Clinical Policy Bulletin: Intraoperative Electromyographic Monitoring

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Policy

I. Aetna considers intra-operative electromyographic (EMG) monitoring of the facial nerve medically necessary for members undergoing any of the following intra-cranial neuro-otological surgeries:

A. Microvascular decompression of the facial nerve for hemifacial spasm; or
B. Surgery for acoustic neuroma, congenital auricular lesions, or cranial base lesions; or
C. Surgical excision of neuromas of the facial nerve; or
D. Vestibular neurectomy for Meniere's disease.

Aetna considers the combined use of intra-operative EMG monitoring of facial nerve and intra-operative monitoring of somato-sensory evoked potentials not medically necessary.

II. Aetna considers intra-operative EMG monitoring of the facial nerve during cochlear implant surgery, parotid gland surgery, tympanoplasty, or maxillofacial surgery experimental and investigational because its value for these indications has not been established.

III. Aetna considers intra-operative EMG monitoring during selective dorsal rhizotomy medically necessary when selection criteria for the procedure set in CPB 0362 are met.

IV. Aetna considers intra-operative EMG monitoring of any of the following cranial nerves medically necessary for surgical excision of neuromas of these cranial nerves.

- Abducens nerve
- Glossopharyngeal nerve
■ Hypoglossal nerve
■ Oculomotor nerve
■ Recurrent laryngeal nerve
■ Spinal accessory
■ Superior laryngeal nerve
■ Trochlear nerve

V. Aetna considers intra-operative EMG monitoring during spinal surgery experimental and investigational because there is insufficient evidence that this technique provides useful information to the surgeon in terms of assessing the adequacy of nerve root decompression, detecting nerve root irritation, or improving the reliability of placement of pedicle screws at the time of surgery.

Aetna considers intra-operative EMG monitoring during intra-cranial tumor resections experimental and investigational (unless the resection involves a cranial nerve) because there is insufficient evidence that this technique provides useful information to the surgeon.

VI. Aetna considers intra-operative monitoring of the recurrent laryngeal nerve/intra-operative neuromonitoring during thyroid and parathyroid surgery experimental and investigational because its clinical value has not been established.

VII. Aetna considers intra-operative EMG monitoring during hip replacement surgery, or during placement of dorsal column stimulator experimental and investigational because its clinical value for these indications has not been established.

VIII. Aetna considers intra-operative surface EMG monitoring experimental and investigational because its clinical value has not been established.

See also CPB 0181 - Evoked Potential Studies, and CPB 0362 - Spasticity Management.

Background

Cranial nerves (CNs) can be damaged during various neurosurgical procedures. Intra-operative monitoring of the function of CNs by means of electromyography (EMG), compound nerve and muscle action potentials (MAP), and auditory evoked potentials (AEP) has been used to reduce the risk of injuries to these nerves. Intra-operative EMG monitoring of CNs entails electrical stimulation of the proximal (brain) end of the nerve and recording via EMG in the facial or neck muscles. Thus, the monitoring of CNs is done in the direction opposite to that of sensory-evoked potentials, but the purpose is similar to verify the integrity of the neural pathway.

Electromyographic monitoring of the facial nerve (7th CN) is used to predict post-operative facial function after skull base surgery, which is associated with considerable risk to the functioning of the cerebral hemispheres, the brain stem and the CNs. This risk is due to problems associated with maintaining an
adequate blood flow while exposing and removing the tumor, as well as direct or indirect trauma to the brain, perineural tissues and CNs.

EMG Monitoring of Facial Nerve:

Harner and associates (1987) compared with the results of patients who underwent acoustic neuroma resection with (n = 48) or without (n = 48) intra-operative monitoring of facial nerve. They reported that anatomical preservation of the facial nerve in patients with large tumors was substantially improved in the monitored patients (67 %) when compared with those without monitoring (33 %). Although no difference was noted in facial nerve function in the 2 groups of patients immediately post-operatively, the degree of improvement in the monitored group exceeded that observed for those who were not monitored at 3 months, particularly in those with medium-sized and large tumors.

Kwartler and colleagues (1991) compared a group of monitored translabyrinthine acoustic tumor removals (n = 89) to a similar un-monitored group (n = 155) in regard to facial nerve function. Function was assessed immediately post-operatively, at time of discharge, and at 1 year post-operatively using the House 6-point scale. Results were grouped as satisfactory, intermediate, or poor, and were analyzed by tumor size. Facial nerve results were better at all time intervals in the monitored groups, although the difference was not statistically significant at the 1-year interval. There was no difference between monitored and un-monitored patients in the subgroups with tumors smaller than 2.5 cm in diameter. The findings of this study supported the usefulness of intra-operative facial nerve monitoring in improving facial nerve results, especially in larger tumors.

Olds et al (1997) stated that “routine facial nerve monitoring is not considered the standard of care in most communities; however risk of facial nerve injury appears to be greatly reduced when this adjunctive technique is employed”. Spielholz (1997) stated that intra-operative facial nerve monitoring is especially helpful during removal of large (4 cm or greater) acoustic neuromas in which the incidence of facial weakness can reach 31 %. Fabregas and Gomar (2001) noted that facial nerve monitoring for surgery of acoustic neuromas should be considered an absolute standard of care in neurosurgery. This is in agreement with the observation of Ingelmo et al (2003) who stated that intra-operative EMG monitoring of the facial nerve should be used routinely in acoustic neuroma surgery to reduce the degree of post-operative neurological impairment.

Wilson et al (2003) assessed the cost-effectiveness of intra-operative facial nerve monitoring during middle ear or mastoid surgery. The authors concluded that facial nerve monitoring is cost-effective, and its routine use should be adopted to reduce the risk of iatrogenic facial nerve injury during otologic surgery.

The American Academy of Otolaryngology-Head and Neck Surgery (1998) recognized the proven effectiveness of neurophysiologic monitoring of the facial nerve (7th CN), which may minimize the risk of injury to the nerve during surgical procedures in which the nerve is vulnerable due to site of lesion or extent of disease. The American Academy of Neurology (AAN, 1990; Lopez, 2004) stated that brainstem AEPs and cranial nerve EMG monitoring is safe and effective during surgeries performed in the region of the brainstem or inner ear.
Nevertheless, clinical situations need to be chosen carefully, avoiding those in which the nervous system is only at low-risk.

A Tech Brief by the American Medical Association (1994) stated that the safety and effectiveness of intra-operative monitoring of the facial nerve by the use of either nerve conduction studies or EMG as a means of determining the integrity of the nerve during surgery for acoustic neuromas, cranial base lesions, or congenital auricular lesions were considered to be established by an expert panel. This is in agreement with the reviews by Harper (1998, 2004) who stated that there are controlled data to suggest that monitoring reduces the risk of injury to the facial nerve during resection of acoustic neuromas and other tumors in the posterior fossa.

The facial nerve is often embedded by fibrous tissues in recurrent tumor of the parotid gland. Studies have suggested that facial nerve-monitored patients undergoing parotidectomy for recurrent tumors have a 0 to 4 % risk of permanent facial paralysis. Dulguerov et al (1999) analyzed the incidence and factors responsible for post-parotidectomy facial nerve paralysis when the surgery is performed with the routine use of facial nerve monitoring (n = 70). The authors concluded that despite a stringent accounting of post-operative facial nerve deficits, the data compared favorably to the literature with or without the use of monitoring. An overall incidence of 27 % for temporary facial paralysis and 4 % for permanent facial paralysis was found. Although the lack of a control group precluded definitive conclusions on the role of EMG-based facial nerve monitoring in routine parotidectomy, the authors found its use very helpful. Brennan et al (2001) studied the effectiveness of continuous intra-operative EMG monitoring in patients who underwent parotidectomies, thyroidectomies, and parathyroidectomies (44 facial nerves, and 96 recurrent laryngeal nerves). These investigators concluded that continuous intra-operative nerve monitoring was associated with extremely low rates of temporary and permanent nerve paralysis. However, these reports were not randomized, controlled studies. Therefore, it remains unclear whether facial nerve monitoring significantly lowers the risk of facial nerve injury.

In a retrospective, case-controlled study, Terrell et al (1997) evaluated whether continuous facial nerve monitoring during parotidectomy is associated with a lower incidence of facial nerve paresis or paralysis compared with parotidectomy without monitoring (n = 117). The authors found that continuous EMG monitoring of facial muscle during primary parotidectomy reduced the incidence of short-term post-operative facial paresis, but did not change the incidence of permanent paralysis. Furthermore, Witt (1998) compared post-operative facial nerve function after monitored (n = 20) and unmonitored (n = 33) parotid surgical procedures. No patient showed permanent facial paralysis. In 9 patients (17 %), transient nerve paralysis developed: 5 (15 %) of the 33 patients who underwent lateral parotidectomy without the use of a nerve-integrity monitor and 4 (20 %) of the 20 patients who underwent lateral parotidectomy with the use of a nerve-integrity monitor. Therefore, the clinical value of facial nerve monitoring during parotidectomy is still in question and its routine use in clinical setting awaits findings of well-designed randomized controlled studies.
In a prospective, controlled clinical two-center trial, Grosheva and colleagues (2009) analyzed the benefit of EMG neuromonitoring during primary surgery on benign parotid lesions for post-operative facial function compared to visual observation only. Using an operation microscope, 100 parotidectomies in 96 patients were performed: 50 procedures with a continuous EMG monitoring plus visual facial observation (EMG group), and 50 procedures with only visual facial control (control group). The rate of post-operative facial weakness was detected. Patients with post-operative facial paralysis were followed-up until total recovery or defective healing by repeated EMG examinations. A total of 79 superficial and 21 total parotidectomies were performed. Histological analysis found pleomorphic adenoma in 38 patients, cystadenolymphoma in 39, and chronic parotitis in 18. Immediate post-operative facial paralysis was evident in 41 patients. Six patients had permanent paralysis; in this group definitive defective healing was detected by EMG in 5 cases. Electromyography was not classifiable in 1 case. Intra-operative EMG monitoring had no significant effect on immediate post-operative or definitive facial outcome (p = 0.23 and p = 0.45, respectively). The duration of superficial, but not of a total parotidectomy, was diminished in the EMG group (p = 0.02 and p = 0.61, respectively). This result was independent of the specimen's histology.

The authors concluded that EMG monitoring in parotid surgery in addition to visual facial observation did not diminish either the incidence of post-operative facial paralysis or the final facial outcome. Nevertheless, the duration of surgery for superficial parotidectomy could be reduced by using EMG monitoring.

Shan et al (2014) analyzed the benefits of facial nerve EMG monitoring during parotid tumor surgery. In this study, 92 patients with parotid tumor who underwent surgery were surveyed. The study group consisted of 46 patients who underwent intra-operative EMG monitoring, and 46 patients served as the control group. The incidence of post-operative facial nerve weakness and the operation time were recorded. In primary parotid tumor resection, the operation time of the study group (6 cases) was (50.0 ± 9.1) mins, that of control group (7 cases) was (42.9 ± 5.2) mins (p = 0.064) when the facial nerve needed no dissecting; the operation time of the study group (32 cases) was (74.7 ± 28.0) mins, that of control group (33 cases) was (75.6 ± 29.8) mins (p = 0.893) when the facial nerve needed dissecting. For patients with revision surgery, the mean operation time in the study group [(117.5 ± 37.8) mins] was significantly lower than that of the control group [(175.0 ± 47.8) mins], p < 0.05. In the study group, 8 patients suffered from post-operative facial nerve weakness because of tumor characteristics; in the control group, 6 patients suffered from post-operative facial nerve weakness, with 4 cases because of tumor characteristic, and 2 cases because of operator error. The authors concluded that these findings suggested that continuous EMG monitoring of facial nerve during parotidectomy reduces the mean operation time in patients with revision surgery, but not the incidence of post-operative facial paralysis.

EMG Monitoring of Recurrent Laryngeal Nerve:

The recurrent laryngeal nerve (RLN) is one of the branches of the vagus nerve (10th CN). After the RLN leaves the vagus nerve, it travels into the chest and then loops back up to supply nerves to the larynx. Injury to the RLN is rare but may occur as a complication of surgery in the neck or chest. In this regard, damage to
the RLN remains one of the most devastating complications of thyroid surgery. The nerve can also be injured by tumors or swollen lymph nodes in the mediastinum. Damage to the RLN causes laryngeal palsy on the affected side. Symptoms include hoarseness, difficulty in speaking, and difficulty in swallowing.

During thyroidectomy, the RLN is visually identified and dissected away from the thyroid gland. It has been advocated that intra-operative knowledge of the status of the nerve after dissection could potentially provide the surgeon with important decision-making information. However, it has not been established that intra-operative EMG monitoring of the RLN reduces the incidence of RLN injury during thyroidectomy. There are studies that have calculated the positive-predictive value (PPV) and negative-predictive value (NPV) of RLN monitoring during thyroid surgery. Most recently, Beldi and co-workers (2004) reported that the NPV of intra-operative RLN monitoring was 99 %, but the PPV was only 33 %. These results are similar to those of Otto and Cochran (2002) who reported a NPV of 98.6 % and a PPV of 33.3 %. Beldi et al (2004) concluded that although an intact nerve can be verified by RLN monitoring, the loss of nerve function can not be reliably identified, and that the incidence of RLN lesions was not lowered by intra-operative monitoring. This is in agreement with the findings of Robertson et al (2004) who reported that there were no statistically significant differences in RLN paralysis, paresis, or total injury rates between control and continuous laryngeal nerve integrity monitoring among patients who underwent thyroidectomy (n = 165).

In a prospective study (n = 328 patients with 502 nerves at risk), Hermann et al (2004) examined the ability of neuromonitoring to predict post-operative outcome in patients undergoing thyroid surgery for different indications. These authors concluded that neuromonitoring is useful for identifying the RLN, in particular if the anatomical situation is complicated by prior surgery, large tissue masses, aberrant nerve course. However, neuromonitoring does not reliably predict post-operative outcome. Thus, the value of intra-operative EMG monitoring of the RLN has not been established.

Chiang et al (2008) determined the causes of RLN palsy and identified potentially reversible causes of RLN injury during thyroid surgery with the use of intra-operative neuromonitoring (IONM). A total of 113 patients with 173 nerves at risk were enrolled in this study. All operations were performed by the same surgeon. The 4-step procedure of IONM was designed to obtain EMG signals from the vagus nerve and RLN before and after resection of thyroid lobe. A total of 16 nerves had loss of EMG signals after thyroid dissection, and the causes of nerve injuries were well elucidated with the application of IONM. One nerve injury was caused by inadvertent transection, which led to permanent RLN palsy. Among the remaining 15 nerves, 1 injury was caused by a constricting band of connective tissue, which was detected precisely and released intra-operatively, 2 by inadvertent clamping of the nerve, and 12 by apparent over-stretching at the region of Berry's ligament (5 nerves regained signals before closing the wound, but 1 showed impaired cord movement. Another 7 nerves did not regain signals before closing the wound, and all developed temporary RLN palsy). The authors concluded that their 4-step procedure of IONM is useful and helpful in elucidating the potential operative pitfalls during dissection near the RLN. However, the rates of RLN palsy were not decreased in this study.
The National Institute for Health and Clinical Excellence’s (NICE) guidance on intra-operative nerve monitoring during thyroid surgery (2008) noted that the evidence raises no major safety concerns. However, only 2 of the 9 specialist advisers stated that this procedure is useful for teaching; while 1 adviser stated that there are significantly different opinions between surgeons as to whether this technology improves outcomes or whether it gives false reassurance to inexperienced surgeons.

The NICE (2008) assessment reported that 4 non-randomized studies of 16,448, 684, 639 and 136 patients (29,998, 1,043, 1,000 and 190 nerves) reported permanent rates of vocal cord paralysis ranging from 0 % to 2 % in the intra-operative nerve monitoring groups, compared with 0 % to 1 % in the control groups (visual recurrent laryngeal nerve identification or no recurrent laryngeal nerve identification). No statistically significant differences were seen between procedures undertaken with or without intra-operative nerve monitoring. The NICE assessment also found that 3 case series of 328, 288 and 171 patients reported rates of permanent vocal cord paralysis using intra-operative nerve monitoring in 3 % (15/502), 1 % (6/429) and 1 % (2/271) of recurrent laryngeal nerves, respectively.

The NICE (2008) assessment also indicated that 4 non-randomized studies of 684, 639, 165 and 136 patients (1,043, 1,000, 236 and 190 nerves) reported rates of transient vocal cord paralysis ranging from 3 % to 5 % in the intra-operative nerve monitoring groups, compared with 3 % to 4 % in the control groups (none was statistically significant). The NICE assessment stated that another non-randomized study reported that vocal cord immobility was detected at 3-month follow-up in 6 % (6/104) of patients when intra-operative nerve monitoring was used and 5 % (5/100) of patients when intra-operative nerve monitoring was not used (p = 0.55). The 3 case series of 328, 288 and 171 patients reported rates of transient recurrent laryngeal nerve palsy as 9 % (43/502), 9 % (37/429) and 5 % (13/271), respectively.

Barczyński and colleagues (2009) tested the hypothesis that identification of the RLN during thyroid surgery reduces injury, and that IONM may be of additional benefit. A total of 1,000 patients scheduled to have bilateral thyroid surgery were randomized to standard protection or additional nerve monitoring. The primary outcome measure was prevalence of RLN injury. Of 1,000 nerves at risk in each group, transient and permanent RLN injuries were found respectively in 38 and 12 nerves without RLN monitoring (p = 0.011) and 19 and 8 nerves with RLN monitoring (p = 0.368). The prevalence of transient RLN paresis was lower in patients who had RLN monitoring by 2.9 % in high-risk patients (p = 0.011) and 0.9 % in low-risk patients (p = 0.249). The NPV and PPV of RLN monitoring in predicting post-operative vocal cord function were 98.9 and 37.8 %, respectively.
The authors concluded that nerve monitoring decreased the incidence of transient but not permanent RLN paresis compared with visualization alone, particularly in high-risk patients.

In a retrospective case control study with 993 patients, Cavicchi et al (2009) examined the accuracy of neurostimulation with laryngeal palpation (NSLP) and IONM to predict the post-operative function of RLN in thyroid surgery. The control group (799 patients with 1,450 nerves at risk) included patients who underwent NSLP and the case group (194 patients with 354 nerves at risk) consisted of those who underwent NSLP in association with IONM. Sensitivity, specificity, PPV, NPV, and accuracy were calculated for NSLP and IONM, with nerve palsy as the target outcome. A significant difference in nerve injury between the case and the control group (p = 0.31) was not observed. The presence or absence of laryngeal twitch (LT) (p < 0.0001) and the acoustic response to electrical stimulation (p = 0.003) were significantly associated with nerve function at the end of the surgery. The authors concluded that these findings indicated that NSLP is a safe and reliable intraoperative method of RLN monitoring. Moreover, these results confirmed that IONM is not a helpful tool to reduce the rate of palsy in thyroid surgery.

Harrison and Triponez (2009) reviewed the evidence regarding the use of intraoperative parathyroid hormone (PTH), radio-guided parathyroidectomy (RGP), methylene blue (MB), frozen section, and IONM during surgery for primary hyperparathyroidism (PHPT). A Medline keyword search of English-language articles led to the production of a draft document, subsequently revised by committee, containing levels of evidence and the grading of recommendations as proposed by the Agency for Healthcare Research and Quality. Literature review provided the basis for clear recommendations on the use of intra-operative PTH at surgery for PHPT. In contrast, there is little evidence to support the use of RGP, MB, routine frozen section, and IONM.

Kiviniemi and colleagues (2010) stated that the knowledge of the anatomy of the parathyroid and thyroid glands helps a surgeon to localize important details and lessen complications, especially laryngeal palsy and hypo-parathyroidism. The ligament of Berry and tuberculum Zuckerkandl cover the recurrent laryngeal nerve in the upper part of the thyroid lobes. The recurrent laryngeal nerve or its branches are exposed during the mobilization of these structures during total thyreoidectomy. The upper parathyroid gland can be found on the upper part of the tuberculum Zuckerkandl behind the recurrent laryngeal nerve, whereas the lower parathyroid gland can be found in front of the nerve on the under surface of the thyroid lobe or in the thymus below. The tertiary branches of blood vessels are cut preserving the function of the parathyroid glands. If the parathyroid has lost its blood circulation, it is made into pieces and transplanted into the pockets of sternocleidomastoideus muscle. Exposing the recurrent laryngeal nerve during operation seems to decrease permanent recurrent laryngeal nerve injury. The authors noted that the role of neuromonitoring during parathyroid and thyroid surgery is still controversial.

Dionigi et al (2013) stated that IONM contributes in several ways to RLN protection. Notwithstanding these advantages, surgeons must be aware that the current, intermittent mode of IONM (I-IONM) has relevant limitations. To
overcome these I-IONM limitations, a continuous IONM (C-IONM) technology has been proposed. These investigators performed a PubMed indexed literature review of the current limitations of I-IONM and provided a commentary about C-IONM; presenting the preliminary results of research on this topic. These researchers concluded that RLN traction injury is still the most common cause of RLN injury and is difficult to avoid with the application of I-IONM in thyroid surgery. Continuous-IONM is useful to prevent the imminent traction injury by detecting progressive decreases in electromyographic amplitude combined with progressive latency increases; C-IONM seems to be a technological improvement. Likely, C-IONM by vagal nerve stimulation should enhance the standardization process, RLN intraoperative information, documentation, protection, training, and research in modern thyroid surgery. They stated that although C-IONM is a promising technology at the cutting edge of research in thyroid surgery, more studies to assess in an evidence-based way all its advantages are needed.

**EMG Monitoring of Other Cranial Nerves:**

Schlake et al (2001) reported that EMG is effective as a mapping tool for intra-operative localization and identification of ocular motor nerves -- the oculomotor nerve (3rd CN) and the abducens nerve (6th CN) in skull base surgery. However, the predictive value of conventional neurophysiological parameters for clinical outcomes appears to be rather poor. Further investigations on a larger number of patients are thus needed to develop new quantification techniques which enable an intra-operative prediction of ocular motor nerve deficits. More studies are also needed to extend this technique to the trochlear nerve (4th CN). Furthermore, in a review on the electrophysiological examination of CNs, Vial and Bouhour (2004) stated that intra-operative monitoring of various CNs can be useful but techniques still need to be validated.

There are no controlled studies that examined whether EMG monitoring of the oculomotor, trochlear, and abducens nerves during surgery in the middle cranial fossa reduces the risk of post-operative ophthalmoplegia. Moreover, although there are reports of monitoring, either alone or in combination, of glossopharyngeal, laryngeal branches of the vagus (e.g., the superior laryngeal nerve and the recurrent laryngeal nerve), spinal accessory, and hypoglossal nerves during skull base surgeries such as surgical resection of tumors in the region of the foramen magnum, jugular foramen, hypoglossal foramen, and clivus, there are no controlled data to indicate that the risk of CN injury is reduced by monitoring (Harper, 2004). Thus, the clinical value of intra-operative monitoring of the oculomotor, trochlear, abducens, glossopharyngeal, laryngeal branches of the vagus, spinal accessory, and hypoglossal nerves has not been established.

**EMG Monitoring During Spinal Surgery:**

Spinal surgery is associated with a risk of injury to the spinal cord. Methods to intra-operatively monitor spinal function have been employed to minimize such risks. These neurophysiological techniques include somato-sensory evoked potentials (SSEP - see CPB 0181), dermatosensory evoked potentials (DSEP - see CPB 0181), and motor evoked potentials (MEP - see CPB 0181). This CPB specifically addresses the continuous, free-running monitoring of EMG activity and stimulus-triggered EMG activity from anatomically appropriate muscles done to
detect injury to nerve roots during surgery. The main objective of intra-operative neurophysiological monitoring of spinal cord or nerve root function is to identify induced neurophysiological alterations so that they can be detected as they occur and corrected during surgery; thus avoiding post-surgical complications such as myelopathy or radiculopathy, as well as permanent injury.

Weiss (2001) discussed the application of intra-operative neurophysiological monitoring to surgical treatment of lumbar stenosis. The author noted that benefits of SSEP and MEP studies during surgical correction of spinal deformity are well known and documented. Continuous free-running and stimulus-triggered electromyography (EMG) monitoring during placement of pedicle screw is an accepted practice at many institutions. Moreover, the functional integrity of spinal cord, cauda equina, and nerve roots should be monitored throughout every stage of surgery including exposure and decompression. Continuous free-running EMG provides feedback regarding the location and potential for surgical injury to the lumbo-sacral nerve roots within the operative field, while stimulus-triggered EMG can confirm that transpedicular instrumentation has been positioned correctly within the bony cortex. Continuous free-running EMG is monitored from muscles innervated by nerves or nerve roots considered to be at risk during spinal surgery. Surgical trauma to these nerve roots and motor nerves will produce high-frequency spikes or trains of motor unit potentials in monitored muscles. These neural discharges can be used to alert the surgeon of inadvertent trauma to nerve roots/peripheral nerves, and avoid more severe or irreversible injury. Multiple channels of continuous free-running EMG activity can be monitored simultaneously, providing real-time information regarding lumbosacral nerve root motor function throughout the operation (Holland, 2002).

Electro-stimulation of intact motor nerves will elicit compound muscle action potentials (CMAP) in innervated muscles. Intra-operative CMAP responses (all-or-none) are usually recorded by means of intra-muscular needle electrodes and submaximal stimulation, in contrast to those measured in diagnostic EMG laboratories where surface electrodes and maximal stimulation are employed. Electro-stimulation is usually performed by the surgeon using a hand-held monopolar or bipolar device within the operative field. The advantage of bipolar stimulation is that it evokes a localized stimulating current, thus avoiding unwanted current spreading to nearby nerves. This is especially useful during peripheral nerve or plexus surgeries, when multiple nerves lie in close proximity. Two examples of stimulus-triggered EMG monitoring are as follows: (i) the presence of a stimulus-triggered CMAP response can be used to differentiate nerve root from fibrous bands during surgical dissection for tethered cord release (Legatt et al., 1992), and (ii) the failure to produce a CMAP response from stimulation of pedicle screws and holes at a stimulus intensity of 7 to 11 mA is the electrophysiological criterion most commonly used to exclude a pedicular cortical perforation (Maguire et al., 1995). However, since the expected finding is negative (i.e., no CMAP responses), it is always beneficial to test and document a positive control response to confirm the reliability of the test results. This is best achieved by directly stimulating an exposed nerve or nerve root at the same stimulus intensity (Holland, 2002).

Although intra-operative monitoring of EMG has been used to monitor spinal cord function during spinal surgery, there is disagreement regarding its clinical value.
In a clinical trial, Owen and colleagues (1994) examined the use of mechanically elicited EMG during placement of pedicle screws in patients undergoing surgery for spinal stenosis (n = 89). Mechanically elicited EMG was recorded in muscle groups innervated by cervical or lumbar nerve roots. Confirmation of surgical activity with the level of the EMG was correlated. Results of this study indicated that mechanically elicited EMG is very sensitive to nerve root irritation. Compared to other neurophysiological methods, EMG is a viable alternative. These authors concluded that mechanically elicited EMG is sensitive and specific to nerve root firings and should be considered for use during the dynamic phases of surgery.

In a case series study, Beatty et al (1996) discussed their experiences with the use of continuous intra-operative EMG recording during spinal surgery. A total of 150 patients underwent spinal surgery for radiculopathy (120 underwent lumbar surgery and 30 had cervical operations). All of the surgeries were performed to alleviate symptoms due to disc herniation, spondylosis, or both. During the surgical procedures, continuous intra-operative EMG recordings were taken from the muscle corresponding to the involved nerve root. In baseline recordings taken in the operating room 10 minutes before lumbar surgery, electrical discharge or firing was recorded from the muscle in 18% (22 of 120 patients) of the cases. Once the nerve was decompressed, muscle firing ceased. Electrical discharges were produced with regularity on nerve root retraction. These authors concluded that continuous EMG monitoring can be accomplished easily and yields valuable information that indicates when the nerve root is adequately decompressed or when undue retraction is exerted on the root. The findings of Owen et al (1994) as well as Beatty et al (1996) are in congruous with that of Limbrick and Wright (2005) who stated that surgeon-driven evoked EMG threshold testing may provide a simple, effective adjunct to lumbar microendoscopic diskectomy for intra-operative verification of nerve root decompression as well as that of Jimenez and co-workers (2005) who reported that the incidence of post-operative C-5 palsies was lowered from 7.3 to 0.9 % as a consequence of intra-operative continuous EMG monitoring. Jimenez et al (2005) also noted that no patient suffered a post-operative C-5 palsy when intra-operative evidence of root irritation was absent.

Continuous intra-operative EMG plus SSEP have also been used in spinal surgery to prevent neural injury. However, only limited data are available on the sensitivity, specificity, and predictive values of intra-operative electrophysiological changes with regard to the occurrence of new post-operative neurological deficits. Gunnarsson and colleagues (2004) retrospectively analyzed a prospectively accrued series of 213 consecutive patients who underwent intra-operative monitoring with EMG and SSEP during thoraco-lumbar spine surgery. The authors examined data on patients who underwent intra-operative monitoring with continuous lower limb EMG and SSEP. The analysis focused on the correlation of intra-operative electrophysiological changes with the development of new neurological deficits. A total of 213 patients underwent surgery on a total of 378 levels; 32.4 % underwent an instrumented fusion. Significant EMG activation was observed in 77.5 % of the patients and significant SSEP changes in 6.6 %. Fourteen patients (6.6 %) had new post-operative neurological symptoms. Of those, all had significant EMG activation, but only 4 had significant SSEP changes. Intra-operative EMG activation had a sensitivity of 100 % and a specificity of 23.7 % for the detection of a new post-operative neurological deficit, while SSEP had a
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Intraoperative EMG activation has a high sensitivity for the detection of a new post-operative neurological deficit but a low specificity. In contrast, SSEP has a low sensitivity but a high specificity. They noted that combined intra-operative monitoring with EMG and SSEP is helpful for predicting and possibly preventing neurological injury during thoracolumbar spine surgery.

In a prospective clinical study, Raynor et al (2002) assessed the sensitivity of recording rectus abdominis-triggered EMG to evaluate placement of thoracic screw. A total of 677 thoracic screws were inserted into 92 patients. Screws placed from T-6 and T-12 were evaluated using an ascending method of stimulation until a CMAP was obtained from the rectus abdominis. Threshold values were compared both in absolute terms and also in relation to other intra-patient values. Screws were divided into 3 groups: (i) group A (n = 650 screws) had thresholds greater than 6.0 mA and intra-osseous placement, (ii) group B (n = 21) had thresholds less than 6.0 mA but an intact medial pedicle border on re-examination and radiographical confirmation, and (iii) group C (n = 6) had thresholds less than 6.0 mA and medial wall perforations confirmed by tactile and/or visual examination. Thus, 3.9 % (27 of 677) of all screws had thresholds less than 6.0 mA. Only 22 % (6 of 27) had medial perforation. Group B screws averaged a 54 % decrease from the mean as compared with a 69 % decrease for group C screws (p = 0.016). There were no post-operative neurological deficits or radicular chest wall complaints. These investigators concluded that for assessment of thoracic pedicle screw placement, triggered EMG thresholds of less than 6.0 mA, coupled with values 60 to 65 % decreased from the mean of all other thresholds in a given patient, should alert the surgeon to suspect a medial pedicle wall breach. These investigators further stated that although this retrospective analysis of electrophysiological observations and subsequent guidelines are not currently validated, this electrophysiological approach can be used in conjunction with precise surgical techniques, careful pedicle tract palpation, as well as intra-operative biplanar fluoroscopy and/or radiography to create the safest environment for placement of thoracic screw. They noted that further investigations of these guidelines will be carried out to validate this electrophysiological approach.

It is interesting that the conclusion of the study by Raynor et al (2002) was directly opposite to that by Reidy et al (2001), who, in a prospective study, examined the use of inter-costal EMG monitoring as an index of the accuracy of the placement of pedicle screws in the thoracic spine. A total of 95 thoracic pedicle screws in 17 patients were studied. Prior to insertion of the screw, the surgeon recorded his assessment of the integrity of the pedicle track, and then stimulated the track using a K-wire pedicle probe connected to a constant current stimulator. A CMAP was recorded from the appropriate inter-costal or abdominal muscles. Post-operative computed tomography (CT) was performed to establish the position of the screw. The stimulus intensity needed to evoke a muscle response was correlated with the position of the screw on the CT scan. There were 8 unrecognized breaches of the pedicle. Using 7.0 mA as a threshold, the sensitivity of EMG was 0.50 in detecting a breached pedicle and the specificity was 0.83. Thoracic pedicle screws were accurately placed in more than 90 % of patients. These investigators concluded that EMG monitoring did not significantly improve the reliability of placement of the screw.
Regarding the observations by Raynor and colleagues (2002), Finkelstein (2003) stated that "the value of a screening test should be such that the outcome could be altered by the prediction of an adverse event. The protocol of the study by Raynor et al would suggest that the damage of a medially placed screw would have already occurred by the time the screws were tested for CMAP and then compared to the other screws, determining an "average" of all other thresholds. Aside from improving the radiograph, it would seem to have little clinical utility". Finkelstein also noted that the utility of a screening test is defined by its sensitivity and specificity, as well as its positive predictive value. These were assessed in the study by Reidy and associates, and deemed unable to improve the accuracy beyond an experienced surgeon’s knowledge of well described anatomical landmarks.

In a review on intra-operative EMG monitoring during thoracolumbar spinal surgery, Holland (1998) stated that this approach has a number of potential limitations, including: (i) EMG is sensitive to blunt lumbosacral nerve root irritation or injury, but may provide misleading results with "clean" nerve root transaction, (ii) EMG must be recorded from muscles belonging to myotomes appropriate for the nerve roots considered at risk from surgery, (iii) EMG can be effective only with careful monitoring and titration of pharmacological neuromuscular junction blockade, (iv) when transpedicular instrumentation is stimulated, an exposed nerve root should be stimulated directly as a positive control whenever possible, (v) pedicle holes and screws should be stimulated with single shocks at low-stimulus intensities when pharmacological neuromuscular blockade is excessive, and (vi) chronically compressed nerve roots that have undergone axonotmesis (wallerian degeneration) have higher thresholds for activation from electrical and mechanical stimulation. Hence, whenever axonotmetic nerve root injury is suspected, the stimulus thresholds for transpedicular holes and screws must be specifically compared with those required for the direct activation of the adjacent nerve root (and not published guideline threshold values).

Krassioukov et al (2004) examined the neurological outcomes after complex lumbo-sacral surgery in patients undergoing multi-modality neurophysiological monitoring. A total of 61 patients were consecutively enrolled in this study. These subjects underwent complex intra- and extra-dural lumbosacral procedures with concomitant intra-operative EMG monitoring of the lower-limb muscles, external anal and urethral sphincters (EAS and EUS), and lower-limb SSEP. Long-term (minimum of 2 years) clinical follow-up data were obtained in all cases. Most subjects were treated for spinal/spinal cord tumors (61 %) or adult tethered cord syndrome (25 %). Recordable lower-extremity SSEP were reported in 54 patients (89 %). New post-operative neurological deficits occurred in only 3 patients (4.9 %), and remained persistent in only 1 patient (1.6 %) at long-term follow-up examination. In only 1 of these cases was a significant decrease in SSEP amplitude detected. Spontaneous EMG activity was observed in the lower-extremity muscles and/or EAS and EUS in 51 cases (84 %). Intra-operatively, EMG demonstrated activity only in the EUS in 5 % of patients and only in the EAS in 28 %. In 7 patients (11 %) spontaneous intra-operative EMG activity was observed in both the EAS and the EUS; however, in only 3 of these cases was EMG activity recorded in both sphincters simultaneously. In addition to spontaneously recorded EMG activity, electrically evoked EMG activity was also
used as an intra-operative adjunct. A bipolar stimulating electrode was used to identify functional neural tissue before undertaking microsurgical dissection in 58 individuals (95%). In the majority of these patients, evoked EMG activity occurred either in 1 (33%) or in 2 muscles (9%) simultaneously. The presence of electrically evoked EMG activity in structures encountered during microdissection altered the plan of treatment in 24 cases (42%). The investigators concluded that the combined SSEP and EMG monitoring of lower-limb muscles, EAS, and EUS is a practical and reliable method for obtaining optimal electrophysiological feedback during complex neurosurgical procedures involving the conus medullaris and cauda equina. Analysis of the results indicates that these intra-operative adjunctive modalities positively influence decision making with regard to microsurgery and reduce the risk of peri-operative neurological complications. Moreover, the authors noted that validation of the clinical value of these approaches, however, will require further assessment in a larger prospective cohort of patients.

In a review on electrophysiological intra-operative monitoring for spinal surgeries, Slimp (2004) stated that the advent of equipment capable of performing SSEP, MEP, and EMG in a multi-plexed fashion, and in a timely manner brings a new level of monitoring that far exceeds the previous basic monitoring done with SSEP only. However, the author noted that whether this more comprehensive monitoring will result in greater protection of the nervous system awaits future analysis. It is also interesting to note that when Erickson and co-workers (2005) from the technology assessment unit of the McGill University Health Center developed a report on the use of intra-operative neurophysiological monitoring during spinal surgery, they only examined the use of SSEP and MEP. These investigators recommended that combined SSEP/MEP should be available for all cases of spinal surgery for which there is a risk of injury to the spinal cord.

The American Association of Neurological Surgeons/Congress of Neurological Surgeons’ guidelines for the performance of fusion procedures for degenerative disease of the lumbar spine (Resnick et al, 2005) stated that there does not appear to be support for the hypothesis that any type of intra-operative monitoring improves patient outcomes after spinal surgery such as lumbar decompression or fusion procedures for degenerative spinal disease. The report noted that evidence does indicate that a normal evoked EMG response is predictive for intra-pedicular screw placement (high negative predictive value for breakout); while the presence of an abnormal EMG response does not, however, exclude intra-pedicular screw placement (low PPV). The majority of clinically apparent post-operative nerve injuries are associated with intra-operative changes in SSEP and/or DSEP monitoring. Thus, changes in DSEP/SSEP monitoring appear to be sensitive to nerve root injury. However, there is a high false-positive rate, and changes in DSEP and SSEP recordings are often not associated with nerve injury. A normal study has been shown to correlate with the lack of a significant post-operative nerve injury. There is insufficient evidence that the use of intra-operative monitoring of any kind provides clinically useful information to the surgeon in terms of assessing the adequacy of nerve root decompression at the time of surgery. Furthermore, the authors stated that a randomized prospective study comparing clinical and radiographical outcomes in similar groups of patients undergoing lumbosacral fusion with or without intra-operative monitoring would provide Class I evidence (well-conducted randomized prospective trials) supporting or refuting the
hypothesis that the added expense associated with the use of intra-operative
monitoring is justified by a clinical benefit.

In a prospective analysis, Paradiso and colleagues (2006) evaluated the
sensitivity, specificity, as well as PPV and NPV of multi-modality intra-operative
neurophysiological monitoring in surgery for adult tethered cord syndrome. The
results of multi-modality intra-operative neurophysiological monitoring were
compared with the "gold standard" (neurological outcomes). Multi-modality intra-
operative neurophysiological monitoring included posterior tibial nerve SSEPs,
continuous EMG monitoring of the L2 to S4 myotomes, and evoked EMG. Follow-
up neurological evaluations were performed for at least 1 year. A total of 44
consecutive patients, including 19 males and 25 females (aged 43 +/- 15 years),
who underwent microsurgery for adult tethered cord syndrome were evaluated.
After surgery, new neurological deficits, including 1 transient and 1 permanent,
developed in 2 patients. There was 1 patient who had persistent posterior tibial
nerve SSEP amplitude reduction following microsurgical manipulation. In 1
patient, a transient posterior tibial nerve SSEP amplitude reduction prompted a
change in microneurosurgical strategy. This patient awoke with no new post-
operative neurological deficits. For SSEPs, the sensitivity was 50 % and
specificity 100 %. Electromyographical bursts were recorded in 36 patients (82
%). The 2 patients with post-operative neurological worsening had EMG activity in
the myotomes, where their new deficits presented. Continuous EMG had a
sensitivity of 100 % and a specificity of 19 %. The authors concluded that this was
the largest series to date reporting the use of multi-modality intra-operative
neurophysiological monitoring in the surgical management of adult tethered cord
syndrome. Posterior tibial nerve SSEPs have high specificity, but low sensitivity,
for predicting new neurological deficits. In contrast, continuous EMG showed high
sensitivity and low specificity. Evoked EMG accurately identified functional neural
tissue. The combined recording of SSEPs in concert with continuous and evoked
EMGs may provide a useful adjunct to complex microsurgery for adult tethered
cord syndrome.

In a systematic review, Fehlings and colleagues (2010) examined if intra-operative
monitoring (IOM) is able to sensitively and specifically detect intra-operative
neurologic injury during spine surgery and to assess whether IOM results in
improved outcomes for patients during these procedures. A review of the English
language literature was undertaken for articles published between 1990 and
March 2009. MEDLINE, EMBASE, and Cochrane Collaborative Library databases
were searched, as were the reference lists of published articles examining the use
of IOM in spine surgery. Two independent reviewers assessed the level of
evidence quality using the Grading of Recommendations Assessment,
Development, and Evaluation (GRADE) criteria, and disagreements were resolved
by consensus. A total of 103 articles were initially screened and 32 ultimately met
the pre-determined inclusion criteria. These researchers determined that there is
a high level of evidence that multi-modal (SSEP and MEP) IOM is sensitive and
specific for detecting intra-operative neurologic injury during spine surgery. There
is a low level of evidence that IOM reduces the rate of new or worsened peri-
operative neurologic deficits (a grade of “low” means that further research is very
likely to have an important impact on our confidence in the estimate of effect and
is likely to change the estimate). There is very low evidence that an intra-
operative response to a neuromonitoring alert reduces the rate of peri-operative
neurologic deterioration (a grade of "very low" means that any estimate of effect is very uncertain). The authors concluded that based on strong evidence that multi-modality intra-operative neuromonitoring is sensitive and specific for detecting intra-operative neurologic injury during spine surgery, it is recommended that the use of multi-modality intra-operative neuromonitoring be considered in spine surgery where the spinal cord or nerve roots are deemed to be at risk, including procedures involving deformity correction and procedures that require the placement of instrumentation. Furthermore, they stated that there is a need to develop evidence-based protocols to deal with intra-operative changes in multi-modality intra-operative neuromonitoring and to validate these prospectively. Intra-operative EMG monitoring was not recommended as a means of neurophysiological monitoring during spinal surgery.

Kundnani et al (2010) reported the analysis of prospectively collected intra-operative neurophysiological monitoring data of 354 consecutive patients undergoing corrective surgery for adolescent idiopathic scoliosis (AIS) to establish the efficacy of multi-modal neuromonitoring and to evaluate comparative sensitivity and specificity. The study group consisted of 354 patients (45 males and 309 females) undergoing spinal deformity corrective surgery between 2004 and 2008. Patients were monitored using electrophysiological methods including SSEP and MEP simultaneously. Mean age of patients was 13.6 years (+/- 2.3 years). The operative procedures involved were instrumented fusion of the thoracic/lumbar/both curves. Baseline SSEP and neurogenic MEP (NMEP) were recorded successfully in all cases. Thirteen cases expressed significant alert to prompt reversal of intervention. All these 13 cases with significant alert had detectable NMEP alerts, whereas significant SSEP alert was detected in 8 cases. Two patients awoke with new neurological deficit (0.56 %) and had significant intra-operative SSEP and NMEP alerts. There were no false-positives with SSEP (high specificity) but 5 patients with false-negatives with SSEP (38 %) reduced its sensitivity. There was no false-negative with NMEP but 2 of 13 cases were false-positive with NMEP (15 %). The specificity of SSEP (100 %) is higher than NMEP (96 %); however, the sensitivity of NMEP (100 %) is far better than SSEP (51 %). Due to these results, the overall sensitivity, specificity and PPV of combined multi-modality neuromonitoring in this adult deformation series was 100 %, 98.5 % and 85 %, respectively. The authors concluded that NMEP monitoring appears to be superior to conventional SSEP monitoring for identifying evolving spinal cord injury. Used in conjunction, the sensitivity and specificity of combined neuromonitoring may reach up to 100 %. Multi-modality monitoring with SSEP and NMEP should be the standard of care.

In a cross-sectional study of non-consecutive cases (level III evidence), de Bla et al (2012) reported the findings of a series of young patients with thoracic scoliosis who were treated with pedicle screw constructs. Data obtained from triggered EMG (t-EMG) screw stimulation and post-operative computed tomographic scans were matched to find different threshold limits for the safe placement of pedicle screws at the concavity (CC) and convexity (CV) of the scoliotic curves. The influence of the distance from the medial pedicle cortex to the spinal cord on t-EMG threshold intensity was also investigated at the apex segment. A total of 23 patients who underwent posterior fusions using 358 pedicle thoracic screws were reviewed. All patients presented main thoracic scoliosis, with a mean Cobb angle of 58.3 degrees (range of 46 to 87 degrees). Accuracy of the screw placement
was tested at surgery by the t-EMG technique. During surgery, 8 screws placed at the CC showed t-EMG threshold values below 7 mA and were carefully removed. Another 25 screws disclosed stimulation thresholds within the range of 7 to 12 mA. After checking the screw positions by intraoperative fluoroscopy, 15 screws were removed because of clear signs of mal-positioning. Every patient underwent a pre-operative magnetic resonance imaging examination, in which the distances from the spinal cord to the pedicles of the concave and convex sides at 3 apex vertebrae were measured. Post-operative computed tomographic scans were used in all patients to detect screw mal-positioning of the final 335 screws. According to post-operative computed tomographic scans, 44 screws (13.1 %) showed different mal-positions: 40 screws (11.9 %) perforated the medial pedicle wall, but only 11 screws (3.2 %) were completely inside the spinal canal. If these researchers considered the 23 screws removed during surgery, the true rate of misplaced screws increased to 18.7 %. In those screws that preserved the pedicle cortex (well-positioned screws), EMG thresholds from the CC showed statistically significantly lower values than those registered at the CV of the deformity (21.1 ± 8.2 versus 23.9 ± 7.7 mA, p < 0.01). In the concave side, t-EMG threshold values under 8 mA should be unacceptable because they correspond to screw mal-positioning. Threshold values above 14 mA indicate an accurate intrapedicular position with certainty. At the convex side, threshold values below 11 mA always indicate screw mal-positioning, and values above 19 mA imply accurate screw placement. At the 3 apex vertebrae, the average pedicle-spinal cord distance was 2.2 ± 0.7 mm at the concave side and 9.8 ± 4.3 mm at the convex side (p < 0.001). In well-positioned screws, a correlation between pedicle-dural sac distance and t-EMG threshold values was found at the concave side only (Pearson r = 0.467, p < 0.05). None of the patients with misplaced screws showed post-operative neurological impairment. The authors concluded that independent of the screw position, average t-EMG thresholds were always higher at the CV in the apex and above the apex regions, presuming that the distance from the pedicle to the spinal cord plays an important role in electrical transmission. They stated that the t-EMG technique has low sensitivity to predict screw mal-positioning and can not discriminate between medial cortex breakages and complete invasion of the spinal canal.

Also, an UpToDate review on “Treatment and prognosis of adolescent idiopathic scoliosis” (Scherl, 2012) mentions the use of intra-operative SEP and MEP monitoring; but not intra-operative EMG monitoring.

In summary, there is insufficient scientific evidence that intra-operative monitoring of EMG during spinal surgery provides useful information to the surgeon in terms of assessing the adequacy of nerve root decompression, detecting nerve root irritation, or improving the reliability of placement of pedicle screw at the time of surgery.

Monitoring During Intra-Cranial Tumor Resections:

Grabb and colleagues (1997) reviewed the results of continuous intra-operative EMG monitoring of muscles innervated by cranial nerves in 17 children whose pre-operative imaging studies showed compression or infiltration of the 4th ventricular floor by tumor to determine how intra-operative EMG activity correlated with post-operative cranial nerve morbidity. Bilateral lateral rectus (6th) and facial (7th)
nerve musculatures were monitored in all children. Cranial nerve function was documented immediately post-operatively and at 1 year. Of the 68 nerves monitored, 9 new neuropathies occurred in 6 children (6th nerve in 4 children and 7th nerve in 5 children). In 5 new neuropathies, intra-operative EMG activity could be correlated in 1 of 4 6th nerve injuries and 4 of 5 7th nerve injuries. Electromyographic activity could not be correlated in 4 children with new neuropathies. Of 59 cranial nerves monitored that remained unchanged, 47 had no EMG activity. Twelve cranial nerves (3 6th nerves and 9 7th nerves) had EMG activity but no deficit. Of 4 children with lateral rectus EMG activity, 3 had new 7th nerve injuries. Lateral rectus EMG activity did not predict post-operative abducens injury. The absence of lateral rectus EMG activity did not assure preserved abducens function post-operatively. Likely because of the close apposition of the intra-pontine facial nerve to the abducens nucleus, lateral rectus EMG activity was highly predictive of 7th nerve injury. The authors noted that although facial muscle EMG activity was not an absolute predictor of post-operative facial nerve dysfunction, the presence of facial muscle EMG activity was associated statistically with post-operative facial paresis. The absence of facial muscle EMG activity was rarely associated with facial nerve injury. The authors speculated that EMG activity in the facial muscles may have provided important intra-operative information to the surgeon so as to avoid facial nerve injury.

Kombos et al (2000) stated that intra-operative cranial nerve monitoring has improved the preservation of facial nerve function following surgery in the cerebello-pontine angle (CPA). Facial EMG was performed in 60 patients during CPA surgery. Pairs of needle electrodes were placed subdermally in the orbicularis oris and orbicularis oculi muscles. The duration of facial EMG activity was noted. Facial EMG potentials occurring in response to mechanical or metabolic irritation of the corresponding nerve were made audible by a loudspeaker. Immediate (4 to 7 days after tumor excision) and late (6 months after surgery) facial nerve function was assessed on a modified House-Brackmann scale. Late facial nerve function was good (House-Brackmann 1 to 2) in 29 of 60 patients, fair (House-Brackmann 3 to 4) in 14, and poor (House-Brackmann 5 to 6) in 17. Post-manipulation facial EMG activity exceeding 5 minutes in 15 patients was associated with poor late function in 5, fair function in 6, and good function in 4 cases. Post-manipulation facial EMG activity of 2 to 5 minutes in 30 patients was associated with good late facial nerve function in 20, fair in 8, and poor in 2. The loss of facial EMG activity observed in 10 patients was always followed by poor function. Facial nerve function was preserved post-operatively in all 5 patients in whom facial EMG activity lasted less than 2 minutes. The authors concluded that facial EMG is a sensitive method for identifying the facial nerve during surgery in the CPA. EMG bursts are a very reliable indicator of intra-operative facial nerve manipulation, but the duration of these bursts do not necessarily correlate with short- or long-term facial nerve function despite the fact that burst duration reflects the severity of mechanical aggression to the facial nerve.

Furthermore, UpToDate reviews on "Clinical manifestations and initial surgical approach to patients with malignant gliomas" (Batchelor and Curry, 2012) and "Overview of the management of central nervous system tumors in children" (Lau and Teo, 2012) do not mention the use of intra-operative EMG.
EMG Monitoring During Placement of Dorsal Column Stimulator:

Shils and Arle (2012) demonstrated that spinal cord stimulators (SCSs) may be placed safely and accurately under general anesthesia (GA) and that the proposed evaluation method activates structures predominantly in the dorsal columns. Data were retrospectively analyzed from 172 electrodes implanted with spinal cord SCSs at the Lahey Clinic between September 2008 and July 2011. All patients had their SCS placed under GA. Electromyography was recorded from upper or lower limb muscle groups related to the placement of the stimulator electrode. Laterization was performed based on electromyographic responses and electrode pairs stimulated. In a select group of patients, standard neurophysiologic tests, paired pulse, and collision studies were performed to demonstrate that the pain stimuli were activating the dorsal columns. A total of 155 patients had standard thoracic or cervical SCS placement. Pre-operatively this cohort of patients had a visual analog score (VAS) of 7.51 ± 1.93, while post-operatively the VAS was 3.63 ± 2.43 (a reduction of 52.11 %). Based on the electromyographic recording technique, the electrodes were re-positioned intra-operatively in 15.9 % of patients. The recovery time (initial approximately 70 msec and complete approximately 150 to 300 msec) in both the paired-pulse tests and the collision studies showed that the stimulation used to elicit the compound muscle action potentials came from antidromic activation of the dorsal columns and not from the cortico-spinal tract. The authors concluded that GA-SCS is safe and appears to be at least as accurate and efficacious as using the awake-SCS placement technique based on a 50 % improvement in the VAS. In addition, the technique presented herein demonstrated that the test stimuli activate the same fiber tracts as that of the therapeutic stimulation.

Mammis and Mogilner (2012) noted that placement of spinal cord stimulating paddle leads has traditionally been performed under local anesthesia with intravenous sedation to allow intraoperative confirmation of appropriate placement. It may be difficult to maintain appropriate sedation in certain patients because of medical co-morbidities. Furthermore, patients undergoing lead revision frequently have extensive epidural scarring, requiring multi-level laminectomies to place the electrode appropriately. These investigators reported their technique of neurophysiologic monitoring that allows these procedures to be performed under GA. Data from 78 patients who underwent electromyography during laminectomy for paddle lead placement were retrospectively reviewed; 70 patients presented for first-time permanent system placement after a successful trial, and 8 were referred for revision or replacement of previously functioning systems. Surgeries were performed under GA with fluoroscopic guidance. Electromyography was used to help define the physiological midline of the spinal cord and to guide appropriate lead placement. Somatosensory evoked potentials were used as an adjunct to minimize the possibility of neural injury. Immediately post-operatively, 75 of 78 patients reported that the paresthesia coverage was as good as (or better than) that of the spinal cord stimulation trial. At the long-term follow-up, 1 system was removed for infection, and 6 systems were explanted for lack of efficacy. A total of 64 of the 78 implanted patients reported continued pain relief with stimulator use. Revision surgery was performed in 9 patients. The authors concluded that the use of intra-operative electrophysiology for the
placement of spinal cord stimulation paddle leads under GA is a safe and efficacious alternative to awake-surgery.

Also, an eMedicine review on “Intraoperative Neurophysiological Monitoring” lists the following clinical uses of intra-operative EMG:
http://emedicine.medscape.com/article/1137763-overview#aw2aab6b4

- Facial nerve/other cranial nerve monitoring
- Pedicle screw placement
- Selective dorsal rhizotomy
- Tethered spinal cord release

Placement of spinal cord stimulator is not one of the listed indications.

**CPT Codes / HCPCS Codes / ICD-9 Codes**

**Intra-operative electromyographic (EMG) monitoring of cranial nerves:**

**CPT codes covered if selection criteria are met:**

- 95867
- 95868
- 95887
- 95940

**HCPCS codes covered if selection criteria are met:**

- G0453 Continuous intraoperative neurophysiology monitoring, from outside the operating room (remote or nearby), per patient, (attention directed exclusively to one patient) each 15 minutes (list in addition to primary procedure

**CPT codes not covered when combined with intra-operative monitoring of facial nerve:**

- 95925
- 95926
- 95927

**CPT codes for intra-cranial tumor resection surgery where intra-operative EMG is not covered:**

- 61518
- 61519
- 61520
- 61521
Other CPT codes related to the CPB:

21010 - 21499
42300 - 42699
69631 - 69646

ICD-9 codes covered if selection criteria are met:

160.1 Malignant neoplasm of auditory tube, middle ear, and mastoid air cells
171.0 Malignant neoplasm of connective and other soft tissue of head, face, and neck
173.2 Other malignant neoplasm of skin of ear and external auditory canal
212.0 Benign neoplasm of nasal cavities, middle ear, and accessory sinuses
215.0 Other benign neoplasm of connective and other soft tissue of head, face, and neck
216.2 Benign neoplasm of skin of ear and external auditory canal
232.2 Carcinoma in situ of ear and external auditory canal
351.0 - 352.99 Facial nerve disorders and disorders of other cranial nerves
386.00 - 386.04 Meniere’s disease

ICD-9 codes not covered for indications listed in the CPB:

191.0 - 192.1 Malignant neoplasm of brain, cranial nerves, and cerebral meninges
195.0 Malignant neoplasm of head, face, and neck
198.3 - 198.4 Secondary malignant neoplasm of brain and spinal cord or other parts of nervous system [intracranial only]
225.0 - 225.2  Benign neoplasm of brain, cranial nerves, or cerebral meninges

237.5 - 237.6  Neoplasm of uncertain behavior of brain and spinal cord or meninges [intracranial only]

383.0 - 385.9  Mastoiditis and related conditions, other disorders of tympanic membrane, and other disorders of middle ear and mastoid

524.00 - 524.9  Dentofacial anomalies, including malocclusion

527.0 - 527.9  Diseases of the salivary glands

802.20 - 802.5  Fracture of mandible, malar, and maxillary bones

830.0 - 830.1  Dislocation of jaw

Intra-operative EMG monitoring during spinal surgery:

CPT codes not covered for indications listed in the CPB:

51784
51785
95860
95861
95863
95864
95869
95870
95885
95886
95887
95937

HCPCS codes not covered for indications listed in the CPB:

G0453  Continuous intraoperative neurophysiology monitoring, from outside the operating room (remote or nearby), per patient, (attention directed exclusively to one patient) each 15 minutes (list in addition to primary procedure)

CPT codes covered for spinal surgery where intra-operative EMG is covered: :
63185
63190

CPT codes for spinal surgery where intra-operative EMG is not covered:

22010 -
22865
62263 -
63182, 63191
- 63746
64470 -
64484
64561
64581
64633
64634
64635
64636
64772

HCPCS codes for spinal surgery where intra-operative EMG is not covered:

S2348  Decompression procedure, percutaneous, of nucleus pulposus of intervertebral disc, using radiofrequency energy, single or multiple levels, lumbar

S2350 -  S2351  Diskectomy, anterior, with decompression of spinal cord and/or nerve root(s), including osteophytectomy; lumbar, single interspace or each additional interspace (list separately in addition to code for primary procedure)

S2360 -  S2361  Percutaneous vertebroplasty, one vertebral body, unilateral or bilateral injection; cervical or each additional cervical vertebral body (list separately in addition to code for primary procedure)

Intra-operative EMG monitoring of the recurrent laryngeal nerve/intraoperative neuromonitoring during thyroid and parathyroid surgery:

CPT codes not covered for indications listed in the CPB:

95867
95868
Other CPT codes related to the CPB:

60000 -
60512

HCPCS codes not covered for indications listed in the CPB:

G0453 Continuous intraoperative neurophysiology monitoring, from outside the operating room (remote or nearby), per patient, (attention directed exclusively to one patient) each 15 minutes (list in addition to primary procedure

ICD-9 codes not covered for indications listed in the CPB:

Too many to list

*Intra-operative EMG monitoring during hip replacement surgery:*

CPT codes not covered for indications listed in the CPB:

95870 Needle electromyography; limited study of muscles in one extremity or non-limb (axial) muscles (unilateral or bilateral), other than thoracic paraspinal, cranial nerve supplied muscles, or sphincters

Other CPT codes related to the CPB:

27130 Arthroplasty, acetabular and proximal femoral prosthetic replacement (total hip arthroplasty), with or without autograft or allograft

The above policy is based on the following references:

**Monitoring of Facial Nerve:**


Monitoring of Recurrent Laryngeal Nerve:


Monitoring of Other Cranial Nerves:


Monitoring During Spinal Surgery:


22. Scherl SA. Treatment and prognosis of adolescent idiopathic scoliosis. Last reviewed June 2012. UpToDate Inc. Waltham, MA.

Monitoring During Intra-Cranial Tumor Resections:


3. Batchelor T, Curry WT. Clinical manifestations and initial surgical approach to patients with malignant gliomas. Last reviewed April 2012. UpToDate Inc. Waltham, MA.

4. Lau C, Teo W-Y. Overview of the management of central nervous system tumors in children. Last reviewed April 2012. UpToDate Inc. Waltham, MA.

Monitoring During Placement of Dorsal Column Stimulator:


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