The Accuracy of Multimodality Intraoperative Neuromonitoring to Predict Postoperative Neurologic Deficits Following Cervical Laminoplasty

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BACKGROUND: **Intraoperative neuromonitoring (IONM) has been reported to be sensitive and specific in the detection of neurologic injury during spinal surgery. The purpose of this study was to clarify the incidence of C5 palsy using multimodality IONM and to compare the accuracy of multimodality IONM to predict postoperative C5 palsy with isolated transcranial motor evoked potentials (MEPs).**

METHODS: **We retrospectively reviewed 135 consecutive patients at a single institution with cervical spondylotic myelopathy who underwent open door laminoplasty using MEPs combined with somatosensory evoked potentials and free-running electromyography.**

RESULTS: **Multimodality IONM was obtained in 131 cases. Ossification of the posterior longitudinal ligament was present in 19 patients (14.1%). Postoperative C5 palsy occurred in 3 patients (2.2%). Significant MEP alerts occurred in 12 patients. Significant somatosensory evoked potential change was not observed. To predict acute-onset C5 palsy, MEP alerts in the deltoid or biceps had 100% sensitivity and 98.4% specificity. Transient or persistent MEP alerts in the deltoid or biceps had same positive predictive value with sensitivity of 50.0% and specificity 99.2%.**

CONCLUSIONS: **Incidence of any neurologic deficit, including C5 palsy, during laminoplasty while using multimodality IONM was relatively low. MEP alerts in the deltoids or biceps had 100% sensitivity and 98.4% specificity for predicting a postoperative deficit. Somatosensory evoked potentials did not appear to be helpful in predicting postoperative deficits.**

INTRODUCTION

Intraoperative neuromonitoring (IONM) has recently increased in popularity as a way to possibly detect intraoperative neural injury during spinal surgery. Several studies have reported on the utility of IONM, including transcranial motor evoked potentials (MEPs), somatosensory evoked potentials (SSEPs), and free-running electromyography (EMG), during cervical spine surgery.[1-3] Among these modalities, MEPs with EMG have been reported to have a high specificity for identifying an evolving motor tract injury.[4-6] The utility of SSEPs to predict iatrogenic neural injury during cervical spine surgery remains controversial.[7] However, given the potential of rare, catastrophic neurologic complications, such as spinal cord injury (3 per 1000 in the cervical spine),[8] multimodality IONM has been recommended when the spinal cord or nerve roots are deemed to be at risk.[9]

Postoperative C5 palsy is a relatively common complication in patients with cervical spondylotic myelopathy with an incidence of 0%–30% (average 4.6%).[10] Several theories for the pathologic cause of C5 palsy have been proposed, including inadvertent nerve injury during surgery[11]; tethering, which places tension on the nerve root as the cord drifts dorsally after decompression[12]; thermal injury owing to heat created by the drill[13,14]; spinal cord dysfunction, in which myelomalacia corresponds to increased risk of C5 palsy[15,16]; and iatrogenic foraminal stenosis.[17-20] At the present time, there are no reports focusing on cervical laminoplasty and C5 palsy using multimodality IONM. The purpose of this study is to clarify the incidence of C5 palsy in patients

Key words
- C5 palsy
- Cervical laminoplasty
- Cervical spondylotic myelopathy
- Neuromonitoring
- Ossification of the posterior longitudinal ligament

Abbreviations and Acronyms
EMG: Electromyography
IONM: Intraoperative neuromonitoring
MEP: Motor evoked potential
SSEP: Somatosensory evoked potential

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undergoing cervical laminoplasty while using multimodality IONM and to compare the accuracy of IONM in predicting C5 palsy between isolated MEPs and multimodal IONM.

MATERIALS AND METHODS

Data Source

This study was reviewed and approved by the Committee on Human Research at the University of California, San Francisco. We retrospectively reviewed charts from our institution for patients with cervical spondylotic myelopathy who underwent a cervical laminoplasty while using IONM from January 1, 2012, to October 31, 2015. Patients who had sustained spinal cord injury as a result of trauma and were graded American Spinal Injury Association A, B, or C were excluded (1 patient). All surgeries were performed by experienced spine surgeons (B.T., D.C., and P.M.). Hospital charts were examined for aspects of past medical history (e.g., history of diabetes, body mass index) and surgical details (i.e., laminoplasty level, laterality of open door laminoplasty). Neurologic motor deficits related to surgery were noted. C5 palsy was defined as postoperative paresis of deltoid, with or without involvement of biceps but without loss of strength in other muscles. The laterality of C5 palsy and time of occurrence were also documented.

Intraoperative Neuromonitoring

SSEPs were recorded to bilateral ulnar nerves at the wrists and posterior tibial nerves at the ankles using asynchronous stimulation via surface electrodes at 2.1 m/second. Sterile needle electrodes were placed over the somatosensory hand and foot cortex at scalp sites C3′, Cz′, and C4′ with referral to frontal lead Fz, over somatosensory hand cortex at scalp sites C3′ and C4′ with referral to frontal lead Fz, and over somatosensory foot cortex at scalp sites Cz′—Fz and at C3′—C4′, to record the primary cortical responses. Averaged SSEPs (N = 200) were collected on a Cadwell Cascade system (Cadwell Industries, Inc., Kennewick, Washington, USA), displayed for comparison with baseline responses, and stored on magnetic disk. MEPs were recorded by multipulse transcranial electrical stimulation (0—800 V, 75 mcs pulse duration, 0—9 pulses at 1—3 ms interstimulus interval; transcranial stimulation —4) delivered to electrodes placed over motor cortical regions at C3 and C4. EMG responses were recorded from needle electrodes placed bilaterally in the deltoid (axillary nerve, C5-C6), biceps (musculocutaneous nerve, C5-C7), triceps (radial nerve, C6-C8), thenar and hypothenar eminences (hand, C8-T1), tibialis anterior (L4-L5), extensor hallucis longus (L5-S1), and toe flexor muscles (foot, S1-S2). EMG was continuously monitored to detect any mechanical irritation of nerve roots from traction, dissection, or positioning.

Alert Criteria

A licensed technologist (Certified in Neurophysiological Intraoperative Monitoring or Diplomat of the American Board of Neurophysiological Monitoring) works under physician guidance at our institution. A significant MEP alert was defined as an abrupt decrease in peak-to-peak amplitude of >50% for >3 successive trials over a period of 1—3 minutes.[21] The alert criteria used for SSEPs were a decrease in somatosensory cortical amplitude of >50% and/or 10% increase in latency.

Table 1. Demographic Characteristics of 135 Patients with Cervical Compressive Myelopathy

Characteristic	Value
Age, years, average ± SD	62.2 ± 10.9
Sex, female, number (%)	91 (67.4)
Diabetes, number (%)	16 (12.0)
BMI, kg/m^2, average ± SD	28.1 ± 5.7
OPLL, number (%)	19 (14.1)
Laminoplasty level, number (%)	
C3-C6	57 (42.2)
C4-C6	50 (37.0)
C3-C7	10 (7.4)
C3-C5	8 (5.9)
Others	10 (7.4)
Length of stay, days, mean (IQR)	4 (3—5)
Postoperative C5 palsy, number (%)	3 (2.2)
Acute, number	2
Delay, number	1
Quadriplegia owing to transverse myelitis, number (%)	1 (0.7)

BMI, body mass index; OPLL, ossification of posterior longitudinal ligament; IQR, interquartile range.

Surgical Technique

All patients underwent an open door laminoplasty with titanium miniplates without bone grafting as previously described (before 2013, 1 of the authors used structural allograft without fixation in the laminoplasty procedures).[22] Briefly, a drill with a matchstick burr was used to open the hemilamina on the side associated with more symptoms. A shallow trough was scored on the contralateral hemilamina with the same drill bit. This side was used as a hinge to open the laminoplasty. The open door laminoplasty was secured using a preshaped titanium miniplate or allograft bone spacer. Screws (4—6 mm) were placed through the plate apertures into the lateral mass on 1 side and into the opened lamina on the canal side. Foraminotomies were performed as needed.

Statistical Analysis

To determine if C5 palsy during laminoplasty could be predicted using multimodal monitoring, we used the following statistical approach. We first collected all the patients who underwent laminoplasty and documented if they had a C5 palsy or note. We then formed a contingency table based on the predicted C5 palsy from the intraoperative monitoring as well as the actual C5 palsy. We used this table to detect the sensitivity and specificity for detecting C5 palsy.

RESULTS

We identified 135 patients for this study. Multimodality IONM data from 131 cases were obtained. The mean patient age was 62.2 years

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