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UTILITY OF INTRAOPERATIVE NEUROPHYSIOLOGICAL MONITERING (IONM) IN VARIOUS SURGERIES AT A TERTERY CARE HOSPITAL IN KARACHI, PAKISTAN.

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ABSTRACT

Objective: Utility of real time multimodal intraoperative neurophysiological monitoring in different intracranial, spinal and peripheral nerve at a tertiary care hospital in Karachi Pakistan.**Study design:** A retrospective observational study **Place and duration of study:** Patients admitted in neurology and neurosurgery services as well as out-patients presenting to the clinical neurophysiology lab at the Aga Khan University Hospital Karachi between January 2012 to December 2013.**Methodology:** The study consisted of 14 patients undergoing different intracranial, spinal and peripheral nerve surgeries including correction of spinal scoliosis, spinal cord lesion ,acoustic neuroma resection and plexus and peripheral nerve repaired. Among the electrophysiological methods patients were monitored using including SSEP, BAEP and EMG (free-running and triggered). EMG was done on Nihon Kohden Viking Quest from Nicolet Co. For SSEPs GillioNT from EB Neuro Co, and for NIOM carefusion from Nicolet Co was used.**Results:** Mean age of patients was 39 years (4-70 years). SSEP, BAEP and EMG (free-running and triggered) were recorded, during various surgeries. Of total 14 patients, no patient expressed a significant alert to prompt reversal of ongoing intervention. No patients awoke with a new neurological deficit and none had significant intraoperative SSEP /EMG alerts. **Conclusion:** Neurophysiologic intraoperative monitoring appears to be the modern standard of care for monitoring functional integrity and minimizing the risk of iatrogenic damage to the central and peripheral nervous system.

Keywords: electrophysiological monitoring, spinal cord surgeries, somatosensory evoked potentials, brainstem evoked potentials

INTRODUCTION

IONM is used to monitor thefunctional integrity of the central or peripheral nervous system in “real time” ,that is during the ongoing operative procedures. It alarms the surgeon to potential neurologic injury and prompt implementation of corrective measures to prevent permanent disability, thus improves surgical outcomes[1]. IONM is performed using a variety of neurophysiologic techniques including; Evoked potentials (EPs), Electromyography (EMG), Nerve action potential (NAP)and Electroencephalography (EEG) to monitor the functional integrity of certain neural structures (e.g. nerves, spinal cord and parts of the brain) during surgery. [2]

Somatosensory Evoked Potentials (SSEP)

SSEP evaluates the integrity of the large fiber sensory system. SSEP are obtained by direct electrical stimulation of peripheral nerves and recording at different levels within the neuraxis. Serially recorded responses are compared with laboratory norms. Establishing a reproducible baseline recording prior to any positioning or surgical manipulations is important. Changes from the baseline responses are the most important indicators of neurological dysfunction. Blood pressure, temperature and volatile anesthetics effects (halogenated and nitrous oxide) should be monitored simultaneously with the neurophysiologic data. [3] SSEP uses in different surgical procedures like spinal surgery, carotid surgeries including endarterectomy, cerebral aneurysm surgery, Aortic cross-clamping and localization of sensorimotor cortex.

Brainstem Auditory Evoked Potentials (BAEP)

BAEPs are short-latency potentials reflecting the depolarization of several structures within the auditory pathways. It is essential that these baseline BAEPs be recorded using the same parameters for stimulation and recording that are to be used for intraoperative monitoring.

Anatomical localization of BAEP Waves:-

Name Wave	Anatomical location (probable)
I	Distal acoustic nerve (Action potential)
II	Proximal acoustic nerve / Cochlear nucleus
III	Lower pons
IV	Mid/upper pons
V	Lower midbrain(inferior colliculus)

Recordings are obtained by stimulating with auditory clicks in the ear. Compression, traction, thermal injury, and ischemia are the commonest causes of surgical injurries to auditory system. Ischemia of the cochlea occurs from trauma to the internal auditory artery and causes a sudden loss of all BAEP waveforms. BAEP is insensitive to anesthetics including volatile agents. [4] Changes in latency, interlatencies difference and amplitude of BEAP waves I, III and V can be monitored during CPA tumors surgery, microvascular decompression (MVD) of VII nerve,V nerve and IX nerve, skull base surgery, suboccipital decompression and vascular surgeries of posterior circulation.The stimulus use for BAEP is an auditory click which is a broad band sound range between (500-4000 Hz) delivering various audio frequencies so BAEP cannot exclude a specific frequency hearing deficit or a mild hearing deficit(<500hz). BAEP can change dramatically in neonates and infants before the age of two years.

Motor Evoked Potentials(MEP):-

SSEP monitoring was used in the past to reduce the risk of motor system injury. [5]However, significant motor deficits have been seen in patients undergoing spinal surgery despite normal SSEPs.[5][6] In conjunction with MEP and SSEPs, the anterior and posterior portions of the spinal cord can be monitored together. MEPs are sensitive to volatile anesthetic(halogenated and nitrous oxide) and especially neuromuscular blockade. Motor evoked potentials (MEPs) are obtained by electrically stimulating the brain and recording the response over the spinal cord (Direct = D and Indirect = I waves), peripheral nerves (nerve action potentials), or muscles (compound muscle action potentials). For robust MEP signals, complete loss of MEP signal or abrupt significant decrease in amplitude of 80% or more in the absence of an explanation other than surgical injury is considered significant. Gradual changes in MEP signals more commonly reflect systemic factors or an "anesthetic fade" phenomenon [7].Indications for MEP monitoring include any surgery risking motor injury. The most common indications arise during tumor or epileptic focus resections near the motor cortex or corticospinal tract, intracranial aneurysm clipping, posterior fossa surgery, craniocervical junction and spinal operations, spinal cord procedures and tethered cord or caudaequinasurgeries.Vascular indications include descending aortic procedures, spinal arteriovenous malformation interventions and carotid endarterectomy.Safety issues include thermal injury of the brain or scalp, bite injuries, seizures, movement-induced injury and arrhythmias. Relative contraindications include patients with epilepsy, cortical lesions, skull defects, intracranial vascular clips, shunts, or electrodes; and pacemakers or other implanted bioelectric devices. [8]

Free-running and Triggered EMG :-

Free-run EMG (f-EMG) consists of recording spontaneous muscle activity, thus allowing its real-time assessment. IONM use as a monitoring tool helps for detecting surgically driven mechanical irritation of the peripheral nervous system and of the cranial nerves, before irreversible damage to these structures occurred. Triggered EMG consists of applying an electrical stimulus, directly on the peripheral motor nerves or roots, for eliciting CMAPs to be recorded in the corresponding muscles. Thus, it can be used as a mapping tool for detecting the location of peripheral or cranial nerves that may be difficult to distinguish from tumoral, fibrous and fatty tissues during surgical resections. Triggered EMG can also be used in checking the functions of injured nerves, roots, or trunks by assessing the electrical transmission through such structures and comparing it with a healthy (or presurgical) baseline. Free-run and triggered EMG uses in facial nerve/other cranial nerve monitoring, selective dorsal rhizotomy,tethered spinal cord release and pedicle screw placement.[9][10]

Methodology:-

We evaluated the retrospectively collected neuromonitoring data of 14 consecutive post operated cases including idiopathic spinal scoliosis, tethered cord syndrome, intramedullary spinal cord tumor, Acoustic neuroma , Post traumatic right Brachial plexopathy repair, Right Spastic hemiparesis by independent observer from 2012 -to -2013. Patients with established diagnosis with age group 4 to 70 years operated at single institution Aga Khan University Hospital Karachi, Pakistan. Retrospectively collected medical records, intraoperative monitoring records, operative narratives and outpatient clinical notes for all patients were reviewed. SSEP, Free-running and Trigged- EMG and BEAP were the used methods of IONM. Important demographic and clinical data were documented including age, gender.Preoperative neurological status obtained from the outpatient clinical notes, baseline neurophysiologic and radiographic data were reviewed by an observer. The operative reports, intraoperative monitoring records were recorded retrospectively and to determine specific intraoperative events, changes in the amplitude or latency of SSEP/BEAP and neurotonic discharges and CMAP response of Free-running and Trigged- EMG. Filumterminale or other tether wereidentified before transection by help of EMG monitoring of sphincter and lower limb muscles.

Monitoring:-

All neurophysiologic monitoring was performed by consultant neurophysiologist and trained technologists with experience in IONM. Baseline (Pre operative) and serial neurophysiologic monitoring was done. SSEP, BEAP, Free-running and Trigged- EMG were recorded pre and per operatively. Repeated recordings were taken from both lower and upper-extremities for Free-running and Triggered- EMG potentials. Lower-extremity (posterior tibial nerves) and upper-extremity (median nerves) were recorded for SSEP.

Somatosensory-evoked potentials (SSEP):-

Both cortical (N20,P37) and peripheral (popliteal and erbs potentials) SSEP were elicited by a 300-μs square-wave electrical pulse presented, in turn, to the posterior tibial and median nerves at a rate of 4.7/s. Stimulation intensity levels ranged from 25 to 45 mA.The recording band pass was typically 30 – 1 kHz (-3db). An analysis time of 75-150 ms for lower limb and 50 ms for upper limb was used.Generally 250 – 1000 trials were needed; the number of trials depended on the amount of noise present and the amplitude of the SSEP signal itself (signal to noise ratio)[11].Cortical potentials were recorded from standard disc EEG electrodes affixed to standard cranial locations and referenced as per international criteria of monitoring [12][13][14][15].

Continuous Free-Running EMG Monitoring:-

Identification of neurotonic discharges are used to alert the surgeon of inadvertent trauma to roots and peripheral nerves in an effort to prevent irreversible nerve injury. Electromyography was typically recorded using paired intramuscular needle electrodes, which were insertedafter the patient was anesthetized but before the surgery started. The time base was100 msec/division and the display sensitivity was 50microV/division [2].

Stimulus-Triggered EMG :-

Intraoperative CMAP responses are typically recorded using intramuscular needle electrodes and submaximal stimulation and polyphasic responses with variable onset latencies and amplitudes [16].The stimulator used was typically a hand-held monopolar or bipolar sterile device used within the operative field by the surgeon. The time base was 10 msec/ division and the display sensitivity was 50 microV/division.

Significant alert:-

Significant alert demanding intervention was defined as persistent neurotonic discharges in continuous free-running EMG monitoring and all-or-nothing CMAP-responses in Stimulus-triggered EMG monitoring, $\geq$50% of the amplitude reduction and or increase in the latency by $\geq$10% of the SSEP relative to a stable baseline.[2][3][13][17]

Results:-

There were 14 patients (8 male, 6 female patients) ranging in age from 4 to 70 years (average age 39 years old) at the time of surgery. Preoperative baseline monitoring with the standard neuromonitoring protocol of SSEP was available in all required patients. A total of 14 patients underwent for different corrective surgeries. All 14 patients did not show any signal alert and had no postoperative new neurodeficit. However one patient with acoustic neuroma on clinic follow up had worsening of facial weakness (House-Brackmann grade from II- to –III). Out of 14 patients in this study, six patients were spinal scoliosis, four patients had tethered cord syndrome with or without lipo/meningomyelocele, one patient with intramedullary thoracic spinal cord tumors, one patient with acoustic neuroma, one patient with post trumatic right brachial plexopathy and one patient with right Spastic hemiparesis. Filumterminale or other tether were identified before transection by help of triggered-EMG monitoring of sphincter and lower limb muscles.Out of the total of 14 patients, eight patients showed no neurodeficit in outpatient clinic and five patients were lost to follow up while one patient showed minimal worsen of facial neuropathy.

Serial No	***Indication***	***Surgical procedure***	***IONM-Modality Used***	***Alarm to surgeon***	***Follow Up***	***Outcome***
01	Idiopathic scoliosis	posterior spinal fusion(PSF) and instrumentation	SSEP (post:tibial)	No change in lat: or Amp: of P-37 wave	Lost	-----
02	Tethered cord synd:	Laminectomy and filum terminale or other tether transection	SSEP (post:tibial)	No change in lat: or Amp: of P-37 wave	Lost	------
03	scoliosis	posterior spinal fusion(PSF) and instrumentation	SSEP (post:tibial)	No change in lat: or Amp: of P-37 wave	No deficit noted	good
04	Right Spastic hemiparesis	Right Selective motor post tibialfasiculotomy	Free-running and Trigged-EMG of right tibial nerve.	No neurotonic discharges and intact CMAP response.	No deficit noted	good
05	Post trumatic right Brachial plexopathy	Exploration and neurotizationof right brachial plexus	Free-running and Trigged-EMG +SSEP(median)	No neurotonic discharges and intact CMAP response. No change in lat: or Amp: of P-37 wave	No deficit noted	good

06	scoliosis	posterior spinal fusion(PSF) and instrumentation	SSEP (post:tibial)	No change in lat: or Amp: of P-37 wave	No deficit noted	good
07	scoliosis	posterior spinal fusion(PSF) and instrumentation	SSEP (post:tibial)	No change in lat: or Amp: of P-37 wave	lost	-----
08	scoliosis	posterior spinal	SSEP (post:tibial)	No change in lat: or	lost	----
09	Intramedullary thoracic spinal tumor	Laminectomy and tumor resection	SSEP (post:tibial)	No change in lat: or Amp:of P-37 wave	Lost	-----
10	Tethered cord synd:+meningomyelocle	Laminectomy and tether transection and tumor resection	Free-running and Trigged-EMG	No neurotonic discharges and identifyfilum terminale or other tether before transection	No deficit noted	good
11	Acoustic neuroma	transtemporal approach	Free-running and Trigged-EMG of CN VII,V	No neurotonic discharges and intact CMAP response innervated muscles.	House-brackmann grade II->III	neurodeficit
12	scoliosis	posterior spinal fusion(PSF) and instrumentation	SSEP (post:tibial)	No change in lat: or Amp: of P-37 wave	No deficit noted	good
13	Tethered cord synd: thoracic lipomeningomyelocle	Laminectomy and tether transection and tumor resection	Free-running and Trigged-EMG	No neurotonic discharges and identifyfilum terminale or	No deficit noted	good

				before transection		
14	Tethered cord synd: lipomeningomyelocle	Laminectomy and partial excision of lipoma without of tether transection	Free-running and Trigged-EMG	No neurotonic discharges.	No deficit noted	good

Discussion:-

IONM is the use of electrophysiological methods such as evoked potentials (e,g.SSEP,MEP,BAEP) and electromyography (EMG) to monitor the functional integrity of certain neural structures (e.g.nerves, spinal cord and parts of the brain) during surgery. The purpose of IONM is to reduce the risk of iatrogenic damage to the peripheral and central nervous system, and provide optimal functional guidance to the surgeon.Patients benefit from neuromonitoring during almost any surgery where there is risk to the nervous system. Most neuromonitoring is utilized by spine surgeons, but neurosurgeons, vascular, orthopedic, and otolaryngologists have all utilized neuromonitoring. The most common applications are in spinal surgery; selected brain surgeries; carotid endarterectomy, ENT procedures, acoustic neuroma resection, parotidectomy and peripheral nerve surgery. Motor evoked potentials have also been used in surgery for TAAA (thoracic-abdominal aortic aneurysms). Intraoperative monitoring is used to localize neural structures, to test function of these structures; and for early detection of intraoperative injury, allowing for immediate corrective measures.SSEP is used to monitor spinal cord function. A baseline pre-operatively is obtained, and if there are no significant changes during surgery the assumption is that the spinal cord has not been injured. If there is a significant change, corrective measures can be taken promptly. More recently transcranial electric motor evoked potentials (MEP) have also been used for spinal cord monitoring. EMG is used for cranial nerve monitoring in skull base pathologies and for nerve root monitoring and testing in spinal surgery. BAEP is used for monitoring of the acoustic nerve during acoustic neuroma and brainstem tumor resections.In 1992, the Scoliosis Research Society issued a position statement regarding the use of neurophysiologic monitoring during spinal surgery. They concluded that, 'A substantial body of research has demonstrated that neurophysiologic monitoring can assist in the early detection of complications, and can possibly prevent postoperative morbidity in patients undergoing operations on the spine [18]. The Scoliosis Research Society considers neurophysiologic monitoring a viable alternative, as well as an adjunct, to the use of the wake-up test during spinal surgery.The goal of neurophysiologic monitoring is rapid detection of any neurological insult during surgical intervention on the nervous system and prompt early intervention, thus reversing the insult and avoiding adverse clinical sequelae. In our study, there was no case that had signal change in SSEP or neurotonic discharges on free-running EMG. Our study supports that neuromonitoring with SSEP and EMG during surgical correction is feasible and provides useful neurophysiologic data to reverse neurological insult. However in our study, IONM for spinal cord surgical correction was done with SSEP only. Isolated SSEP monitoring is not the standard of care anymore [19][20] .With MEP, combined multimodal spinal cord monitoring is more reliable to avoid neurological injury and provides additional information concerning the integrity of all neurological tracts of the spinal cordnot obtained with SSEP alone[21][22] .There are limitations of this study. Firstly all cases of spinal cord corrective surgeries particularly for scoliosis were used only SSEP modality without MEP monitoring due to unavailability in our hospital. Secondly, very few trained neurosurgeons request for neurophysiological intraoperative monitoring and therefore it was a very small sample size. Thirdly, there were no proper grounding setup in the operative room (OR) for otherwise preventable artifacts seen during monitoring. Fourthly, lack of knowledge of drugs effect on neurophysiologic modalities during NIOM by anesthetic team were also noted.

Conclusion:-

Multimodality neurophysiologic intraoperative monitoring appears to be the standard of care for monitoring functional integrity and reducing the risk of iatrogenic damage to the nervous system and to provide functional guidance to the surgeon. SSEP and MEP should be used together for spinal cord surgeries to minimize nervous tissues insults.

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Author's contribution:

Liaquat Ali: Study concept and design, protocol writing, data collection, data analysis, manuscript writing, manuscript review
Ambreen Iqrar: data collection, data analysis, manuscript writing, manuscript review
Bhojo Khealani: Study concept and design, data analysis, manuscript writing, manuscript review