers to measure movement. Most actigraphs are worn on the wrist like watches. Movement measures can be used to estimate the amount of time spent in waking and sleep states. However, it is important to note that these estimates are not always accurate. For example, periods of no movement are generally interpreted by actigraphs as being due to sleep but may be due to 'still' waking states, such as watching television. For this reason, actigraphy was found to have low specificity for detecting sleep/wake state, in a study which compared actigraphy to PSG methods in 77 adults.[37] Apart from this shortcoming, actigraphy has been found to be relatively accurate in relating to estimating sleep/wake state, especially wakefulness (indicated by movement).[37]

Although actigraphy shows some promise, given the relatively wide adoption of home sleep testing, it may not be widely adopted or may be adopted only in specific clinical applications (for example, rehabilitation). Overall, in the field of sleep testing, home testing for OSA using mobile monitoring technology appears to be the most significant technological development in recent years. This is already being utilised in private practice and has potential for wider uptake in the future.

1.1.7 Neuromodulation

Emerging brain stimulation technologies and techniques are beginning to be used to treat certain neurological or mental health conditions. Neuromodulation is the name given to techniques that stimulate and modulate the activity of the brain or nervous system. This is mainly done using electrical or magnetic stimulation. Cochlear implants are considered a form of neuromodulation as they involve stimulation of the auditory nerve. The website of the International Neuromodulation Society[38] contains further background information about this growing field.

Another neuromodulation technique is deep brain stimulation, which is used to treat movement disorders such as Parkinson's Disease. This involves surgical implantation of stimulating electrodes into structures deep within the brain. Deep brain stimulation was first trialled approximately 30 years ago and has been in routine clinical practice for well over a decade.[39]

A detailed review reported increases over the past 15 years in the numbers of publications and published patents relating to neuromodulation technologies in neurosurgery. The majority of these patents related to deep-brain stimulation.[39]

Non-invasive brain stimulation **(NIBS)** techniques involve magnetic or electrical stimulation of the brain in a non-invasive manner. This uses stimulating devices positioned on or near specific regions of the head. The two most common NIBS techniques are transcranial magnetic stimulation (**TMS**) and transcranial direct current stimulation (**tDCS**).

A growing body of published evidence indicates that NIBS techniques can have therapeutic value for specific neurological or psychiatric conditions. A group of European experts, commissioned by the International Federation of Clinical Neurophysiology (**IFCN**), concluded that "*it is likely that the indications of NIBS techniques will increasingly develop in routine clinical practice in the future, mostly due to their excellent ratio between benefit and risk*".[40] Additional findings indicate that there is sufficient evidence to indicate "*probable efficacy*" of tDCS for treatment of depression, fibromyalgia and craving.[40]

Transcranial magnetic stimulation (**TMS**) involves a magnetic 'coil' placed in a specific location above or near the head. This receives pulses of electric currents from a stimulator and induces small electric currents in the brain region just under the coil. These currents modulate brain activity. TMS devices have received FDA clearance, including for clinical usage to inform neurosurgery planning (see: [41]).

Stimulation involving repetitive TMS pulses is known as **rTMS**. A group of European experts commissioned by the IFCN published guidelines on the therapeutic use of rTMS. They found there is sufficient published evidence to state that rTMS has "*definite efficacy*" in relation to an analgesic effect for neuropathic pain and an antidepressant effect in depressed patients.[42] They also stated there is sufficient evidence to claim that rTMS has "*probable efficacy" for treatment of negative symptoms of schizophrenia, motor deficits in chronic stroke patients and "possible efficacy" for treatment of several conditions including tinnitus*.[42]

Current clinical practice guidelines of the Australian and New Zealand College of Psychiatrists state that "*The findings from studies supporting the use of rTMS treatment have led to its approval and use in many countries, and it is increasingly being used in clinical practice in Australia*".[43] These guidelines recommend rTMS as an effective therapy for treatment-resistant (non-psychotic) depression and note that Level I evidence (per the NHMRC framework) exists for this treatment application.[43]

At least one private hospital in Brisbane is known to be using rTMS treatment. On the basis of recommendations in European and Australasian guidelines (summarised above) it seems likely that rTMS will be more widely adopted in clinical practice over the next decade, at least for treatment of depression.

On the other hand, tDCS should still be considered an emerging technology. Although it is being used in some private settings[44], its evidence base is gradually developing. Currently there is insufficient evidence to indicate that it is likely to be used in public practice within the next decade.

1.1.8 Neurofeedback

A form of brain training which involves EEG monitoring is showing genuine potential to help treat psychological or psychiatric conditions. Neurofeedback training is a biofeedback technique that uses EEG that gives the client (or patient) real-time information about patterns of their own EEG in audio-visual form. Neurofeedback can be used to teach self-regulation of brain function, for example, in people with **ADHD** (see below). Over the past decade there has been a large increase in the evidence base supporting the benefits of neurofeedback training.[45]

Typically, three or more EEG electrodes are used to monitor brain activity. Information about specific EEG patterns (when they occur) is communicated back to the client using visual displays and/or sounds. This is done using specialised software, sometimes in a game-like format. It involves a form of 'brain-computer interface'. Neurofeedback is used, chiefly by psychologists (and also by psychiatrists, social workers and others), to treat symptoms of ADHD, mental health and other conditions.

Numerous scientific articles about neurofeedback have been published over the past four decades. The greatest amount of published evidence indicates beneficial effects for the treatment of ADHD.

At least eight randomised controlled trials have investigated the effects of neurofeedback on ADHD symptoms. All but one of these reported significant improvements in ADHD symptoms of inattention, hyperactivity or impulsivity compared to control groups (for review see[46]). A meta-analysis of 15 studies (total of 1194 participants) concluded that neurofeedback results in large, clinically relevant effect sizes for inattention and impulsivity in ADHD (and a low-medium effect size for hyperactivity[47]). In addition an international position paper formulated nine recommendations, the first being: "*Neurofeedback is a safe and efficacious treatment intervention for ADHD, meeting the rating of: Efficacious and Specific*".[48]

Information summarised in the three publications cited above collectively amounts to Level I evidence (per the NHMRC framework) for a beneficial effect of neurofeedback training on ADHD symptoms.

Neurofeedback has been found to have positive impacts on various mental health conditions including post-traumatic stress disorder.[49-51] Similarly, the NSW Service for the Treatment and Rehabilitation of Torture and Trauma Survivors (STARTTS) employs neurofeedback to help alleviate the symptoms of refugee trauma.[52]

The International Society for Neurofeedback and Research[53] supports education and professional development in the field of neurofeedback training. The website of the Australian member society, the Applied Neuroscience Society of Australasia, lists approximately 90 neurofeedback practitioners across Australia.[54]

The practice of neurofeedback has advanced in recent years due to the increasing evidence base and technological advances. Such advances particularly relate to wireless capability, enhanced computer processing and software capabilities.[55] These generally enhance the interactive nature and effectiveness of neurofeedback training. Ongoing technological developments such as these are likely to help lead to more widespread employment of neurofeedback in clinical practice over the next decade.

As noted above, neurofeedback training is being used across Australia in the private practices of psychologists, psychiatrists and other health practitioners. It is also being utilised in a NSW public service (STARTTS; see above). It is uncertain whether neurofeedback will be adopted in public practice over the next 5–10 years. It may be used in mental health outpatient clinics for treatment of PTSD, for example. Further evidence of its efficacy in treating other conditions, perhaps in neuro-rehabilitation settings, would help stimulate further clinical adoption.

1.2 New technologies in operating theatres

Delivering appropriate levels of patient care during surgical procedures and anaesthesia requires continuous close monitoring of patients' vital signs, respiration, gas measurements, ventilation and other parameters.[56] As detailed below, various new and emerging technologies are facilitating such monitoring, and further developments over the next decade will advance clinical practice.

1.2.1 Intra-Operative Neurophysiological Monitoring

Monitoring the nervous system during specific types of surgery is being performed in some hospitals in Australia and abroad, and this is likely to become more widespread over the next 10 years. Intraoperative neurophysiological monitoring (**IONM**) involves usage of neurophysiological methods during surgery to monitor the function and integrity of one or more neural structures (for example, brain, spinal cord, peripheral nerves). The key aim of IONM is to minimise the risk of damage to the nervous system by informing surgeons and anaesthetists about neural function. For example, the loss of neural signals (which can only be detected by IONM) can alert a surgeon to stop or modify a particular procedure, whereas the maintenance of signals during complex operations can reassure clinicians that it is safe to proceed. The "*Practice guidelines for the supervising professional: intraoperative neurophysiological monitoring*" endorsed by the American Society of Neurophysiological Monitoring state that "*IONM is the use of physiological techniques (1) to assess neural integrity and/or (2) to map or neuro-navigate within at-risk neural structures* *during surgical procedures*".[57] The most common type of surgery to employ IONM to date is spinal surgery. The most commonly-employed methods to date are evoked potentials (motor or somatosensory) and electromyography (EMG).

There is a growing body of evidence supporting the clinical value of IONM. For example, a study of 171 glioma (tumour) neurosurgery cases reported that performance of IONM was associated with a significantly higher survival rate.[58] In addition, a review of 470 brain aneurysm repair procedures observed that "*IONM changes demonstrated high sensitivity, specificity, and negative predictive value for postoperative neurological deficits*" and that IONM (chiefly somatosensory evoked potential) changes were found to be reversible in 66.7% of cases.[59]

EEG monitoring during some vascular surgery procedures, such as carotid endarterectomy, is used in some centres to monitor for signs of reduced brain blood flow (cerebral hypoperfusion), as an early warning for risk of stroke.[20] The rationale for such monitoring is that EEG can uniquely provide early warning or detection of abnormal brain activity, indicative of cerebral hypoperfusion, and thus prompt appropriate action to prevent stroke and resulting brain damage. Monitoring with EEG and complimentary techniques during carotid endarterectomy surgery are discussed further below.

In assessing the efficacy of IONM, and potentially enabling demonstration of highest-level evidence, some debate exists over whether controlled studies such as randomised trials are appropriate (ethical) and required, or whether expert consensus suffices.[60, 61] A recent opinion piece states that "*Observational evidence for IONM is growing yet more is required to understand the conditions under which IONM, in its variety of settings, can benefit patients*".[60] In relation to ethics it has been stated that "*Despite the view that there is a lack of evidence for IONM, there is no ethical basis for not using IONM in cases in which IONM has become standard, nor for not acting on changes in monitoring*".[62] In any case IONM has entered clinical practice in Australia, at least in some settings. For example, a position involving IONM (as well as EEG, at a Brisbane public hospital) was advertised in June 2017 and at least one private company offers IONM services across Australia and New Zealand.[63]

Although not strictly within the general scope of IONM, it is noteworthy that EEG/QEEG monitoring also is used quite widely to help monitor depth of anaesthesia during surgery to guide anaesthetists regarding appropriate dosages of anaesthetic drugs. Such guidance is important as too little anaesthetic can lead to a patient being aware of what is happening during surgery, while too much anaesthetic can result in longer recovery times. The UK National Institute for Health and Care Excellence (NICE) has recommended three types of EEG monitoring systems for this purpose.[64]

1.2.2 Continuous non-invasive arterial pressure monitoring

Some evidence supports the usage of devices which non-invasively monitor blood pressure during surgery. However, a review of many studies reports that these devices are not always accurate enough, suggesting caution about their clinical usage.

Monitoring of haemodynamic parameters, such as blood pressure and cardiac output, is vital to effective clinical care and management during surgery. Technological developments such as microcomputers and digital signal processors have enabled small devices to perform complex computational functions to facilitate such monitoring. One such class of devices performs continuous non-invasive arterial pressure (**CNAP**) monitoring, which can continuously assess arterial blood pressure in real-time without the need for cannulation.

CNAP monitors are small and relatively inexpensive and the continuous monitoring which they enable has advantages over the traditional, intermittent assessments using a sphygmomanometer (involving a cuff on the upper arm). That is, the latter technique carries a risk of missing dangerous hypotensive episodes but this is not the case with CNAP. For example, a study of of 65 women undergoing Caesarean section under spinal anaesthesia reported that the CNAP device detected more hypotensive episodes and proposed that CNAP monitoring may improve clinical management in this setting.[65] At least one recent study reports that the overall accuracy of CNAP devices is comparable to those of a 'gold standard' invasive intra-arterial catheter system during general anesthesia.[66]

However, a considerable body of evidence is not consistent with the findings of Jagadeesh et al. A systematic review and meta-analysis[67] of 28 studies (14 of which focused on commercially available devices) compared CNAP monitoring with invasive arterial pressure monitoring. The authors' concluded: "*The results from this meta-analysis found that inaccuracy and imprecision of continuous noninvasive arterial pressure monitoring devices are larger than what was defined as acceptable. This may have implications for clinical situations where continuous non-invasive arterial pressure is being used for patient care decisions*".[67] Overall the results of the meta-analysis carry more weight than the results of a single study[66] and Level III (rather than Level I) evidence currently supports CNAP monitoring technology. Thus, while CNAP monitoring may add value in some specific contexts, it would be premature to suggest that such technology can currently replace invasive monitoring methods.

1.2.3 Haemodynamic monitoring and fluid management

Devices for monitoring heart function during surgery are commercially available and in clinical use. There is some evidence that these devices perform at least as well as more invasive monitoring devices, although further trials may be needed before this technology is more widely adopted.

Appropriate management and administration of fluids during the perioperative period is critical and has significant impacts on postoperative outcomes. A recent consensus statement demonstrates the risks involved with administering either too little or too much fluid, highlighting the value of individualised fluid management, known as goal-directed fluid therapy (**GDFT**).[68]

GDFT is predominantly based on haemodynamic parameters, such as cardiac output and stroke volume, which have commonly been monitored by invasive methods. However non-invasive haemodynamic monitoring technologies are available or emerging and are showing promise as alternatives to inform GDFT. For example, a commercially available device[69] uses non-invasive 'bioreactance' sensor pads applied to the thorax; a small electric current is applied between one pair of sensors and a voltage signal is recorded from the other pair. Blood flow in the thorax affects these signals, and the device's proprietary algorithms analyse these to estimate stroke volume.

The above device (previously called "*NICOM*") was compared to a widely-used, more invasive esophageal Doppler monitor (EDM) in a prospective study of 100 patients undergoing colorectal surgery.[70] The NICOM was found to perform similarly to the EDM in guiding GDFT and the former had fewer missing data points. The authors concluded that the NICOM may be a viable alternative monitor to guide GDFT.[70]

Hence Level III evidence (at least) supports the usage of this non-invasive technology to guide GDFT during surgery. While some would argue that further evidence is required before this technology is employed more widely, at least one such device is already on the market[69] and similar devices may well be more widely utilised over the next 5–10 years.

In addition decision support technologies, including visual displays of 'target parameter zones', are available which may facilitate tracking of haemodynamic variables and thereby help optimise GDFT and fluid management during the perioperative period.[71] Visual display modalities and technologies are further discussed below.

1.2.4 Near-infrared spectroscopy

Devices for monitoring oxygen levels in blood vessels in the brain are available and considerable evidence suggests they are useful in various clinical settings. These are likely to be adopted in clinical practice over the next decade, particularly for monitoring during (or after) surgery.

Near-infrared spectroscopy **(NIRS)** is a non-invasive method of monitoring the brain's oxygenation status (oxygen saturation of haemoglobin in cerebral blood vessels). NIRS monitoring of certain high-risk patient groups (for example, brain injury) and commercial NIRS devices have been approved by regulatory bodies such as the FDA.[72] NIRS devices use small light sources and sensors/detectors placed on the scalp. The light source (for example, a light-emitting diode or 'LED') transmits near-infrared light through the scalp and skull into the brain and the detector measures the parameters of the ensuing signals exiting the brain.

A 2010 review article reported that NIRS "*has many potential advantages over other neuromonitoring techniques, but further technological advances are necessary before it can be introduced more widely into clinical practice*".[73] Evidently some such advances have been achieved in recent years since publication of that review (see below).

One intraoperative clinical application of NIRS monitoring is during vascular surgical procedures which carry a risk of eliciting stroke, due to cerebral arterial blockage by an embolus such as a blood clot. Brain monitoring, aiming to prevent perioperative stroke, is becoming increasingly supported and employed during such procedures. Such monitoring can detect early warning signs of impending stroke, such as reduced cerebral perfusion, enabling appropriate action to be taken to prevent stroke and associated brain damage. During carotid endarterectomy (**CEA**) surgery monitoring with electroencephalography (EEG) and transcranial Doppler ultrasound has generally been more standard practice, however recent results indicate the value of NIRS monitoring in this setting.[20, 74] In addition, NIRS monitoring has some apparent advantages over transcranial Doppler monitoring in this context.[74]

NIRS technology is approved and being used in various settings including assessments of (suspected) brain injury and post-neurosurgery patients.[72] A 2015 review article states that "*NIRS offers noninvasive monitoring of cerebral and overall organ oxygenation in a wide range of clinical scenarios. There is increasing evidence that the optimized cerebral oxygenation is associated with improved outcomes in both neurologic and major organ morbidity in a variety of surgical settings*".[75] Although further research, development or trials may be required it currently appears feasible that NIRS monitoring will be more widely adopted for one or more intra-operative applications (for example, monitoring for signs of ceberal ischemia during CEA) over the next decade.

1.2.5 Image guidance and navigation

Image guidance is a term used to indicate guidance of a device or procedure on the basis of information from imaging (such as MRI). Image guidance technologies are being used in some clinical applications, such as surgery. Their clinical usage is likely to increase over the next decade, although in some cases further studies or technological developments are needed.

Regional anaesthesia refers to anaesthetisation of body parts larger than those typically treated by local anaesthesia — for example, the anaesthetisation of a leg or an arm. A primary focus of new and emerging technologies for regional anaesthesia is tracking the precise positioning of the anaesthetic needle. This is important because neurological injury can result from injection of anaesthetic agents directly into nerves and can be debilitating.

Ultrasound imaging of the anaesthetic needle has been introduced over the past two decades to reduce the risk of neurological injury. However, with standard ultrasound images being two-dimensional, continuous viewing of the needle tip is technically challenging, operator-dependent and not guaranteed.[76] Further technological developments are aiming to improve upon this scenario. Some commercially-available needles contain electromagnetic tracking technology which can facilitate real-time tracking of the orientation and position of the needle, as demonstrated in a proof-of-concept study.[77]

In the field of neurosurgery, a detailed review of both PubMed and patent databases reported substantial increases over the past 20 years in the numbers of publications and published patents relating to image guidance technologies. The authors interpret these statistics as indicative that image guidance technologies have been undergoing "*a phase of exponential growth and as such can be forecast to have an increasing influence in the future of operative neurosurgery*".[39] This forecast assumes a strong correlation between publications and subsequent clinical translation of such technologies, which is not always the case (see discussion below regarding approval by the Therapeutic Goods Administration).

A study of 171 glioma (tumour) neurosurgery cases reported that image guidance was associated with a significantly higher survival rate.[58] The image guidance technique involved functional MRI brain scanning and the usage of a stereostatic image-guided device[78] to increase anatomical precision. This constitutes level III evidence supporting this form of image guidance in this clinical setting.

Traditionally, image guidance of neurosurgery has often relied upon MRI scans performed some time (up to several days) before surgery. However, this can be associated with issues such as reduced accuracy due to 'brain shift' (between the scan and surgery) and other factors.[79] Over the past decade intra-operative MRI, using MRI scanners in rooms adjacent to the operating suite, has been adopted in some hospitals.[80] There is some evidence that intra-operative MRI can help improve surgical accuracy, although there are some challenges which must be addressed before broader clinical adoption could be recommended.[79]

Overall, image-guidance technologies show promise for use in clinical settings such as local anaesthesia and neurosurgery. It appears quite likely that such technologies will be used more widely in clinical practice by 2027, although further trials and supporting evidence are required before this could be strongly recommended.

1.2.6 End-tidal gas monitoring

Technologies which automatically control the amounts of oxygen and anaesthetics given to patients during surgery, have been adopted in clinical practice. These devices offer important advantages over other methods and they are likely to be adopted even more widely over the coming 5–10 years.

Anaesthetists routinely monitor respiratory and haemodynamic parameters, and utilise such information to guide control of blood gas concentrations (around target levels). In simple terms, these clinicians want to ensure that patients are receiving appropriate amounts of oxygen (O2) and anaesthetic agents, and also that there is not too much carbon dioxide (CO2) in patients' systems. O2 and CO2 levels are commonly assessed using measures of 'partial pressure' (which are also sensitive to the volumes of these gases).

The partial pressure of "*end tidal*" gas (measured at the 'flat' portion of expiration) is commonly considered a surrogate marker for alveolar gas and the partial pressure of arterial blood. End tidal O2 and/or CO2 measures can be applied to monitoring respiration and/or fluctuations in organ or tissue function. Commercial monitoring systems are used to monitor and even integrate these with other physiological measures. For example, one product monitors an index which is sensitive to four respiratory parameters (end-tidal CO_2, respiratory rate, pulse oximetry and pulse rate) and incorporates these into a single measure, with the aim of providing a single overall 'respiratory profile' index.[81]

Until recent years the control of end-tidal gas concentrations has been performed manually. However computational algorithms, such as "*dynamic end-tidal forcing*", have been developed with the aim of dynamically altering partial pressures of O_2 and CO_2. Hence new devices are able to achieve this automatically via the breath-by-breath modulation of the concentrations of these gases (and of inhaled anaesthetic agents) as they are inspired by intubated, anaesthetised patients.[82, 83] That is, the amounts of these gases given to a patient can be changed frequently depending on the amounts of these gases detected during each previous breath made by that patient.

Tay et al.[82] compared the financial and environmental costs of manual versus automated control of end-tidal gases, before and after the planned replacement of anaesthesia devices in a tertiary hospital. Over 1,800 cases with each technology type (manual vs automated) were studied. This study found that automated control of end-tidal gases delivers both economic (costs reduced by 27%) and environmental (greenhouse gas emissions reduced by 44%) benefits.

Devices enabling automated control of end-tidal gas concentrations are in clinical use and it appears likely that they will be increasingly adopted over the next 5–10 years.

1.2.7 Visual displays

Emerging technologies can improve the communication of important information to clinicians during surgery. It seems likely that such technologies will be utilised in more clinical settings by 2027.

Delivering appropriate levels of care during anaesthesia requires continuous close monitoring of patients' vital signs, respiration, gas measurements, ventilation and other parameters (for example, see:[56]). Anaesthetists also need to make other observations (for example, patients' chest movements) and perform other activities in operating theatres. Consequently, inspection of information on the patient monitor can at times be restricted to periodic, brief glances. Head-mounted displays (HMD) are of increasing interest in operating theatres, as they enable augmentation of part of a user's field of vision with additional information. Use of a HMD could facilitate viewing a patient's vital signs (on the HMD) while also watching the patient (for example, chest movements) with required head movements and significant shifts in the field of vision. Drake-Brockman et al.[84] investigated anaesthetists' feedback following their usage of the Google Glass HMD. Forty anesthetists each used this device for the duration of a theater list and over 80% of anesthetists found it was comfortable, easy to read and not distracting, and 76% reported that they would use the device again. The investigators proposed that further enhancements to the device software, rather than hardware, was the main challenge for future adoption.[84]

Emerging visual display technologies are being utilised as decision support tools. For example, mapping of "*target parameter zones*" may facilitate tracking of haemodynamic variables and facilitate enhanced fluid management during surgical procedures.[71] While further research and development are warranted it seems feasible that new technologies to improve visual monitoring of physiological variables during surgery will be adopted in clinical practice over the next decade.

1.2.8 Disagreement or debate

In relation to some technologies reviewed in this section there is debate or disagreement regarding their suitability or readiness for clinical adoption. For example, some studies report evidence in favour of CNAP monitoring[65, 66] whereas others suggest that current CNAP devices are not yet accurate enough to be used in clinical settings.[67] In this case there currently is Level III evidence supporting CNAP monitoring technology and further evidence is required before it could replace invasive monitoring methods in clinical settings. Differing proposals also exist regarding the suitability of Motor Unit Number Index (**MUNIX**) techniques in clinical trials and settings. For example, a study by Neuwirth et al.[29] suggests MUNIX is suitable for usage in clinical assessment and trials, whereas Henderson and McCombe[28] recommend that further evidence is required.

Differing viewpoints relating to emerging technologies and the results of clinical trials of drugs or other treatments are quite commonplace in the peer-reviewed literature. In some cases, those in favour of a particular new treatment or technology may be influenced by bias. For example, this may occur on the part of technology or pharmaceutical companies, investigators sponsored financially by such companies, or even futurists who generally tend to 'over-speculate' about change and new developments. Likewise, others may be biased against the clinical adoption of new treatments or technologies, for other reasons. Regardless, it is rare for new treatments, techniques or technologies to achieve clinical implementation without being the subject of some level of debate or disagreement (or perhaps, controversy).

2. Skills to support new and emerging technologies

Emerging technologies, such as those summarised above will increase the skills and training required of technicians working in these areas and some may increase the scope of practice for technicians, particularly those working at more advanced levels. Generally speaking, technicians will be required to be adept at programming, operating and maintaining various technologies, as well as interpreting and responding to data signals. Depending on the types of technologies they are working with, technicians will also require more specialised skills and training, as outlined below.

2.1 Specialised skills

2.1.1 Purchasing and maintenance

Technicians will be involved in purchasing decisions or processes, and liaison with device/technology companies or their distributors. They will continue to perform appropriate maintenance of devices, including:

- Installing or updating software
- Modifying technical parameters (for example, data resolution, number of electrodes) and
- In some cases, this may require specialised technical skills, (for example, programming or 'coding').

Technicians will be responsible for ensuring devices are operating properly, and for interacting with service engineers in the course of repair or servicing of equipment.

Some technicians will perform cleaning and storage of equipment after use in accordance with infection control procedures and workplace health and safety legislation. They will also be responsible for re-stocking and purchase of supplies or consumables associated with specific technologies (for example electrodes, gels, sensors, cables).

2.1.2 Specialised skills for Electroencephalography (EEG)

Various specialised skills for EEG monitoring will be required, depending on technicians' levels of experience and employment. The most senior EEG technicians will require significant skills and training. Training of EEG technicians and neurophysiology technicians should continue to adhere to the applicable guidelines published by the International Organisation of Societies for Electrophysiological Technology.[85]

As described above, a two-part consensus statement of a task force of the American Clinical Neurophysiology Society (**ACNS**) attests that continuous EEG monitoring (for hours or days) "*has an important role in detection of secondary injuries such as seizures and ischemia in critically ill adults and children*".[13, 14] It is proposed that over the next decade "*critical care continuous EEG*" monitoring should become more routine practice in several clinical applications, including brain injury, brain haemorrhage, stroke and during or after particular surgical procedures.[14]

As this occurs and 'smarter' EEG monitors are used in such applications, EEG technicians appear well-suited to be 'first responders' for the identification of particular EEG patterns or trends, perhaps prompted by alerts from signal processing software. These technicians would be trained in at least some aspects of screening and initial interpretation of quantitative EEG trends (as well as the corresponding "raw' EEG signals, including to screen for potential noise or "artefacts" in the signals) and would have the capacity to make informed decisions about whether or not to take appropriate action, such as escalation of a query to a more experienced clinician (for example, a neurologist, intensivist or clinical neurophysiologist).

Part II of the ACNS consensus statement proposes various EEG technician levels and their recommended responsibilies, qualifications and certifications.[14] In the US, neurodiagnostic technologist is the term equating to Australian terms such as neurophysiology technician or EEG technician. Herman et al. propose five different levels of the neurodiagnostic technologist professional stream (see **Table 1**).

Table 1 The various EEG technician (or neurodiagnostic technologist [NDT]) levels and associated responsibilities, as recommended by the Critical Care Continuous EEG Task Force of the American Clinical Neurophysiology Society (Herman et al., 2015b).

Technician Level	Key responsibilties
Neurodiagnostic Technologist I (Trainee)	Basic troubleshooting during recordings; Electrode set-up & removal (under supervision)
Neurodiagnostic Technologist II	All responsibilities of NDT I; Performs continuous EEG under direct supervision
Neurodiagnostic Technologist III	All responsibilities of NDT II; Performs continuous EEG independently; Can superivse NDT I-II
Neurodiagnostic Technology Specialist I ICU	All responsibilities of NDT III; Technical operation & supervision of continuous EEG; Review of QEEG trends & selection of segments for analysis (under physician supervision); Notify physician of EEG changes that may reflect deterioration of brain function
Neurodiagnostic Technology Specialist II ICU	All responsibilities of NDTS I ICU; Development of EEG technical policies & procedures in conjunction with physician; Supervision & training of EEG personnel (including NDT, nurses, ICU staff)

These well-informed proposals are applicable to the Australian setting, particularly to large public hospitals caring for neurocritical patients with conditions such as brain injury or coma. Over the next decade, it is likely that corresponding EEG technician roles (see **Table 1**) will be implemented in large Australian public hopsitals, including the most senior EEG technicians level proposed in the ACNS consensus statement.[14] This does not imply that EEG technicians could replace experienced clinicians such as neurologists but that experienced EEG technicians can provide input into EEG interpretations. Ultimately this should lead to improved patient care, including earlier detection and treatment of seizures.

In terms of education and certification, the most basic (trainee) of the five proposed technician levels would require an 'Associate's degree' (Associate Diploma) or equivalent. The intermediate (third level) would require this plus registration as an EEG technologist by the American Board of Registration of Electroencephalographic and Evoked Potential Technologists (ABRET). The most advanced level (neurodiagnostic technology specialist II ICU) would require certification in long-term monitoring by ABRET, meeting National Competency Skills Standards of The Neurodiagnostic Society (for continuous, critical care EEG monitoring), plus three years of post-certification experience in long-term EEG monitoring.[14] Therefore, EEG technicians at the most advanced levels will require significant amounts of training and experience.

2.1.3 Specialised skills for Neuromodulation

Some future neurophysiology technicians may be involved in non-invasive brain stimulation (NIBS) treatments.

As discussed earlier in this report, level I evidence exists for repetitive transcranial magnetic stimulation (rTMS) for treatment of depression and this is recommended by institutions including the International Federation of Clinical Neurophysiology[42] and the Royal Australian and New Zealand College of Psychiatrists.[43] There is also sufficient evidence to suggest that rTMS has definite efficacy for treatment of neuropathic pain and probable efficacy for treatment of symptoms of stroke or schizophrenia.[42]

Currently there is not any specialised professional stream of technicians, allied health, medical or nursing professions pertaining specifically to neuromodulation and NIBS techniques, such as rTMS. Given the evidence (summarised above) for the efficacy of NIBS techniques in the treatment of various conditions it appears pertinent that such a professional stream would be created over the next decade. Of the existing medical technician categories, the neurophysiology technician is the category best suited to NIBS methods. However, it is feasible that a new category of technician (or perhaps 'therapist') be created which specialises in rTMS (or NIBS) techniques. In any case, those applying NIBS treatments will need in-depth knowledge of neurobiology, as well as of all appropriate safety aspects of the respective NIBS modalities. For example, rTMS can, in rare cases, be associated with acute adverse effects[86] and technicians involved in rTMS administration could receive training in relation to these as well as to their management, rTMS contraindications, safety parameters (for example, magnetic field exposure limits), hardware design and specifications.

2.1.4 Specialised skills for Neurofeedback

Over the coming decade, some EEG technicians may become involved in neurofeedback training, at least in private practice.

As discussed in section 1.1.18, neurofeedback is likely to become more widespread in clinical practice over the next decade, at least for treatment of ADHD (for which Level I evidence already exisits). There is also growing evidence to support its value for for treatment of other conditions including neurodevelopmental disorders, stroke and/or mental health conditions (for example, PTSD).

Currently many neurofeedback practitioners are psychologists by training, and most do not have pre-existing EEG or neurophysiology experience. Some centres may employ a technician to perform set-up, apply EEG electrodes, run training sessions and clean up after training (see below). In addition, while some practitioners use as few as three electrodes, others use a standard clinical configuration which involves 21 electrodes (at least for the initial EEG assessment session). As neurofeedback becomes more widely used, an appropriate operational strategy could be to have EEG technicians routinely involved in the set-up and operation of neurofeedback sessions, particularly when numerous electrodes are employed.

Currently EEG technicians are trained and adept in the application of electrodes, performance of EEG recordings and clean-up, but are not trained in neurofeedback. Determining which neurofeedback protocols are appropriate would remain the role of the practitioner (for example, psychologist or psychiatrist). EEG technicians would require knowledge about such protocols and the associated neurofeedback software packages. For example, the EEG technician would need to be aware that a particular protocol for a particular patient would aim to train (or 'reward') particular high-frequency EEG patterns and also to discourage (or 'inhibit') particular low-frequency patterns. They would also need to be aware of how the occurrence of such EEG patterns would influence the software interface and the neurofeedback training process (see below). This would inform trouble-shooting or instructions to the patient/client during training sessions. In summary, in addition to routine EEG technician skills and knowledge, those working with neurofeedback practitioners would require specialised training (for example, a short course; see below) in neurofeedback techniques, protocols and software interfaces.

The Biofeedback Certification International Alliance (BCIA)[87]is the international body responsible for training, education and certification of neurofeedback practititoners. BCIA administers Board Certification for Neurofeedback practitioners. It is notable that, for those working in the USA and Canada, BCIA offers the option of 'Technician Certification' (as well as 'Clinical Certification') for those "*who are currently working for a licensed and BCIA certified professional who is providing legal supervision*". This scenario is consistent with the above proposal that, in future, technicians operating in Australia may perform neurofeedback training sessions with clients under the supervision of neurofeedback practitioners. BCIA Certification for neurofeedback practitioners requires (amongst other things) completion of an accredited, 36-hour didactic education program to learn about the science, principles, studies, history and theory of neurofeedback. It appears appropriate that EEG technicians in Australia would also be required undertake such a course before assisting practitioners in the performance of neurofeedback training sessions.

Depending on their specific workplaces and roles, in the future, some neurophysiology technicians will likely need to be skilled in emerging assessment techniques such as:

- Magnetic root motor stimulation
- Pain-related (electrical stimulation) evoked potentials
- Motor unit function assessments (for example MUNIX), or
- Vestibular tests such as VEMPs or vHIT.

2.1.5 Specialised skills for Operating Theatres – Intra-Operative Neurophysiological Monitoring (IONM)

IONM is likely to be more widely adopted over the next 10 years. Technicians with specialised skills sets, covering both neurophysiology and operating theatre aspects, will be required to support such monitoring.

The "*Practice guidelines for the supervising professional: intraoperative neurophysiological monitoring*" endorsed by the American Society of Neurophysiological Monitoring[57] propose IONM professional and technologist roles: "*A traditional patient-physician/practitioner relationship exists whether or not the*

Intraoperative Neurophysiological Monitoring Supervising Professional (IONM-P) is a physician or other qualified healthcare professional practitioner… IONM-P is the provider of real time technological supervision, interpretation, and diagnostic/therapeutic (interventional) suggestions or recommendations during IONM… However, the technological component may be carried out in whole or in part by an appropriately experienced/credentialed Intraoperative Neurophysiological Monitoring Technologist (IONM-T)". In this context *"The technological component involves placement of appropriate electrodes, acquisition of high quality data, data recording, troubleshooting problems, and providing a description of the recordings"*.[57]

The duties of the IONM-Technologist role are broadly consistent with those of EEG or neurophysiology technicians. In addition, those working in IONM-T roles would also need to be trained in peri-operative procedures, safety, and particular surgical or anaesthetic techniques or practices, as appropriate. The training and working practices of IONM technicians should be consistent with the Guidelines for Performing EEG and Evoked Potential Monitoring During Surgery published by the International Organisation of Societies for Electrophysiological Technology.[85]

2.1.6 Specialised skills for Operating Theatres – Other

Depending on their exact workplaces, operating theatre technicians and anaesthetic technicians in the future may need to be experienced in the set-up and operations of emerging technologies such as:

- Anaesthetic devices enabling automated control of end-tidal gas concentrations
- (Non-invasive) haemodynamic monitoring technology to guide fluid management during surgery
- Near infra-red spectroscopy (NIRS) monitoring of cerebral oxygenation during surgery
- Image-guidance techniques
- Novel visual display modalities and other decision-support tools.

In each case the respective technicians will require experience in the information and data provided by these technologies. They should be able to distinguish between genuine signals or data, as opposed to 'noise' or 'artefacts' which can be caused by interference, patient movement, or other events unrelated to the patient parameters being assessed. These future technicians should generally able to perform some preliminary interpretations of the information, or to integrate and compare information from a device with other relevant patient information.

2.1.7 Specialised skills – Data selection, management and integration

Future technicians will require additional skills and will need to be even more 'tech-savvy' (technologically capable) than those of today. They will also need to be adept at identifying specific signals or patterns from particular devices and, in some cases, interpreting these. They will also need to be competent at integrating data from various assessments or modalities (for example, EEG and imaging data from a single patient) and at saving, storage and retrieval of data.

In the future, experienced technicians will be required to perform some screening and selection of data, and perhaps some data processing or analysis (using software). These activities would result in the delivery of 'clean', assessment-ready data to medical specialists for interpretation or diagnosis. For example, experienced technicians would identify and exclude 'noise' in continuous bedside EEG recordings from ICU patients and provide neurologists with the usable, 'clean' EEG data for assessment.

A number of the monitoring procedures or paradigms summarised in this report generate relatively large amounts of data, often from multiple devices and assessment modalities. Some examples include:

- Polysomnography generally involves simultaneous measurement of seven modalities (including respiration, oximetry and various electrophysiological methods) typically for seven hours or more

- Continuous EEG monitoring will at times involve EEG data from numerous electrodes, for periods of up to several days. This will often be done simultaneous with video recording of the patient (to monitor movements) and can also involve consideration of QEEG trends (see Section 1.1.1) or other patient-related variables
- Intraoperative monitoring involves continuous assessment of patients' vital signs, respiration, gas measurements, haemodynamic and other parameters — such as neurophysiological data — simultaneously.

While medical specialists (for example, anaesthetists and sleep physicians) have often assumed ultimate responsibility for this multi-modality monitoring, in the future experienced technicians may perform some of these monitoring duties. Such task shifting will likely become increasingly valuable as technological developments result in greater amounts of monitoring data being gathered from patients.

In the future, experienced technicians will be more involved in 'data integration', which involves combining and intepreting data from different sources or modalities. In some cases, the amounts of monitoring data recorded from patients (for example from seven modalities for 24 hours) may approach the level of 'big data' (data sets so large or complex that traditional information processing approaches become unable to effectively process them). As the amount and complexity of monitoring data increases there will be a need for technologies which can integrate various data measurements into a unified representation, index or snapshot. An example of this is the commercially-available "*respiratory profile*" index, which incorporates and is sensitive to four respiratory parameters (see Section 1.2.6). Some future technicians will also need to have specialised data management skills to retrieve selected patient data from patient databases.

Therefore, in the future, experienced technicians will probably have greater responsibilities in relation to these operations and processes, as well as those discussed in the following section.

2.1.8 Specialised skills – Data interpretation and decision-making

As the amount and complexity of monitoring data from emerging technologies increases over the next 5–10 years, technicians are likely to have additional responsibilities in relation to the results of assessments. In some settings experienced technicians may be the first responders to monitoring information, including technology-generated alerts or alarms. These technicians will probably be required to assess and perform some initial interpretations of such information, and to make informed decisions about appropriate courses of action. For example, the responsibilities of EEG technicians working with continuous EEG monitoring of brain injury patients could include:

- Initial response to alarms generated by automated EEG seizure-detection technology
- Inspection of associated EEG and other monitoring information, including video footage
- Decision-making and interpretation regarding whether seizures have occurred (as opposed, for example, to a false alarm caused by patient coughing or movement)
- Decision-making about appropriate course of action, such as escalation to a neurologist for further assessment and/or intervention.

In summary, it appears that many technicians in the future will require a broad range of skills, probably broader than those required of current technicians, in some cases. This seems particularly applicable to advanced technicians, who may become more vital, informed mediators between patient data, as captured and represented by technology, and medical specialists responsible for making clinical management decisions.

2.2 Gaps in the evidence

Level I evidence for the efficacy of many of the techniques and technologies covered by this report has not yet been published. Published evidence can influence the regulatory approval process, including the particular application(s) for which a given device may be approved. However, the key milestone which must be achieved to enable clinical uptake is regulatory approval from the FDA or the TGA. In Australia, a given device must be listed on the Australian Therapeutic Goods Register before it can be used clinically. Ultimately, such regulatory approval is more vital than the level of evidence (per the NHMRC or any other similar framework).

Discussion/synthesis of findings

This rapid review provides detailed information about the new and emerging technological advancements occurring in the fields of neurophysiology and operating theatres. The review confirms these are two areas which are rapidly diversifying, with new technologies enhancing the way assessment, diagnosis and treatment of certain conditions takes place. This has implications for the technician workforces, who will be required to be adept at programming, operating and interpreting the associated technologies. Technicians will need to be appropriately trained and experienced. Some will be increasingly relied upon as informed mediators between technologies which monitor and record patient data and the clinical staff that use this data to inform clinical decision and practice. Demand for technician workforces will also likely increase as technologies are more widely used, including outside of acute care settings.

New and emerging technologies

Over the coming decade, several new techniques and technologies are likely to be adopted in clinical practice. This rapid review suggests those that are expected to have the most substantial impacts on the related technician workforce, including increased demand for technicians, are:

- Continuous EEG monitoring of neurocritical patients for early detection of secondary brain injuries (including computer-assisted EEG)
- Intra-operative neurophysiological monitoring for early detection of nervous system dysfunction during surgery
- Repetitive transcranial magnetic stimulation for treatment of conditions such as depression
- Sleep testing (polysomnography) for diagnosis of sleep disorders (including home testing)
- Continuous EEG monitoring for epileptic seizures (including mobile/outpatient monitoring).

In addition, other technologies and techniques appear quite likely to impact on the technician workforce and have potential to result in increased need for technicians over the next decade. For operating theatres, these include non-invasive haemodynamic monitoring and near-infrared spectroscopy monitoring. In neurophysiology, these include vestibular testing (vestibular-evoked myogenic potentials, video-assisted head impulse test), motor unit assessments (involving stimulation and electromyography) and neurofeedback training (involving EEG). However, it is important to note that these neurophysiological techniques will probably only be useful for specific conditions (and thus, relatively smaller numbers of patients).

Some of the key technologies and techniques identified by this rapid review can improve early detection or diagnosis of specific conditions. In relation to early detection of abnormalities in the brain or nervous system, these include EEG monitoring of neurocritical patients (usually in ICUs), intra-operative neurophysiological monitoring and near-infrared spectroscopy monitoring during surgery. Mobile technologies enable monitoring outside the hospital inpatient setting for detection of seizures and diagnosis of epilepsy (using EEG), or diagnosis of sleep disorders such as obstructive sleep apnoea (using polysomnography). Other techniques and technologies are being used for treatment, especially of psychological or psychiatric conditions such as depression (rTMS) and ADHD (neurofeedback training, involving EEG).

Skills to support new and emerging technologies

As these new and emerging technologies become more widespread, the expectations of technicians in terms of their required skills and training will also progress. The introduction of some technologies may also result in an increased scope of practice for technicians working at more advanced levels.

It will be important for future technicians to be adept at using various technologies. Depending on their position, they may need to be competent in relation to: operating, programming, trouble-shooting or updating technologies; managing data; and, identifying specific signals or responding to automatic alerts from devices. It will also be imperative that technicians understand the limitations of the technologies they are working with and know how to use them appropriately. Although some technologies may analyse data or identify patterns automatically, technicians would still need to interpret the results and respond accordingly. In some cases, this will involve making informed decisions, such as whether to refer to a specialist. Therefore, some technicians will play important roles as informed mediators between patients and their data as captured by technology, and clinicians.

In summary, future technicians will need to be technologically competent, and some will act as facilitators between patients, technologies and clinicians. They should be educated and trained accordingly, as discussed in the following sections.

Implications for training and education

To ensure these workforces are appropriately skilled, future technicians will require more education and training relating to technologies and techniques, including data management. Some of this may be increasingly specialised.

Neurophysiology and operating theatre technicians will need to have knowledge and skills in relation to:

- Physiology
- Anatomy
- Relevant clinical measurement methods (for example EMG)
- Relevant clinical conditions.

Future technicians will also require multi-disciplinary skills and expertise in:

- Digital technologies
- Data management and integration and/or informatics
- Informed decision-making in response to information from monitoring technologies
- Skills previously considered more specific to information technology and/or engineering fields (for example, programming or coding).

Currently in Australia there are no universal minimum education requirements for the technician categories relevant to this report. Appointment to some technician positions may require a bachelor's degree, while for others the minimum requirement may be a diploma. Although the value of on-the-job training will continue to be high, a bachelor's degree may be the minimum requirement in the future.

Some Australian universities offer bachelor degree programs which appear well-suited to the technician positions which are the subject of this review, including the Charles Sturt University (see:[88]):

- Bachelor of Medical Science (Clinical Physiology) *BMedSc(ClinPhysiol)*
- Bachelor of Medical Science (Biotechnology) *BMedSc(Biotech)*

It seems appropriate to recommend that a relevant bachelor's degree be a minimum requirement for appointment (or promotion) to an advanced or senior neurophysiology technician level position. In the future a bachelor's degree, such as those listed above, may even be a minimum requirement for employment in a more basic technician level.

The clinical adoption of some new technologies and techniques will require technicians to be certified in their operation and procedures. Some example situations include Certification in:

- Long-term EEG monitoring (or similar) from the Association of Neurophysiological Technologists of Australia
- Neurofeedback ('Technician Certification') from the Biofeedback Certification International Alliance (Australian chapter)
- Transcranial magnetic stimulation treatment (no current certifying body known)
- Intra-operative neurophysiological monitoring (no Australian certifying body known).

There will probably be other instances in which certification of future technicians will become appropriate. This depends on exactly which new technologies and techniques are translated into clinical practice.

Some emerging techniques and technologies have specific safety considerations. These include neuromodulation technologies such as transcranial magnetic stimulation and intra-operative monitoring. All education, training and certification processes should of course encompass all relevant safety considerations and factors.

Potential new professional stream and degree program

Given the findings and recommendations in this report, it may be appropriate for a new professional stream to be created in future. This possibility is particularly relevant to 'advanced specialist technician' or similar roles. Such roles would occupy a space somewhere between the current domains of technicians, allied health practitioners, medical practitioners and biomedical engineers, or even IT professionals. Their job titles may include a term such as 'technologist' rather than technician, which would help distinguish them as more advanced and specialised roles. Such developments are already occurring internationally. For example, the University of Twente in the Netherlands offers degrees in Technical Medicine. This is a "*discipline aimed at educating professionals who can improve patient care by applying medical technology*". This interdisciplinary field fills the gap between classical medicine and complex technology (for example, engineering). The degree program comprises a three-year Bachelor's and a three-year Master's programme that specialises in Medical Imaging & Intervention or Medical Sensing & Stimulation. Students spend two years in rotating internships at academic and teaching hospitals.[89]

It is possible that a corresponding healthcare professional stream may be realised in Australia by 2030. This would essentially be a new professional stream (although there may be some overlap with roles currently performed by some advanced technicians). Whether or not this occurs will depend in part on whether Australian institutions and jurisdictions elect to innovate, help set the agenda and take a place at the global forefront in this field.

Implications for workforce supply and demand

As these technologies become more widely adopted, so too will demand for a skilled technician workforce. There will be several drivers of this demand. More technicians will be required as new technologies and techniques are adopted. Examples of where this is likely include EEG monitoring of neurocritical patients (including computer-assisted EEG) and intra-operative neurophysiological monitoring.

Additionally, as technologies are adapted and applied for use in different settings (such as outside the hospital) or expanded for use with different patient groups or different conditions, it is anticipated that this will also likely translate into increased demand on the workforce.

Applicability

Applicability to the NSW health setting was a key criterion for inclusion in this report, so all evidence reviewed here is deemed applicable. There are, however, a few distinctions regarding professional roles in other OECD countries which are worth noting — mainly in relation to roles that do not currently exist within Australia.

According to the International Federation of Nurse Anesthetists[90], specialised nurse anaesthetists practice in a number of other countries, including the US and UK (but not Australia). Their duties include administering anaesthesia before surgery, monitoring levels during surgery and assisting in patient recovery from anaesthesia following surgery. In Australia, some anaesthetic technicians are nurses but nursing qualifications are not a systematic requirement and there is no dedicated nurse anaesthetist professional stream.

In the UK, the role of Physicians' Assistant (Anaesthesia) **(PA(A))** was introduced over a decade ago and there now are approximately 150 such assistants in clinical practice.[91] PA(A)s are specialised practitioners who have completed a Postgraduate Diploma and work under the supervision of anaesthetists. They may work more independently in specific situations, such as some regional anaesthesia or sedation procedures.

Nurse anaesthetists and PA(A)s may perform some duties which, in Australia, would be performed by either anaesthetists (administering anaesthesia) or anaesthetic technicians (observing monitors during surgery, assisting with recovery post-surgery). In Australia, the absence of such roles means that duties that would be performed by nurse anaesthetists or PA(A)s must be performed by other anaesthetic team members; relatively simpler duties would be performed by anaesthetic technicians. That is, anaesthetic technicians in Australia (who are not qualified nurses) will perform some roles which would be performed by nurse anaesthetists or PA(A)s in other countries. This may include monitoring anaesthesia levels during surgery or assisting in patient recovery, for example.

In relation to EEG, neurophysiology and sleep technicians, no significant differences are apparent between Australia and other OECD nations. Therefore, the findings and recommendations of this report in these areas are directly applicable to Australia.

Conclusion

Technological developments will continue to alter the nature of patient care over the next decade, including in neurophysiology and operating theatres. The duties of technicians working in these areas will need to progress in parallel with these developments.

In neurophysiology and operating theatres, several techniques and technologies are being adopted, or are likely to be adopted, in clinical practice over the next decade. These include long-term brain monitoring of critically ill patients, intra-operative monitoring, non-invasive brain stimulation treatment and anaesthetic delivery systems.

The clinical implementation of such technologies will have important implications for technicians in these areas. The skills, responsibilities and training of these technicians will need to progress as new technologies enter clinical practice. They will need to be proficient in procedures and practices including:

- Operation and maintenance of technologies
- Processing, integrating and/or interpreting patient data
- Data management
- Decision-making in response to certain data or signals (for example automatic alerts from devices).

There will be new education, training and/or certification requirements for technicians in these areas. This will pertain to technical and also to safety aspects.

As these forecasts and recommendations are realised, future technicians in these areas will operate and interact with more sophisticated technologies. In addition, they will continue to interact with patients and other healthcare professionals. Some technicians will play important roles as facilitators between patients, technologies and clinicians. Therefore, technicians in these areas should be essential members of multi-disciplinary clinical teams delivering quality healthcare to patients.

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Appendices

Appendix A – Search terms utilised (PubMed database searches)

((("2010/01/01"[Date - Publication] : "3000"[Date - Publication])) AND (emerging technolog*[Title/Abstract] OR new technolog*[Title/Abstract])) AND neurophysiolog*[Title/Abstract]

(((("2010/01/01"[Date - Publication] : "3000"[Date - Publication])) AND (emerging technolog*[Title/Abstract] OR new technolog*[Title/Abstract]))) AND vestibular[Title/Abstract]

(((("2010/01/01"[Date - Publication] : "3000"[Date - Publication])) AND (emerging technolog*[Title/Abstract] OR new technolog*[Title/Abstract]))) AND "nerve conduction"[Title/Abstract]

(((("2010/01/01"[Date - Publication] : "3000"[Date - Publication])) AND emerging technolog*[Title/Abstract])) OR new technolog*[Title/Abstract])) AND sleep[Title/Abstract]

(((("2010/01/01"[Date - Publication] : "3000"[Date - Publication])) AND (emerging technolog*[Title/Abstract] OR new technolog*[Title/Abstract]))) AND actigraph*[Title/Abstract]

(((("2010/01/01"[Date - Publication] : "3000"[Date - Publication])) AND (emerging technolog*[Title/Abstract] OR new technolog*[Title/Abstract]))) AND evoked potential*[Title/Abstract]

(((("2010/01/01"[Date - Publication] : "3000"[Date - Publication])) AND (emerging technolog*[Title/Abstract] OR new technolog*[Title/Abstract]))) AND (electromyogra*[Title/Abstract] OR EMG[Title/Abstract])

((("2010/01/01"[Date - Publication] : "3000"[Date - Publication])) AND (emerging technolog*[Title/Abstract] OR new technolog*[Title/Abstract])) AND operating theat*[Title/Abstract]

(((("2010/01/01"[Date - Publication] : "3000"[Date - Publication])) AND emerging technolog*[Title/Abstract])) OR new technolog*[Title/Abstract])) AND (anaesthe*[Title/Abstract] OR anesthe*[Title/Abstract])

((("2010/01/01"[Date - Publication] : "3000"[Date - Publication])) AND (emerging technolog*[Title/Abstract] OR new technolog*[Title/Abstract])) AND surg*[Title/Abstract]

Appendix B – Websites consulted (Professional organisations)

International Federation of Clinical Neurophysiology
American Clinical Neurophysiology Society
Association of Neurophysiological Scientists (UK)
Therapeutic Goods Administration
International Neuromodulation Society
Australian and New Zealand College of Psychiatrists
Food and Drug Administration
Australian and New Zealand Association of Neurologists
Medical Technology Association of Australia
Association of Neurophysiological Technologists of Australia
American Academy of Sleep Medicine
International Society for Neurofeedback and Research
NSW Service for the Treatment and Rehabilitation of Torture and Trauma Survivors
Applied Neuroscience Society of Australasia
Australian and New Zealand College of Anaesthetists
American Society of Neurophysiological Monitoring
National Institute for Health and Care Excellence (UK)
International Organisation of Societies for Electrophysiological Technology
Biofeedback Certification International Alliance
Australasian Sleep Association
American Board of Registration of Electroencephalographic and Evoked Potential Technologists
Australian Anaesthesia Allied Health Practitioners
International Federation of Nurse Anesthetists
Royal College of Anaesthetists
Association of Operating Theatre Practitioners
Charles Sturt University
University of Twente

Appendix C – Websites consulted (Commercial organisations)

Emotiv
NeuroSky
InterAxon
BioPac Systems Inc
NeuroTherapeutics
ANT Neuro
Natus Medical
Nexstim
Compumedics
Cheetah Medical
LifeHealthcare
Infrascanner
Healthy Sleep Solutions
MindMedia
Neurophysiology Services Australia
Medtronic