NEUROMONITORING - A 35-YEAR PERSPECTIVE

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MY BACKGROUND

1966: BS, Electrical Engineering, IIT
1966-72: PhD, Biomedical Engineering, Marquette Univ.
"Mechanisms of Electroanesthesia"
• First exposure to evoked potentials (flash visual EPs); acquired on a computer of averaged transients (CAT)

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BACKGROUND FOR EVOKED POTENTIALS

I. 1875 – Richard Caton discovers perpetual fluctuation of electrical potential (EEG) from animal cortex.
II. Caton also discovers that electrical potential is influenced by sensory visual stimulation. Thus, he discovers evoked potentials.

BACKGROUND FOR EVOKED POTENTIALS

1. 1947 – G.D. Dawson introduces photographic superimposition technique to study evoked potentials. This is a duplication of 19th century method devised by Francis Galton.
2. 1951 – Dawson introduces summation technique thereby initiating present-day growth in study of evoked potentials.

RECOGNIZE THIS FELLOW?

Manfred Clynes
Born: August 14, 1925
Origin: Vienna, Austria
Occupations: scientist, inventor, concert pianist
Years active: 1940-present
Invented the CAT (Computer of Averaged Transients) in 1960
$10,000 portable computer permitting the extraction of responses from ongoing electric. The CAT quickly came into use in research labs all over the world, marketed by Technical Measurements Corp., advancing the study of the electric activity of the brain (Enabled the clinical detection of deafness in newborns).
DEVELOPMENT OF THE NEED FOR SC MONITORING

• 1960s
  • Dawn of the use of aggressive surgical approaches and instrumentation for correction of severe spinal deformities

• 1970s
  • Scoliosis Research Society (SRS) report
  • Use of instrumentation to treat scoliosis resulted in significant incidence of acute neurological complications - J Bone Joint Surg 1975; 57:404-8.

DEVELOPMENT OF TECHNIQUES FOR ASSESSING SPINAL CORD FUNCTION

• Wake-up Test

• Invasive Monitoring Techniques
  • LE peripheral N. Stim, SC Recording
  • SC Stimulation and SC Recording

  • Due to their invasiveness, these techniques did not gain widespread popularity.

DEVELOPMENT OF TECHNIQUES FOR ASSESSING SC FUNCTION

• Use of non-invasive traditional SSEPs

In September of 1977, Jerald Brodkey and Clyde Nash organized the first workshop on spinal cord monitoring.

In January 1979, 35 years ago, another spinal cord monitoring workshop was organized in St. Louis which I happened to attend.

However, at this time my attention was drawn to another modality.

HISTORY OF DSSEPS


  • DSSEPs are reliably obtainable from cutaneous lumbo-sacral root dermatomes
  • Stimulation of individual root levels is more sensitive for establishing and localizing the level of cord function than is common peroneal stimulation
  • DSSEPs appear useful in sequential evaluation of patients with myelodyplasia


  • Dermatomal SSEPs confirmed lumbosacral root entrapment in 92% of patients
  • They were more often “root” diagnostic than myelography
  • They thus appeared to provide valuable support in the selection of patients to undergo disk operation
INITIAL DERMATOMAL SSEP RECORDING MONTAGE

DERMATOMAL DISTRIBUTION FOR LOW BACK PAIN STUDIES

L5 AND S1 STIMULATION SITES

EARLY (1979) DSSEP FINDINGS

ROOT COMPRESSION DSSEPS VS. PTN SSEPS

NICOLET PATHFINDER II

Tracor Northern – 1 Channel Machine

Toolekis JR, Scarff TB, Dallmann DE. Nicolet Potentials, 1(5); Fall, 1982.
Besides Nicolet, other equipment manufacturers at this time included:

- Bio-logic
- Cadwell
- Dantec
- Neuro Diagnostics, Inc.
- Nihon Kohden
- RTI, Inc
- Siegen
- Teca
- Tracor Northern

In September, 1981, the AMA reported that evoked potentials are beginning to play a large part in diagnostic, prognostic, and monitoring techniques.

First Society of its kind in the United States
- Membership of about 125 from Illinois, Indiana, Michigan, and Wisconsin
- Existed until about 1993

We even had a Constitution and Bylaws!

And a newsletter!!!
SSEPS ARE NOT SUFFICIENT

- Motor pathways
  - Blood supply from anterior spinal artery
- SSEPs
  - Blood supply from posterior spinal arteries
  - Sensitive to mechanical distortion of spinal cord
  - May not be sensitive to ischemic events that may produce motor deficits
- Therefore, developing techniques for directly monitoring motor function was of great interest


MONITORING MOTOR FUNCTION

TRANSCRANIAL STIMULATION

- TcMEPs
- TcCMEPs
- Usage concerns
  - Considered experimental
    - Required informed consent; No FDA approval until 2002
  - Contraindications
    - History of epilepsy
    - Vascular clips or shunts
    - Cardiac pacemakers or other implanted devices
    - Skull defects

In 1983, I joined Dr. Tony Koht and Dr. Tod Sloan at the Northwestern University Medical Center and helped to organize this symposium.

This was the start of lasting friendships and many successful collaborations.

ACUTE SPINAL CORD INJURY

STIMULATION SITES USED TO ELICIT DSEPS

ACUTE SPINAL CORD INJURY
NORMAL DSSEPS
ACUTE SPINAL CORD INJURY DIAGNOSTIC STUDIES (APPROX. 1985)

TRANSCRANIAL MAGNETIC STIMULATION (TMS)

EARLY TMS ATTEMPTS

SKULL CAP VERSION OF THE COIL

TOO MUCH TMS!!

DERMATOMAL SSEP USE IN THE OPERATING ROOM

- Adequacy of nerve root decompression
THE 1990'S

- Utilization of pedicle screw instrumentation became widespread and with it a high incidence of misplaced screws and resulting neurological deficits
  - 2% - 7% of patients (Matsuzaki et al., Spine 15:1159, 1990)
  - 2% - 10% of patients (Myers et al., Spine 20:144, 1995)

- We had one such occurrence at Northwestern that resulted in our changing our monitoring practice.

FALSE NEGATIVE SSEP RESULTS

STIMULATION SITES AND TYPICAL INTRAOPERATIVE DSSEP RESPONSES

The start of the ASNM

The first annual meeting of the ASEPM was held May 11-12, 1990 in Livonia, Michigan.

Dr. Jack M. Kartush was the first president of the Society.

A new name for the Society

Goals:
I. Education
II. Quality assurance
III. Possible role in certification
IV. Standardizing intraoperative documentation
V. Demonstrating the efficacy of monitoring to assist in consistent patient reimbursement

The ASNM has been and continues to be a forum for the presentation and discussion of various monitoring modalities as well as other issues.

THE 1990'S

- Many other significant events occurred during this time:
  - 1991 – 95920 CPT code established
  - 1996 – Certification exam for techs offered
  - 1999 – D.ABNM exam offered
  - EMG introduced as a Monitoring Modality for Assessing Nerve Root Function
**Triggered EMG Activity**

- For testing markers, taps, tapped holes, and screw placements
- Stimulus intensity for excitation of normal nerve roots reported to be 1.2 - 3.8 mA*
- Using 3.1 Hz, 0.2 msec pulses to stimulate hardware, triggered activity at < 10 mA provides an indication of potential causes of nerve root irritation or injury *
  - Pedicle Wall Breakthrough
  - Misplaced hardware

  *Calancie et al., Spine 19: 2780, 1994

**Spontaneous and Triggered EMG Activity**

**Study Results**

- 5357 screws were placed in 1024 patients
- Train-of-4 testing was used
- Spontaneous and triggered EMG activity were monitored from appropriate muscles
- Triggered EMG activity was elicited by constant current 3.1 Hz, 0.2 msec pulses (*Calancie et al., Spine 19: 2780, 1994*)
- Activity was considered a significant event if:
  - Spontaneous: sustained > a few seconds
  - Triggered: < 10 mA; resulted in visual inspection

  *Teleki et al., J Spinal Disorders 2003

**Results of EMG Monitoring**

- 42 significant spontaneous events (4.1% of all patients)
- 217 significant triggered events with screw testing (4.1% of all screws) in 205 patients (20.2% of all patients)
- After visual inspection:
  - 137 screws were left in place
  - 29 screws were removed and redirected
  - 51 screws were removed and not replaced

**Stimulation Threshold and Screw Placement**

- Incidence of postoperative neurological deficits has been reported to be 2-10%
- At 2%, our expected incidence of deficits in 1024 patients should have been 20 patients
- Our actual outcomes were:
  - One patient had a new post-op deficit
    - 4 mA threshold, screw left in place
    - One patient had a false negative finding
    - Thresholds > 20 mA, new post-op neuro deficit
- Therefore, EMG monitoring is effective for reducing the incidence of new postoperative neurological deficits
MONITORING MOTOR FUNCTION
TRANSCRANIAL STIMULATION
• More evidence that MEPs were needed
  • SSEP false negative findings
• Equipment and other issues
  • Devices for providing effective transcranial electrical stimulation were not commercially available or FDA approved
  • Digitimer marketed a single pulse stimulation device in 1992
  • Commercial multipulse stimulation device still being developed
• As a result:
  • Adoption T~CE~MEPs techniques was slow and did not gain widespread usage for many years.
  • Meantime, use of another technique prevailed.

SPINAL STIMULATION WITH PERIPHERAL NERVE RECORDINGS
• Neurogenic motor evoked potentials (NMEPs) introduced in 1988
• Reported to be more sensitive and specific than SSEPs to effects of spinal cord compression, ischemia, and distraction
• No possibility of eliciting seizures
• Minimally invasive
• No restrictions on use of muscle relaxants

Electrodes Used to Elicit NMEPs

MONITORING MOTOR FUNCTION
NMEPs
• Well-defined, repeatable averaged responses (N=100)
• Claimed to consist of early biphasic motor and late polyphasic sensory components, based on:
  • Faster conduction velocities of motor components
  • Findings from initial collision studies

Technique for Eliciting NMEPs

NMEP Response
MONITORING MOTOR FUNCTION
NMEPS

• Use of NMEPs became very popular
• Modality of choice for eliciting MEPs
• But NMEP use was also very controversial
  • Numerous presentations/papers either supported or questioned NMEPs efficacy for monitoring motor pathway function
  • 1990s: Period of research and experimentation for examining methods of assessing and monitoring motor pathway function

COLLISION STUDY CONCLUSIONS

• Spinally elicited “NMEPs”:
  • Consist of a prominent biphasic sensory component
  • Mediated by the same neural pathways as SSEPs
  • Leppanen R, et al. 1997 ASNM Annual Meeting, Chicago, IL
  • Toleikis JR, et al. 1997 ASNM Annual Meeting, Chicago, IL
  • These studies employed the same collision methodology of the earlier study.

• Possible small polyphasic motor component
• Therefore, after over 10 years of usage, it was determined that NMEPs were a misnomer for these responses.

FINAL NMEP REMARKS

• In 2002, the use of MEPs was made available on a routine basis when the first device for producing multipulse TceMEPs was granted FDA approval.
• However, despite the collision study results and other evidence, a 2002 survey indicated that 15/39 centers continued to use spinal stimulation with recording of neurogenic (or myogenic) MEPs as their preferred technique to elicit MEPs during SC monitoring.
• Their use now seems a thing of the past.

A RECURRING MESSAGE

“With an ever-decreasing willingness and ability to pay, health care providers are now demanding outcome studies for both new and established technologies. Neuromonitoring advocates must be equipped with these statistical tools to provide accurate and convincing data on the sensitivity, reliability and cost-effectiveness of our neurophysiological methods. Otherwise, we will be viewed as part of the problem rather than the solution.”

Harvey Edmonds, Ph.D.
4th Annual ASNM Meeting
May 25th, 1993
Baltimore, Maryland

A NEW USE FOR TMS

Magnetic therapy easing depression

Chicago Tribune, October 18, 2014
WHAT DOES THE FUTURE HOLD?

• Neuromonitoring will continue to have an important role in patient care.
• However, the extent of that role will likely be dictated by a number of factors:
  • Proven efficacy
  • Monitor only during certain portions of procedure?
  • Correlation to patient outcome?
  • Did monitoring raise a difference or only predict outcome?
  • Reimbursement such as the use of “bundling”?
  • The requirements for remote monitoring
  • What type of patients, i.e., only Medicare?
  • How many patients?
  • Available resources