Churchill Report

Churchill Report 2000: Nerve Monitoring During Brain Surgery — David J. Brown-Rothwell

3rd May to 13th June 2000 (revised January 2003)

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Nerve Monitoring During Brain Surgery

Collateral damage to adjacent structures is a significant risk during brain surgery. The potential risk increases with brain tumours because of tissue adherence, anatomical distortion, and poorly defined boundaries. Microsurgery at the base of the skull is further complicated by problems of access.

The introduction of the operating microscope, specialised microsurgical instruments, computer-assisted stereotactic surgery and improved anaesthetic procedures have facilitated skull base surgery. More recently, nerve monitoring has provided a protective function by enabling the surgeon to better identify and conserve the nerves.

Surgeons Dr Michael Redmond and Dr Ben Panizza at the Princess Alexandra Hospital.

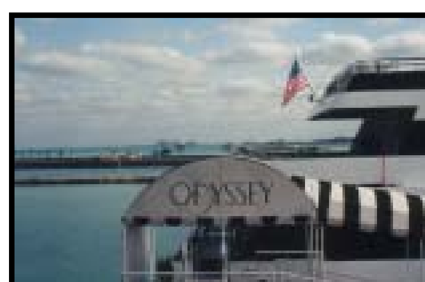
An area of special challenge, is the cerebellopontine angle (CPA), which is formed between the brain stem and the cerebellum, because of the close proximity of major nerve trunks and blood vessels. Acoustic tumours account for approximately 80% of CPA tumours, and surgery involves risk primarily to the facial nerve - the motor nerve of facial expression, and the cochlear nerve - the sensory nerve of hearing. These tumours, which arise from the sheath of the vestibular nerve - the balance nerve, produce symptoms including gradual deafness, tinnitus, and balance disturbance, on the affected side.

Tumour growth progressively involves other nerves and, eventually, the vital centres in the brain stem, which control major body functions. An estimated 60-80 acoustic tumours are detected in Queensland annually. Nerve monitoring has enhanced the surgical treatment by providing the surgeon with dynamic information on the relationship between nerve function and structural integrity.

Odyssey of Discovery

The operating theatre is not an environment conducive to rapid advances using a "trial and error" paradigm.

This Churchill Fellowship provided an opportunity to discover evidence-based neuromonitoring procedures at major centres in the USA and the UK that could be confidently adopted into Australian practice. This was an **"Odyssey of Discovery"**.



An aptly named boat photographed off Navy Pier, Lake Michigan

Note: Feature Photograph above left and throughout Report — Portrait by Karsh of Ottawa, 1942

Schedule

* **4th to 7th May -** Conference, San Diego
* **8th to 11th May -** Henry Ford Hospital, Detroit
* **12th May -** Biologic Systems, Chicago
* **14th to 25th May -** University Hospital, Cincinnati
* **15th May -** SUNY University Hospital, Syracuse
* **29th May -** Flight to London
* **30th May to 1st June** – Symposium, Birmingham
* **2nd June–** Belfast City Hospital
* **5th to 6th June–** Magstim, Wales
* **7th June–** Glan Clwyd Hospital, Wales
* **8th to 10th June–** Addenbrooke's Hospital, Cambridge
* **12th June–** Imperial College, London
* **13th June–** Visit to Chartwell

Calendar of Events: 3rd May — 14th June

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1 May	2	3 Brisbane	4 San Diego	5 San Diego	6 San Diego	7 Detroit
8 Detroit	9 Detroit	10 Detroit	11 Detroit	12 Chicago	13 Chicago	14 Cincinnati
15 Cincinnati	16 Cincinnati	17 Cincinnati	18 Cincinnati	19 Cincinnati	20 Cincinnati	21 Cincinnati
22 Cincinnati	23 Cincinnati	24 Cincinnati	25 Syracuse	26 Syracuse	27 Syracuse	28 Syracuse
29 London	30 Birmingham	31 Birmingham	1 June Birmingham	2 Belfast	3 Belfast	4 Belfast
5 London	6 Wales	7 Wales	8 Cambridge	9 Cambridge	10 Cambridge	11 London
12 London	13 Chartwell	14 Brisbane				

"Intraoperative neurophysiological monitoring of the various cranial nerves has evolved as the gold standard of modern skull base surgery to achieve reduction of morbidity." Levine, 1991

Objectives for the Churchill Fellowship

Goal. To observe intraoperative neurophysiological monitoring at world leading centres, and thereby promote improved knowledge and practice in Australia.

Vision. To gain insight into the significant engineering developments that are generating change in this rapidly evolving technology.

Mission. To observe clinical and community collaborations that are improving patient care post-operatively.

A Parallel Time in History: 1940 and 2000

Almost as if on cue, in May 2000 the face of Sir Winston Churchill appeared on the newsstands — the ***U.S. News*** published a cover story commemorating the dramatic events of sixty years earlier. Speaking in that "solemn hour", at the beginning of WWII, when the tide of defeat was sweeping Europe, the newly appointed Prime Minister rallied the British nation. This was a defining moment in history and while worse was to follow — the surrender of the Netherlands on 14th May, the evacuation from Dunkirk on 27th May,

and the fall of France on 18th June — "The Last Hero" inspired the free world with the words — *"Victory at all costs, victory in spite of all terror, victory however long the road may be; for without victory there is no survival."*

The media coverage of the events reminded everyone of Winston Churchill and provided a unique profile for the Churchill Fellows. The parallel days in May and June 1940 added extra poignancy to the days in 2000.

Conference in San Diego, US

The 11th Annual Conference of the American Society of Neurophysiological Monitoring (ASNM), held in San Diego, provided an opportunity to meet surgeons and clinicians with an interest in intraoperative monitoring. The Society brings together a diverse group that includes neurosurgeons, neurologists, anaesthetists, neurophysiologists, and audiologists.

In the opening address, Dr Marc Nuwer, from the University of California, reviewed the history of nerve monitoring in the US. Neurophysiological measurements were first used intraoperatively in 1970 to assess the relationship between nerve function and structural integrity. The intention was to provide an early warning of the implication of surgical maneuvers before reduced blood flow or nerve trauma produced irreversible damage.

The volume of services has shown a dramatic growth with a total of 23,965 units of service, and an annual growth of 55% in 1997 alone. Approximately 25% were funded by US Medicare, and the predominant providers were neurologists, who accounted for 47.7% of the service units. While the growth in service has been due in part to the perceived benefit, medico-legal concerns have also been prominent.

The ASNM plays a key role in establishing the national standards, and provides a forum for the physician and professional organisations representing the “stake-holders”. It is also involved in the technician’s training program and conducts Board Certification examinations every year. Many

The San Diego
(The Postcard Factory)

procedures are now performed by technicians, and the issues of training, and supervision, are increasingly important.

The Conference provided a perspective on the nerve monitoring “industry” that was both a revelation and an inspiration.

Neuromonitoring of Motor Cranial Nerves

Research was presented that clearly showed the benefit of monitoring efferent (motor) nerves during brain surgery. The facial nerve, the 7th cranial nerve, is now routinely monitored during acoustic tumour surgery in accordance with the standard of care recommended by the NIH Consensus Conference (1991). Paired needle electrodes can be inserted in the muscles of facial expression and muscle activity recorded as an electromyographic response (EMG). The specific measurements can be correlated with operative manipulations and provide the surgeon with immediate knowledge of the physiological impact. One Mayo Clinic study has shown complete anatomic preservation of the facial nerve in 67% of monitored cases, versus 33% in non-monitored cases. While the comparison is less impressive for the smaller tumours, all the data confirms this trend.

The motor components of other cranial nerves are being increasingly monitored. For example: the endotra-

The Endotracheal “tube” electrode.
(Xomed-Treace)

cheal tube electrode, has been developed to be inserted between the vocal chords to measure the Vagus Nerve, the 10th cranial nerve (see above).

Multiple nerve recordings, enabled by 4 and 8 channel systems, are providing additional information because “real-time” measurements can reveal a pattern of response between the nerves. For example, stimulation of the Trigeminal Nerve, the 5th cranial nerve, evokes a “pain” response immediately followed by a facial nerve response indicating a “grimace”.

Because continuous, passive monitoring can fail to detect incremental injury, it was recommended that electrical probe stimulation is utilized to actively monitor nerve integrity, by a process of serial measurements referenced against an established baseline. Hence during prolonged periods of lower level EMG, regular probe stimulation should also be performed.

The importance of the operative context was also highlighted. Aberrant EMG can arise from mechanical or electrical artifacts. While surgeons expect some “false alarms”, uncertainty can be introduced when the occurrence becomes too frequent or the source is unknown. Hence, an understanding of the anatomy of the structures at risk, and the surgical approach can assist the monitoring clinicians to provide more meaningful information.

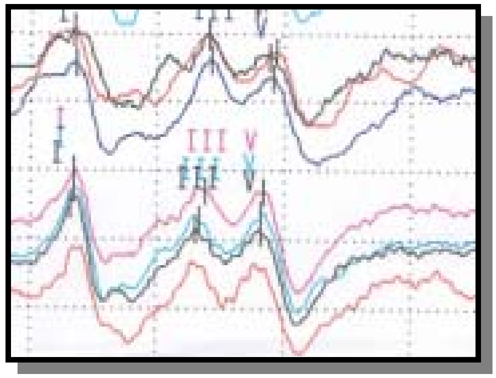
In summary, Dr Richard Ostrup, a San Diego neurosurgeon, succinctly expressed the benefits of nerve monitoring “ *It is a quality of care issue — neuromonitoring helps the surgeon help the patient*”

Neuromonitoring the Cochlear Nerve

The cochlear nerve is monitored during acoustic tumour surgery when a hearing conservation approach is adopted. The procedure is challenging because the pre-existing pathology degrades the function of the nerve and distorts the "brainwaves" recorded. Additionally, reliable waveforms can require the averaging of a large number of responses and hence there can be a significant time delay between detecting a change in the waveform, and the surgical event that might have precipitated it.

This issue was addressed by Dr William Martin, from the Oregon Hearing Research Center, who outlined the potential mechanisms for nerve damage and the optimal procedures for early detection. Damage, resulting from direct trauma or inadequate blood flow, can occur to the inner ear, the nerve, or brainstem centres. Early intervention can sometimes reverse the injury.

The most common measure is the auditory brainstem response (ABR), which is usually recorded from electrodes inserted in the ear canal. The ABR waveform, as illustrated below consists of an evoked potential recorded in the first 10 milliseconds following a sound stimulus. Because of the time delay between the surgical event and the associated ABR waveform, the technique is only useful for relatively slow changes. For example, the disappearance of ABR wave III is reported to be the earliest and most sensitive predictor of reduced blood flow due to cerebellar retraction.

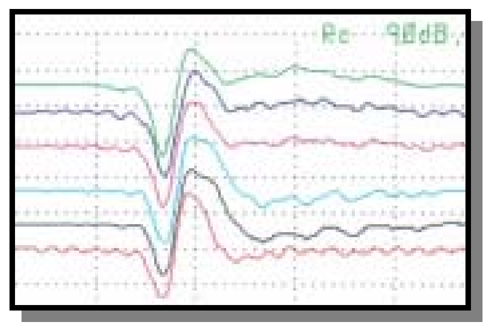


Intraoperative ABR waveform series

Rapid acquisition is a major advantage of Electrocochleography (ECochG), a potential recorded from the inner ear. However, interpretation is limited because the response occurs peripheral to the surgical site.

A more recent technique involves the Cochlear Nerve Action Potential (CNAP), which is recorded directly from the exposed nerve and provides "real-time" information that almost instantly reflects the physiological effect of operative manipulations. Any reduction in the amplitude of the CNAP indicates potential injury. For example, a reduced CNAP waveform in an anatomically intact nerve suggests the microcirculation of the nerve has been disrupted and early intervention, such as reducing pressure or applying vasodilators, can be effective in restoring function.

Nerve monitoring is more problematic for the cochlear than other cranial nerves because of the increased complexity of surgical decisions involved in conservation. However, the ability to reliably correlate the physiological with surgical events holds promise for the future.

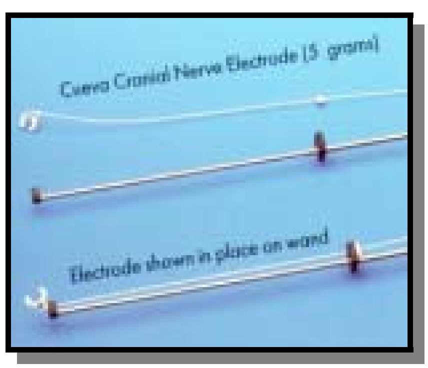


Intraoperative CNAP waveform series

Advances in Electrode Technology

Neurosurgeon, Dr Robert Cueva, outlined the use of the c-electrode for recording the CNAP . This finely-engineered electrode is shaped like a miniature horse shoe, and is available with a 2 mm or 3 mm diameter.

The c-electrode, which is manufactured by Ad-tech Medical Instruments (www.adtechmedical.com), is placed around the nerve and has a self-retaining spring that releases if the lead is inadvertently tugged. A variant of the c-electrode consists of a 1mm platinum square that can be insinuated between nerves.



The 'c-electrode' **(Ad-tech Medical)**

Even more exotic electrode and cable designs have been proposed and could also have intraoperative applications.

Pine (1990) suggested a cultured-neuron electrode probe consisting of neurons trapped within an electrode matrix produced using 'in vitro' techniques. The cultured electrode could act as a conductive conduit between the electrode and the host nerve.

In addition, the development of thin-film silicon electrodes, and ultraflexible cables could improve electrode stability within nerve tissue which is an on-going concern.

Such advances in electrode technology have the potential to expand the applications of nerve monitoring.

Henry Ford Hospital— Detroit

The Henry Ford Hospital (http://www.henryfordhealth.org) was founded by the auto pioneer, Henry Ford, in 1915. It is comprised of an array of acute, primary, tertiary, and super-specialist health services forming one of the leading health care systems in the US. It is the sixth largest employer in Michigan and has more than 16,000 full time employees. Patient contacts exceed 2.5 million annually.

The clinical services are supported by extensive research centres and teaching programmes that are directed at improving diagnosis and treatment. The annual medical research budget exceeds $40 million dollars and the hospital ranks in the top 6% of research centres receiving grants from the National Institute of Health.

About 1 in 5 of the medical consultants have academic positions at the University of Michigan. There are currently about 1000 research projects targeting key areas such as headaches, strokes, heart disease, cancer, and joint disease. For example, investigators are using advanced imaging techniques, such as nuclear magnetic resonance spectroscopy and magnetoencephalography, to study the origin of migraines.

Main Entrance, Henry Ford Hospital

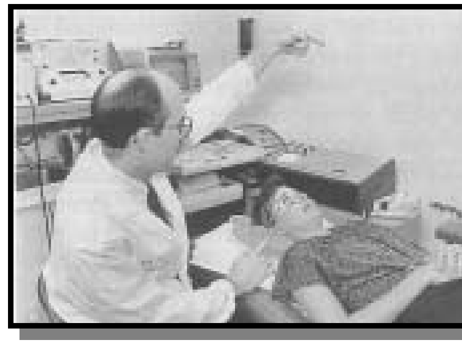
The Audiology Division, which is co-located with the Department of Otolaryngology Head and Neck Surgery, reflects the hospital's focus on clinical excellence and provides an impressive range of services through central and peripheral facilities. The staff consists of 12 master and doctoral level audiologists. Rehabilitative activities consist of hearing aid, cochlear implant, and tinnitus management programmes. Diagnostic activities include hearing and balance assessment.

In addition, these services are supported by a broad research and teaching base and extensive collaborations exist with the speech and language pathologists, and medical specialists. There were many examples of innovative ideas and an almost seamless translation of research into the clinical practice. For example, a balance questionnaire, the Balance Handicap Inventory, which was developed in this clinic, is presented as an "distracter" during balance assessment to minimise the tendency of patients to suppress their dizziness (Jacobson and Calder, 1998).

Dr Jacobson's research interests and expertise extend into many areas of audiology, included intraoperative monitoring, tinnitus management, electrophysiology, and balance function testing. For example, the bipolar probe introduced by Dr Kartush was first developed at the Henry Ford. More recently, the audiological applications of magnetoencephalograpy are being investigated.

Many research publications and book

Developing an audiological centre of excellence is an outstanding achievement - but even more impressive is the broad research and teaching base that underpins the clinical services.



Balance Tests — Dr Gary Jacobson

chapters have emanate from this clinic. Topics have ranged from intra-operative monitoring, to tinnitus evaluation, and to balance assessment (Jacobson and Blazer, 1991; Newman, Jacobson, and Spitzer, 1996; Jacobson and Newman, 1997).

The Henry Ford Hospital represents an inspirational model for other clinics. Despite the common resource, staff and funding issues, through a combination of clinical excellence and administrative expertise, a truly world class facility has been created.

To conclude with a personal anecdote that reinforced for me the important role of family in keeping clinicians connected to the real world. During a breakfast with Dr Jacobson's family, his charming young daughter, Cristina, presented me with the drawing of a dog (see below).

Cristina's dog

The Harper Hospital –Michigan

In Michigan the major provider of intraoperative monitoring services is Biotronic, a company owned by a neurophysiologist, Dr H.B. Calder and based in An Arbor (http://www.biotronic.com/biotronichome.htm). Arrangements were made for me to accompany a senior clinician, Mr Kent Rice, to observe the monitoring procedures during CPA tumour surgery.

The surgery was performed by neurosurgeon, Dr Perez, and neurosurgical residents (the equivalent of registrars). The intraoperative monitoring involved combined facial nerve electromyography (EMG) and the cochlear nerve auditory brainstem response (ABR) recording using a single multichannel monitoring system.

Points of special interest were:

1. The sub-dermal needle electrodes on the vertex were secured with surgical staples;
2. Electrode extension leads had co-axial shielding, grounded to the Mayfield clamp, to minimize electrical interference; and
3. Auto-tracking was used to follow the ABR wave II latency shifts.

“Watching and Waiting” — University Hospital, Cincinnati

Nerve monitoring is routine, but the experience is never ordinary

Advanced Balance Testing

Dr Jacobson, who is co-author of the “Handbook of Balance Function Testing”, has established an advanced diagnostic facility for balance assessment. While electronystagmography (ENG) using the traditional surface electrodes, to record eye movements, and caloric testing, involving thermal stimulation of the balance organ to induce vertigo, continue to be performed, fresh insights into the complex balance mechanisms are being gained from new procedures.

These include posturography, involving posture manipulations using a tilting platform, and rotational vestibular testing (RVT), which delivers a stimulus using a rotating chair.

Computers control and assist these measurements, and detailed eye movements are captured by video cameras (Videonystagmography) .

An example of a integrated system has been developed by ICS Medical (http://www.icsmedical.com).

Videonystagmography (ICS Medical)

Rotary Vestibular Test (ICS Medical)

Magnetoencephalograpy Research

Biological events generate magnetic signals that can be recorded at the skin surface. The technique, magnetoencephalograpy (MEG) is revolutionizing the understanding of brain function (http://www.amershamhealth.com). At the Henry Ford Hospital, the minute biomagnetic signals are being combined with the familiar MRI scans to provide a powerful new tool to measure evoked responses. This technique is superior to electrophysiological methods.

The “whole head” MEG System
(Henry Ford Hospital)

Research is being conducted into epilepsy, migraines, stroke, brain tumours, traumatic brain injury, and hearing loss. Dynamic activity patterns are enabling audiological researchers to gain a new understanding of auditory processing at brainstem, subcortical, and cortical levels. Ultimately, this technology may make an impact on neurophysiological monitoring (Squires, 2000).

Bio-logic Systems Corp - Chicago

Bio-logic (http://www.blsc.com) is a leading manufacturer of the evoked potential (EP) equipment used in intraoperative monitoring. This visit was an opportunity to meet the team of researchers and engineers behind the current products. It was also a special privilege to meet Mr Ravi Gabriel, the company founder and chairman.

Discussions ranged from networking and data storage issues, to recent innovations, such as stimulus interleaving, trending analysis, and compressed spectral arrays, that have potential applications in intraoperative

ECochG Electrode (BioLogic Systems)

monitoring. New Windows-based equipment has been released for neonatal screening and the new software platform is to be extended across the evoked potential range. This will facilitate the storage and retrieval of monitoring data.

More recently a disposable, extra-tympanic electrode for electrocochleography (ECochG) has been introduced which consists of a unique conductive hydrogel tip attached to a fine silver wire.

The visit reinforced the sense that a only close collaboration between clinicians and manufacturers ensures technology is fine-tuned to the intraoperative arena.

University Hospital - Cincinnati

The University Hospital (http://www.health-alliance.com/university.html) has an impressive medical history, because it was here that Dr Sabine developed the polio vaccine; and Dr Mayfield established a world renowned Neurosurgery Department.

For me it was an exceptional opportunity to sit alongside Professor Bob Keith, an eminent clinician, researcher, and academic. It was a special experience to learn from a “master of the craft”.

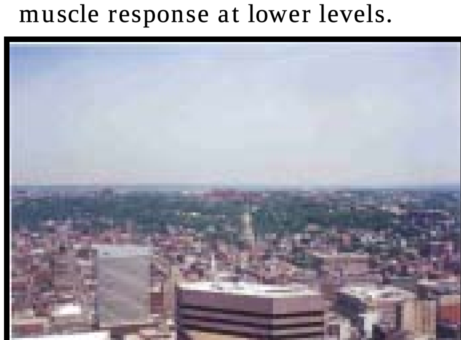
For 10 days I crossed and re-crossed the hospital campus and observed surgery on a total of 17 adults and children. The unique learning experience was interesting and informative, and provided details on many procedures including an understanding of some of the pitfalls that make nerve monitoring deceptively complex.

While my main interest was in monitoring cranial nerves, the predominance of spinal operations reflected the national case mix in the US. For example, Dr Mark Bloom from the New York University Medical School has estimated that 30% of patients undergoing brain surgery (for conditions such as brain tumour and vascular lesions), and 50% of patients undergoing spinal surgery (for conditions such as spinal discectomies and spinal stabilizations) are now routinely monitored.

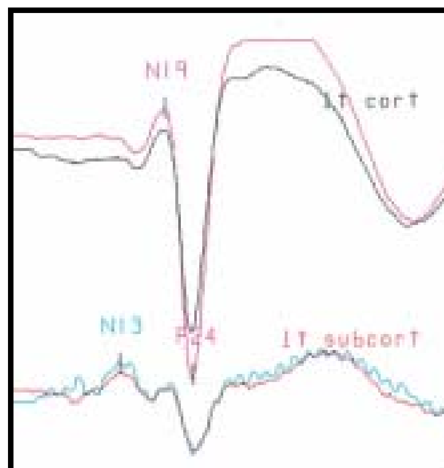
Spinal cord monitoring can be subdivided into somatosensory evoked potentials (SSEP) and motor evoked potentials (MEP) procedures.

SSEP involves the sensory pathways, and a response generated by electrical stimulation of a peripheral nerve, (e.g., median ulnar at the wrist), is recorded at a higher level, such as the sensory areas of the brain surface (the cortex).

In contrast, MEP involves stimulation of the motor areas of the cortex (or spinal motor tract) and recording the muscle response at lower levels.



Cincinnati skyline with the red buildings of the Hospital in the centre horizon.



SSEP recording during the excision of a spinal tumour, at cortical and subcortical levels using ulnar nerve stimulation

The basic principle of spinal cord monitoring is that nerve integrity can be measured by selecting a nerve pathway that carries signals through the region at risk, and then generating a response, and tracing progress at strategic points.

In Cincinnati, consideration was also being given to introducing visual-evoked potential (VEP) recording. This procedures utilizes flash stimulation, through the closed eye-lid, to evoke a response in the visual cortex, so enabling the optic nerve to be monitored.

Intra-operative Monitoring in Cincinnati

The way intra-operative monitoring services are provided in the United States has had a marked impact on the scope of practice of audiologists. The predominance of spinal cord monitoring is a major departure from the traditional audiology focus on the auditory system.

However the surgical challenges remain the same, and nerve monitoring techniques are similar. The role of audiologists in spinal cord monitoring is supported by a significant contribution to research (Keith, Stambough, and Awender, 1990; Lubitz, Keith, and Crawford, 1999).

Cincinnati became an intense learning experience partly due to the large number of cases observed in less than two weeks, but more fundamentally because of the commentary and discussion provided by Professor Keith, who has great abilities as a teacher.

The majority of cases observed involved spinal cord surgery and SSEP. Operations included : spinal fusion to correct curvature (scoliosis); decompression for a herniated disc, and surgery for spinal cord tumours. Some procedures involved the insertion of extensive instrumentation in the form of plates, screws, stainless steel rods, and bone grafts.

Increasingly, monitoring is being extended to motor evoked potentials. However, many surgeons continue to rely on the "wake up test" a procedure that simply involves the patient to "move their toes", and so confirm the motor pathways are intact.

Compared to nerve monitoring during brain surgery, the techniques for spinal cord monitoring are more complex: many more electrodes are used, the monitoring is duplicated on the unaffected side as a control, and both stimulation and monitoring circuitry is involved. Spinal cord monitoring requires measurements from a large number of sites on the body, to enable the signals to be traced through the region at risk. The capability to simultaneously record these sites is provided by 8 or more monitoring and stimulation channels, and multiplexer interfaces alternating between various nerves.

Professor Robert Keith

In addition, because the patient's physiological status has a more pronounced effect on spinal function, the anaesthetic considerations are more important for the interpretation of neurophysiological data.

The increased complexity of the monitoring has influenced practice: audiologists and technicians have been taught to insert the needle electrodes, to understand the potential impact of the level of anaesthesia, and in general are more fully integrated into the operating theatre team. As a consequence, the staff are more likely to be specialists in nerve monitoring.

Points of special interest were:

1. Gold-foil covered foam tips attached to the insert earphones combined the electrode and stimulus delivery function;

2. Bone wax was moulded to seal the "gold foil" electrode into the ear canal to prevent leakage of the skin prep solution; and

3. A dedicated facial nerve monitor was used to facilitate more immediate detection of the EMG "bursts" that indicated potential risk.

The physical layout of the monitoring systems is also critical because of the large number of cables and extensions required. As a precaution, some redundancy has been incorporated into the monitoring, and there is great attention to the stability and security of all connections.

The communication demands on nerve monitoring clinicians has also increased because of the interaction with anaesthetists, and nursing staff. However, the primary communication partner remains the surgeon, and the clinicians must overcome the physical and acoustic barrier imposed by the equipment. In addition, Professor Keith also discusses the nerve monitoring component of the surgery with the families of the patients.

The environment could be challenging and uncomfortable for many clinical audiologists and the training programme and Board Certification provided by the American Society of Neurophysiological Monitoring very important.

The Cincinnati Team with Professor Keith and Angela Bottle sitting to the left.

In conclusion, Professor Keith has developed a model for nerve monitoring practice as a specialty area within audiology, that has a attained a credible professional standing within the surgical team.

Cincinnati — the city, the park-like suburbs, and the river, — and the gracious clinicians, and surgeons, all left a lasting impression.

SUNY University Hospital—Syracuse

This brief visit provided an opportunity to examine the service structure in a large public hospital. The SUNY University Hospital is part of the State University of New York and the total workforce of 5,300 staff makes it one of the largest employers in "upstate" New York.

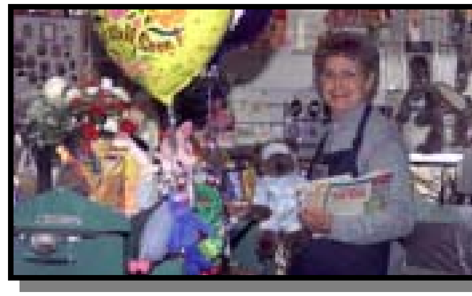
Audiology is located within the Communication Disorder Unit and I joined audiologist, Kaye Muldoon, during her routine clinic sessions. The Head of the Unit, Dr Robert Shtrintzen, is a leading expert on velo-cardio-facial syndrome.

The Hospital's patient-orientation was demonstrated by an informative website (http://www.universityhospital.org) that provides details of services centred around the presenting pathologies. This service model largely involves clinical and program teams structured around the core medical specialists. The major areas of audiology input appeared to be hearing aids and neonatal screening services.

Audiology has minimal involvement with acoustic tumour surgery. Intraoperative monitoring services are sourced from private clinicians and a large proportion of the surgery is performed in the adjacent private hospitals of St Joseph's and Crouse.

A feature of the hospital was a well organised volunteer service that extended far beyond the usual gift shop. Volunteers are in evidence in a significant support role, and in a wide range of areas from the Emergency Room to specialist clinics.

The most positive aspect of the team approach is obviously that it enables a group of clinicians to evolve into a specialist entity dedicated to the provision of a targeted service. Surgery lends itself to such an approach, but the extension into post-operative rehabilitation is more innovative. An example might be rehabilitation following acoustic tumour surgery with a team involving non-clinicians, e.g., beauticians and volunteers. However, there was no evidence of such a team had developed. What was evident was an impression that audiology representation was strong only in some core areas such as paediatric assessment or hearing aids. This illustrates a questionably negative aspect of the team approach for the smaller professions: there may be a tendency to rationalize the team by "squeezing out" members that make only a fractional contribution. The clinician's scope of practice might also be restricted due to forced specialisation. Ultimately, the consequences might be that the "toe-hole" areas, so important to professional development, are lost.



The ever smiling volunteers

When combined with fractional appointments, the team approach can professionally isolate individual clinicians, and impair the development of broad-based clinical skills by restricting practice to a narrow "niche".

My conclusion was that the team approach should be viewed by clinicians with caution, because group dynamics can impact management and professionals issues in unexpected ways. However, the benefit to patients, which is easy access to a group providing all the treatments, is indisputable. The answer may be in a combination of inter-disciplinary and discipline-specific "treatment" teams and well-managed staff rotations.

Comparison with Australia

The contrast between the trickle of intraoperative monitoring services in Australia and the sheer volume of services in the United States is almost as dramatic as the Niagara Falls.

In the US, intraoperative monitoring services are dominated by private providers operating on a vast scale and supported by the medical insurance funds. Services are continuing to expand, driven by quality of care and medicolegal issues, and under the guidance of the American Society of Neurophysiological Monitoring.

Niagara Falls — the sheer volume of water was impressive

What of Australia? While the medical and scientific environments are similar, there is no Medicare item for intraoperative monitoring and hence there is little incentive for private involvement.

Existing services in the public system are largely restricted to facial nerve monitoring, and there is minimal access to spinal cord monitoring. Cochlear nerve monitoring remains in the domain of "special interest" and research.

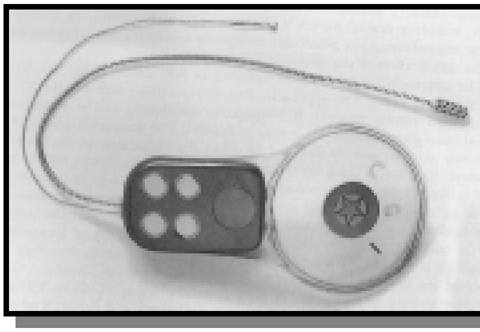
Birmingham, UK. International Symposium

The 3rd International Symposium on Electronic Implants in Otology and Conventional Hearing Aids in Birmingham was attended by 400 delegates from more than 25 countries.

The Symposium was opened by Lord Ashley of Stoke, a powerful advocate for hearing services in the UK. He emphasized the crucial role of habilitation within cochlear implant programmes.

Professor Bill Gibson, from Sydney, presented a paper outlining the benefit of intra-operative electrically-evoked auditory brainstem response (EABR) in determining the optimum position of the electrodes within the cochlea. Areas of auditory neuropathy can thus be identified and avoided.

A series of papers was presented on the progress being made with the Auditory Brainstem Implant (ABI). The ABI draws on bionic ear technology to deliver speech signals directly to the brainstem, thus bypassing the inner ear. This restores a sensation of hearing when the cochlear nerve has been severed due to disease or injury, and is the only treatment when surgery to remove bilateral acoustic tumours results in total deafness.



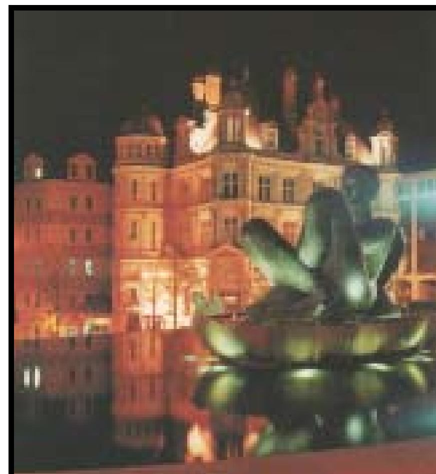
The Nucleus Multi-Channel ABI (Cochlear)

The ABI consists of an electrode array that is implanted into the lateral recess of the fourth ventricle, which is in the same vicinity as the hearing centres in the brainstem. This is connected to internal circuitry that receives a signal transmitted from an externally worn speech processor (Otto et al, 2002). An example of the Australian Nucleus device is shown above (http://www.cochlear.com).

Because there are no clear anatomic markers, intraoperative EABR is utilized to determine optimal electrode positioning. In addition, the facial and glossopharyngeal nerves are sometimes monitored to detect any non-auditory stimulation of face or mouth.

Research was also presented on the recent use of neural response telemetry to adjust the output levels of cochlear implant electrodes in uncooperative children. This technique exploits the bi-directional communication capability of new the speech processors to electrically stimulate and record the evoked compound action potential from selected electrodes.

A further informative aspect of the Symposium was the extensive equipment display. A demonstration of the ability of the laser Doppler to measure fine movements, indicates the considerable potential of this technology to monitor blood flow during acoustic tumour surgery.



Victoria Square, Birmingham
(Programme Cover)

The Belfast City Hospital— Northern Ireland

The Belfast City and Royal Victoria are major hospitals in Northern Ireland (http://www.royalhospitals.org). A significant building programme is transforming the facilities from a haphazard collection of austere brick buildings into a patient friendly campus. My guide was audiologist Vincent Lawless.

The Audiology Department reflects the National Health Service (NHS) model which integrates community and hospital services. Core activities appeared to be a hearing aid clinic, cochlear implant programme, and hearing assessment service. A neonatal screening programme, using oto-acoustic emissions to detect deaf infants, is also being planned. Noteworthy was the community group "Brainwaves" which has achieved great success in providing support to brain tumour patients and their families.

The Main Building — Belfast City Hospital

While the tribal nature of the society is evident to the visitor, the overwhelming impression is of a tightly knit and supportive community structure that would be of significant benefit to any health service.

The MAGSTIM Company Limited - Wales

MAGSTIM, is a leading manufacturer of intra-operative monitoring equipment. The company is located in Whitland, Carmarthenshire, in a picturesque part of Wales.

My visit, at the invitation of Mr Peter Houseman the Product Manger, was an opportunity to observe the manufacture of the Neurosign Nerve Monitor series and the Magnetic Nerve Stimulator system. Both projects are supported by extensive research and development programmes that include regular involvement in intraoperative monitoring in British hospitals.

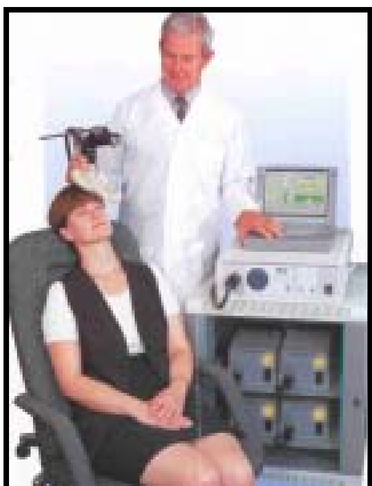
The capacity to monitor multiple cranial nerves is a feature of the Neurosign, which is available in an 8-channel version.

The Magnetic Nerve Stimulator, a relatively recent technology, enables deep nerve structures to be stimulated using a transcutaneous or transcranial technique.

Ancient castles preside over Advanced Science
(John Hinde, UK)

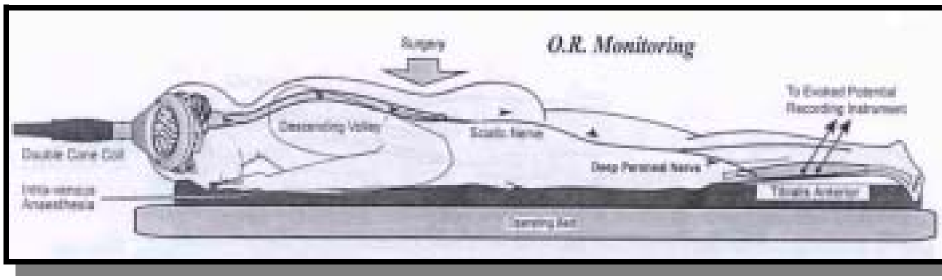
Transcranial Magnetic Stimulation

Magnetic stimulation permits an electrical response to be induced in deep nerve structures, which are otherwise inaccessible, non-invasively and with minimal discomfort.



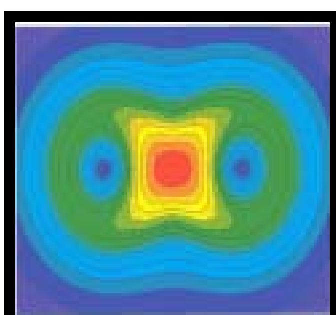
Transcranial Magnetic Stimulation
(Magstim)

For example, historically only the peripheral branches of the facial nerve lying close to the skin surface on the face can be evaluated in the clinic. Only during surgery, when the nerve pathway was exposed, could the integrity of the facial nerve be evaluated from the level of the brainstem. However, transcranial magnetic stimulation, which generates a focused magnetic field deep within the body tissue thereby inducing nerve stimulation, has the potential to bring these measurements into the clinic. The magnetic field generated by a double core coil is shown below.



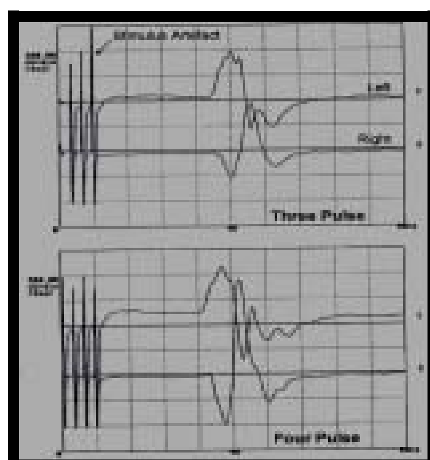
Utilization of Transcranial Magnetic Stimulation during Spinal Surgery (Magstim)

This technique has potential applications, both in the operating theatre and in the clinic. These include: intraoperative monitoring during spinal surgery, assessment of corticospinal function following traumatic brain injury or stroke, evaluation of hearing nerve function prior to cochlear implantation, and monitoring recovery following facial nerve paralysis (Terao, and Ugawa, 2002).



Double coil Magnetic field
(Magstim)

Research is continuing to expand the potential applications and to clarify the underlying mechanisms. This new tool provides a unique ability to evaluate nerve function and the impact of the technology on the practice of neurophysiological monitoring will develop as clinicians become more familiar with the procedure.



Leg Myographic Waveforms
(Magstim)

Glan Clwyd Hospital—Wales

The Audiology Unit at Glan Clwyd Hospital (http://www.glanclwyd.demon.co.uk/audiology/audio.htm) is one of the largest and most impressive in the UK.

Glan Clwyd Hospital, North Wales

Located in North Wales, the unit is a major training centre and provides extensive adult and paediatric services that include hearing aids, tinnitus management, and cochlear implants.

Acute hospital and community based services, such as universal neo-natal screening programmes, are fully integrated. A team of 20, which is headed by a consultant audiological scientist, Clive Sparkes, and includes medical and speech pathology staff, provides in excess of 11,000 appointments annually.

A feature of unit is the utilization of a computer software package running on a local area network (LAN) to completely manage all administrative and clinical aspects of the operation: the Auditbase Audiology Database. The UK version of this software was developed at Glan Clwyd in association with the Danish Company Auditdata (http://www.auditdata.dk) This is an integrated audiology management and clinical database — Patient information is sourced from the hospital network (using SQL connectivity), and then linked with appointment information, audiological data, patient reports, clinical journals, and other management systems. Because the software has been developed as modules, the package can be adapted to different clinic requirements. The net result at Glan Clwyd is a virtually paper-free operation .

Data acquisition directly from the equipment is enabled by integration through NOAH, which is the standard software adopted by many audiological equipment manufacturers. This enables measurements such as hearing thresholds , middle ear function, and hearing aid insertion gain performance, to be directly stored in the database and then retrieved and formatted for the patient report.

The advantages of the integrated clinic management software include: time efficiency, due to less duplication; immediate access to actual clinical information without the need to physically transfer patient records; automatic generation of letters through integration with word processing; and facilitation of data analysis for management or research purposes.

Test Room

Lack of compatibility with some clinic equipment and other hospital systems could prevent the benefits being fully realised in the short term.

In addition, great care is required to maintain a patient-friendly environment while incorporating such new technology. Common with all database systems, security issues are also critical.

However, future health services are likely to involve extensive local area networks (LAN) replacing the cumbersome patient record archives and providing access to integrated database systems. External links to community clinics can also be achieved through wide area networks (WAN) or via the internet. Medicine is embracing this new technology and Glan Clwyd demonstrates the potential for audiology facilities.

Computer Networks and Intraoperative Monitoring

The implications to intraoperative monitoring of a computer network, parallels the clinical application, but carries the additional promise of “remote” operation. For example, if data were transferred to a network in “real-time”, then a clinician remote from the surgery could “monitor” the monitoring, thus facilitating training and supervision. The issue has received considerable attention in the United States e.g., at Rochester University (www.rochester.edu/internet2/projects/remote.html).

Examples from anaesthetics and telemedicine demonstrate the feasibility of “tele-presence” systems. However, in addition to the medicolegal issues, two further questions remain. Firstly, despite the increases in computer memory, data storage for lengthy surgery, involving multi-channel recording, would be prodigious. Secondly, maintaining the immediacy of communication between the surgeon and the remote monitoring clinician would be a significant challenge.

The benefits of technology must be balanced against the safeguards of “real-presence” monitoring.

Addenbrooke's Hospital—Cambridge, England

Addenbrooke's is a prestigious Hospital located in Cambridge, the famous university town. (http://www.addenbrookes.org.uk/). With a total of about 1,100 beds, 6,000 staff, and servicing an area of some 2.5 million, the hospital is one of the largest in the UK. and one of the leading centres for specialist surgery, research and teaching.

The Neurotology and Skull Base Surgery Unit have a specialised interest in acoustic neuromas and are researching the genetics, molecular biology, and clinical presentation of the condition. Addenbrooke's is well represented in the research literature.

Neurosurgery at Addenbrooke's

My visit to the unit had been arranged by neurosurgeon, Dr Bruce Hall, who had been at Addenbrooke's as a registrar.

Close teamwork between surgeons, scientists, and other staff is evident.

The Audiology Department, which is headed by Mr David Baguley, is a major development centre for hearing services in the UK and is participating in the National Health Services (NHS) modernization programme. These enhancements will include the provision of digital hearing aids technology and universal neonatal screening.

Audiology provides a comprehensive range of diagnostic and rehabilitative services which includes cochlear implants, and tinnitus management.

There is significant collaborative research with neurotology and neurosurgery.

Acoustic Neuroma Surgery

Surgeons perform an average of 15 skull base operations each week and I was privileged to be invited by neurosurgeon, Mr Robert MacFarlane to observe an acoustic neuroma (tumour) case involving a combined approach, with neurotologist Mr David Moffat.

Because many Australian surgeons visit Addenbrooke's as registrars the operating theatre procedures were surprisingly familiar. Only the facial nerve was monitored, as the surgical

The Operating Theatres at Addenbrooke's

approach involved access through the labyrinthine system of the ear does not preserve hearing. Facial nerve monitoring was performed by Mr Patrick Axon, a neurotologist. It was noteworthy that the monitor was primarily used as an audible "alarm" system and detailed waveform amplitudes measurements were not recorded.

In addition, at that time there appeared to be no great impetus to introduce cochlear nerve monitoring during surgery involving hearing preservation approaches. There is significant controversy surrounding the benefits of hearing preservation which extend beyond nerve monitoring issues.

Audiology Department— Addenbrooke's Hospital

Addenbrooke's Hospital, and the associated Rosie (Maternity) Hospital, refer patients to the Audiology Department, which has 22 staff. The clinic has a significant complex case load. For example, approximately 450 neurotrauma cases are cared for by the Neurosciences Critical Care Unit annually. A point of interest was that because practitioners of clinical audiology in the UK are designated as "audiological scientists", the term "audiologist" is non-descript. Hearing services are provided by a range of professionals that include hearing

The delightful "child-friendly walls.

therapists and audiological technicians. Again, a significant private hearing aid service is also operated and this merging of public and private facilities seems characteristic of the NHS.

Marked contrasts exist with the Australian system, which largely dichotomizes diagnostic and rehabilitative services. In the UK the synergy between the two services is increasingly evident in the facilitation of the link between community and hospital.

It is equally evident that the role of audiology in nerve monitoring does not occur as a spontaneous side-branch of clinical services but requires special sponsorship.

The Cambridge Colleges, England

Trinity College, Cambridge

No account of a visit to Cambridge would be complete without reference to the famous colleges that have contributed so much to the Australian university tradition.

Dinner at Trinity College was a memorable occasion, made all the more so because the invitation came from an English niece, Dr Julia Gog, a scholar of the college.

Trinity has produced twenty-eight Nobel Prizewinners, including Sir Isaac Newton. Indeed a tree seeded from the famous apple tree, whose falling apple prompted him to experiment with gravitation, grows near the Great Gate!

One of the newer colleges, Churchill, was founded in Sir Winston's honour to be a memorial and living symbol of the 'gratitude of English-speaking peoples'. The College was inspired by a visit by Churchill to the Massachusetts Institute of Technology and was established to encourage science and industry to work together.

The grounds contain the Churchill Archive Centre which contains many of his personal letters and writings. More recently a collection of Lady Margaret Thatcher's paper was added (Jeacock, 1988)

Again there is a tree, or indeed two: a mulberry tree and an oak, which were planted on the college site by Sir Winston in 1958, perhaps to symbolize "victory" and "learning".

Churchill College, Cambridge

British Neurophysiology Meeting— Cambridge

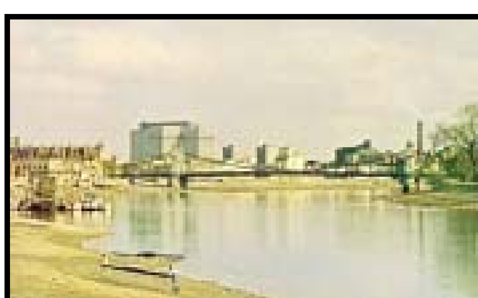
A meeting of the British Society of Neurophysiology at Addenbrooke's Hospital coincided with my visit to Cambridge. The theme of the meeting was transcranial magnetic stimulation (TMS) and a total of sixteen papers were presented. Topics ,which included traumatic brain injury, and cerebral ischaemia, were presented by research centres from throughout the UK.

There was strong evidence of peer review and the best presentation was awarded the inaugural TMS Research Prize. The most impressive aspect of the meeting was the strong evidence of extensive collaborations between universities and hospitals.

The impressive strength of medical research has evolved from a unique collaboration between laboratory scientists and hospital researchers.

Imperial College— London, England

The Imperial College Faculty of Medicine has emerged from the successive mergers of famous medical schools and hospitals such as the Charing Cross (http://www.ic.ac.uk). Research facilities are spread across multiple centres and to increase the confusion for visitors, the names of the buildings seem unrelated to the map localities. However, a map fix on Hammersmith Cemetery soon led to Department of Sensorimotor Systems where I met Dr Nicholas Davey, a lecturer at the School of Medicine.



The "cross- shaped" Charing Cross Hospital viewed from the Thames.

A current research interest is the study of corticospinal control of voluntary movement using transcranial magnetic stimulation of the brain and electro-myography. Other research areas involved movement analysis, recovery following spinal cord injuries, and auditory brainstem response measurements.

The neurophysiological research activity at the Imperial College, and at similar centres throughout the UK, provide a significant foundation for the development of intraoperative neurophysiological monitoring practice.

The Sir Winston Churchill Memorial Trust— London

A visit to the Trust Office in Queen's Gate Terrace provided an interesting insight into the functioning of the British organisation (http://www.wcmt.org.uk) and an opportunity to meet the small group of dedicated staff that run the Trust on a day to day basis.

This visit also enabled me to solve some of the "little" puzzles associated with Sir Winston. For example, the significance of the "mulberry" tree — the planting of a mulberry tree at Churchill College, and Mulberry Piers (the mobile harbours from which the invasion fleets left for France in 1944) — was intriguing. A possible explanation is apparently the naval tradition of "biblical" codes: King David's victory was signaled by " the sound of the wind in the mulberry trees" (II Samuel 5 v 24).

The Trust Board consists of a number of Sir Winston's extended family and other eminent people drawn from many areas of society. About 100 travel fellowships are awarded annually, in selected categories. The programme is appropriately entitled "***The chance of a lifetime"***.

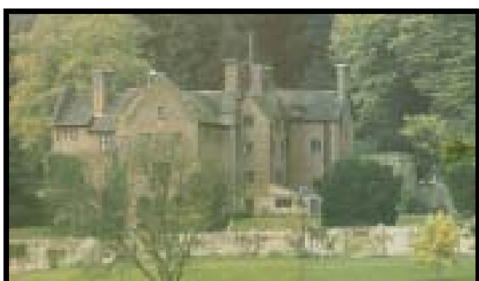
Activities extend far beyond the fellowships and significant collections of historic documents are being established.

Ultimately, the Trust is the guardian of Churchill's vision: a future where the errors of the past are addressed, and the "awful' technologies are developed "in accordance with the needs and glory of mankind".

In a special way the annual travel fellowships enunciate this vision more than archives ever could, because the ideal they represent —"the pursuit of knowledge" — serves as a perpetual memorial.

"It is my earnest hope that pondering upon the past may give guidance in days to come, enable a new generation to repair some of the errors of the former years, and thus govern in accordance with the needs and glory of mankind the awful, unfolding scene of the future."
Sir Winston Churchill

Chartwell— The Family Home



Chartwell Manor

The visit to Chartwell provided a peaceful environment to reflect on the travel fellowship and the qualities that have made Sir Winston Churchill so special.

It was interesting to learn the family motto in Spanish " Fiel Pero Desdichado" translates to "faithful but unfortunate". This must have had special significance for a man who experienced many reversals and adversities, but ultimately whose tenacity and vision brought outstanding success and international recognition: the Knighthood of the Garter, the Nobel Prize for literature, and the Citizenship of the U.S.A.

Chartwell contains an extensive collection of historic objects and memorabilia that add reality to the legend. However, my foremost impression was that this was a family home.

This is evident in the very personal character of many rooms, which are presented to show the everyday life of the Churchill family. For example, the study, dominated by ancient oak beams, appears essentially as Churchill might have left it in 1964 (Parker, 1991) The family atmosphere, and the gardens, lawns, and lakes must have provided a welcome escape from the pressure of government for Sir Winston.

Chartwell was a perfect ending to the "Odyssey of Discovery" that had involved 43,064 kilometers of air travel, 960 kilometres by road, and 28 separate engagements, that included visits to 7 hospital campuses, observation of 19 surgery cases, and attendance at 3 Conferences. The enduring memory of the travel fellowship was people rather than places.

For some brief weeks, in May and June 2000, my path crossed those of a "few" to whom so much is owed.- clinicians, scientists, and surgeons who are quietly transforming the quality of life outcomes for so many patients and their families.

Sir Winston's Study

Final Impressions

This Churchill fellowship has shown the success of intraoperative monitoring in reducing neurological deficits during brain and spine surgery in both the USA and the UK. As a result, there is evidence that the technology continues to evolve rapidly and that the surgical applications are being extended.

Equally the visits showed that the neurophysiological measurements have not replaced the skill and judgment of the surgeon, and indeed most benefit is derived by surgeons who understand the strengths and weaknesses of the procedures.

In addition, interaction and collaboration between the surgeon and the monitoring clinician is essential, because the power of the measurements comes through valid correlation with the surgical events.

While there is no evidence that a single profession is likely to establish exclusive practice in all areas of intraoperative monitoring, it is apparent that the transfer of clinical expertise facilitates some specialty areas. For example, the special expertise of neurophysiologists in mapping cortical centres was obvious from conference presentations, and equally an audiologist's knowledge of hearing greatly facilitates the measurement of auditory evoked responses.

The American Society of Neurophysiological Monitoring (ASNM) continues to play an important role in promoting the field through education and training, and can provide a model for other countries.

The challenge of "remote" or "tele-presence" monitoring must be addressed, particularly with respect to the supervision of monitoring technicians.

New electrode and cable technologies, such as the Cueva c-electrode for the cochlear nerve, are likely to revolutionise monitoring strategies. These could include ultra-flexible connecting cables, to facilitate the placement of electrodes in fragile nerve pathways, and bio-compatible electrodes, such as the cultured-neuron probes.

Further changes to the monitoring procedures are likely to result from different stimulation and measurements paradigms, such as transcranial magnetic stimulation, and laser-Doppler measurements of blood flow.

However, the potential enhancements in the quality of patient care will not occur unless the resources are allocated both for research and the routine application. The strength of basic research in neurophysiology and its associated areas was impressive in both the USA and the UK. This was clearly demonstrated by the range of papers presented at the conferences.

A common observation was that a group of enthusiastic clinicians can achieve success even in the most unlikely environments. Small, but incremental improvements in hospital services, often in partnership with community groups, can generate the momentum for the establishment of significant programmes.

Comparing the current intraoperative monitoring services in the USA and the U.K. demonstrates that access to technology can be limited by the funding structure of the health services. The most vigorous service has emerged in the largely privately funded US system, whereas the publicly funded NHS system in the UK is less active. However, the real issue is more likely to be fund allocation, rather than private versus public provision i.e., it likely that surgeons in the UK are less eager to "buy" a new technology, by diverting funds from another area, than the clinicians in the USA are to "sell" an already funded service to the surgeons.

Because intraoperative monitoring brings together expertise from many disciplines and the knowledge base for the clinical practice is formidable, no single clinician can master all aspects, particularly as new technologies are introduced. The development of effective programmes appears to rely on the establishment of strategic alliances between clinicians and surgeons, universities and hospitals, and collaborative research projects.

In conclusion, intraoperative monitoring is not a skill that can be easily acquired from books or research publications. The opportunity to observe the intricacies of procedures performed by experienced clinicians enables improvements to be confidently introduced.

Even in the age of increased information accessibility, personal exchanges are vital as the nuances of the procedures are so dependent on the almost unique context that exists within each operating theatre.

In addition, if the best health outcomes are to be achieved, then the national service must periodically be "bench marked" against international models of best practice.

Surgery in the new operating theatres at the Princess Alexandra Hospital

Future Implications

Biomedical engineering has the potential to deliver major improvements in neurophysiological monitoring. In particular, the emerging technologies, in the areas of biosensor development, the miniaturization of recording devices, and medical telemetry, are revolutionising health monitoring systems and could have applications in the operating theatre (Hines, 1996; Cellar, Lovell, and Chan, 1999). Even the more modest advances in electrode and equipment design could significantly enhance monitoring practice.

Barriers to Progress

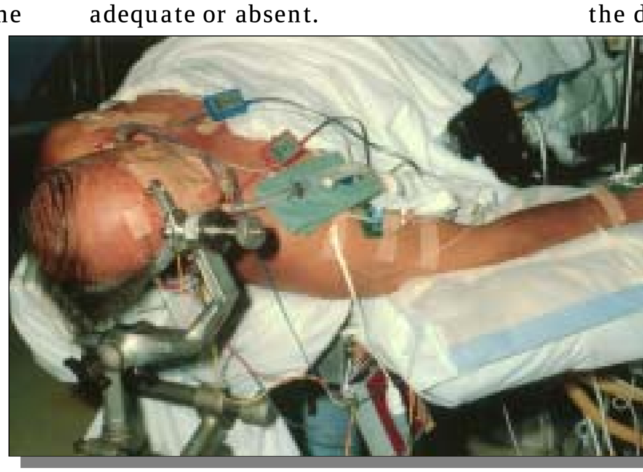
In reality, the barriers to progress are rarely technological, because often the technology tends to lead the practice. For example the introduction of the Cueva c-electrode (Cueva, Morris, and Prioleau, 1998), that perhaps for the first time enables reliable real-time monitoring of cochlear nerve function, has not yet been produced the potential improvements in hearing preservation surgery. The delay in the adoption of new technology is due to clinical inertia. Exploiting new applications in the operating theatre environment is particularly challenging.

There is evidence that nerve monitoring does not always made the surgeon's task any easier, because the goals become more complex, and the quality of life outcomes more demanding. In practice, the identification of nerve structures only protects in so far as the mechanisms of injury are understood and the primary objectives of the surgery can be achieved while protecting the integrity of the nerve and the blood supply (Colletti, and Fiorino, 1998; Guerit, 1998)

The most influential factor in the introduction of intraoperative monitoring in the USA was the active support of surgeons.

Despite the evidence that nerve monitoring improves surgical outcomes, a few surgeons view the technology as optional. While I have observed a number of perhaps less complicated cases in which intraoperative monitoring contributed little to the surgical outcome, the research shows an overall benefit (Wiedemayer, Fraser, Sandacioglu, Schafer, and Stoke, 2002). In addition, "simple" cases provide essential preparation for the more "complex" and a pre-operative distinction between "simple" and "complex" can be impossible to make. Of greater concern is the observation that a surgeon, with a low commitment to monitoring, can provide the clinician with such minimal information as to make the monitoring becomes ineffectual.

Funding issues are a universal barrier to progress, both in terms of research and service provision. The ramifications can be extensive, as illustrated by the failure of a credible spinal cord monitoring service to develop in Australia. Internationally, nerve monitoring during spine surgery is recognized as best practice (Macri, De Monte, Greggi, Parisini, Zanoni, and Merlini, 2000), and dominates nerve monitoring services in the USA. In addition, Australian surgeons regard it as desirable, many hospitals have the evoked potential equipment required, and the clinicians with the neurophysiological expertise — yet services are either inadequate or absent.



The pioneering of cochlear nerve monitoring at the Princess Alexandra Hospital.

One possible explanation for this aberration is the influence of Medicare on the funding arrangements. Because there are no specific items in the schedule of services for intraoperative monitoring; and the semi-relevant electrophysiological items, based on short clinical procedures, do not allow for extended intraoperative procedures (typically 4—16 hours), there is little incentive for a private service. Public services are also impacted, as hospitals are reluctant to fund new initiatives, particularly without private sector precedence.

A questionable barrier to introducing routine intraoperative monitoring could be the lack of qualified clinicians. However, this is not supported by three decades of experience in the USA. Historically anaesthetists, neurologists, neurophysiologists, and audiologists have all contributed to the development of the service. The existence of the American Society of Neurophysiological Monitoring is evidence of the success of the communion of clinicians and surgeons that have fostered the technology. Such a strategic coalition could evolve in Australia

However, proficiency in the operating theatre is more than a simple transference of clinical skills to a new environment. Intraoperative monitoring is intrinsically challenging because of the demand for immediate interpretation of complex neurophysiological measurements which is compounded by electrical artifacts. Anecdotal reports suggest that equipment artifacts have commonly precipitate a crisis of confidence in the operating theatre which has completely undermined inexperienced clinicians.

A final lesson from the US experience is that once services reached a critical mass, medico-legal concerns provided the impetus for general adoption.

(Continued on page 18)

Future Implications

Audiology provides the clinician with an unique opportunity to participate in the diagnostic, intraoperative, and rehabilitative aspects of patient management

Competencies

Much was achieved in Queensland during the pioneering phase of intraoperative monitoring, and this occurred without research or significant publications. However, in the future professional competencies are likely to be increasingly important.

The conferences demonstrated the broad knowledge base underlying neurophysiological monitoring in the scope of the basic and clinical research presented from the fields of neurology, neurophysiology, electrophysiology, bio-engineering, and audiology. In addition, this knowledge must also extend to the surgical aspects, in relation to the pertinent anatomy of the structures at risk, and to the anaesthetic procedures in relation to changes in physiological status that influence the neurophysiological measurements.

No profession appears to have all the attributes and if Australia is develop a world class intraoperative monitoring service, new links will have to be forged between the key clinicians. Such professional linkages were a key feature of the centres of excellence visited. Ultimately these linkages could be formalized into centres of excellence structured around neurotology, and neurosurgery. There are numerous examples of such units in the USA and the UK.

A key benefit of such units is that experience is not be diluted across too many teams. The “learning curve” in specialty areas is an important consideration in a country with a total population-base exceeded by many cities overseas.

A unit has many advantages in terms of efficient management, and professional synergies. There is evidence that significant research benefits can flow from the common focus. There is also an increased capability to exploit new technologies because clinical expertise can be transferred to the surgical unit e.g., with transcranial magnetic stimulation (Terao and Ugawa, 2002). In addition, it was clearly evident that links with universities facilitated the whole process.

Key Players

A feature of the major centres was that the programmes had often been established through the vision and sustained efforts of one key individual.

Common to those individuals was the ability to effectively communicate the vision, and mobilize support through established professional networks. The diversity of clinicians providing intraoperative monitoring makes it difficult to further characterise such individuals, although Professor Bob Keith suggested “stamina and a good bladder” are useful assets!

Volunteer support groups also have a key role to play. Community involvement, particularly in supporting the patients and families can be crucial. A good example of such a group is “Brainwaves” in Belfast, because it has evolved beyond the limitations of the traditional patient organisation into a family and community based support group.

However, in the final analysis, it is the surgeon who is the key player. Intraoperative neurophysiology monitoring, like radiology, or pathology, is one of the information streams, that contributes to the complex decisions underlying surgery. It is the surgeon who determines the priority accorded to each.

The Patient

In conclusion, the contribution of nerve monitoring to the success of surgery can only be judged ultimately in terms of the quality of life outcome for the patient. Surgery is a battle fought and won on a case by case basis, and no case is “just another patient”. This is expressed so clearly below by Ged Cosgrove, one of our patients.

> **“My one certainty was that I had absolute confidence in my (surgeons) — There wouldn’t be better treatment available anywhere in the world and they made me feel like I was more than just another patient”.**
> **Ged Cosgrove (2002) from his book “On the Road to Life” which is a personal account of brain surgery in May 2000.**

Nerve monitoring during brain surgery is one part of that “awful unfolding scene of the future” envisioned by Sir Winston. This Churchill Fellowship has given more substance to the Australian vision of how that future could become a reality.

The Bob and June Prickett Churchill Fellowship

It was my special privilege to receive a Churchill Fellowship sponsored by a fellow Queenslander and Churchill Fellow (1967), Mr Bob Prickett. The fellowship not only enabled the exceptional opportunity to travel to centres of excellence in nerve monitoring and audiology, but the prestige opened doors to an unrepeatable experience.

It is difficult to predict the final outcome of this fellowship in terms of the treatment of patients with brain tumours in Australia, but this award inspired me to fresh endeavours to improve nerve monitoring services.

Bob Prickett with a Citation presented by Rear-Admiral Ian Richards BEc, RAN (Rtd) at the Queensland Churchill Dinner 1999

Through my PhD research, and clinical studies, I continue to build on the foundation of knowledge afforded by this fellowship. Conferences and workshops have already provided opportunities to communicate these ideas to other clinicians, and perhaps through the University courses I teach, new generations of audiologists will also be inspired.

My conclusions were that nerve monitoring technology will continue to evolve and that an effective service has considerable potential to diminish the risk of neural deficits from brain and spinal cord surgery.

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