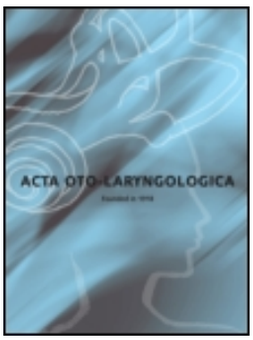

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Effects of Partial Neuromuscular Blockade on Facial Nerve Monitorization in Otologic Surgery

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Objective—Neuromuscular blockade (NMB) is administered as part of a general anesthetic in order to keep the patient immobilized during surgery and has been known to hinder intraoperative neuromonitorization. The aim of this study was to determine the effects of different levels of NMB on electrical stimulation thresholds of the facial nerve during otologic surgery.

Material and Methods—Intraoperative facial nerve monitorization was performed in 29 patients with advanced middle ear disease. Electromyographic (EMG) responses were recorded by insertion of needle electrodes into the orbicularis oris and orbicularis oculi muscles. Minimal facial nerve stimulations causing EMG responses in the facial musculature were measured during full recovery from the effects of muscular relaxants and with 25%, 50%, 75% and 100% levels of NMB. These defined NMB levels were maintained by the administration of a drip infusion of atracurium and were assessed objectively by recording the hypothenar muscle action.

Results—All of the patients had detectable EMG responses of the facial musculature at the 50% and 75% levels of NMB in response to the electrical stimulation of the facial nerve. The corresponding mean stimulation thresholds were 0.10 ± 0.08 and 0.11 ± 0.09 mA, respectively. No responses were measured in 31% of the patients when the level of peripheral NMB was 100%.

Conclusion—This study suggests that a regulated 50% level of peripheral NMB provides reliable intraoperative EMG monitoring of the facial musculature in response to electrical stimulation and adequate anesthesia, with full immobilization of the patient. *Key words*: *facial nerve monitoring*, *neuromuscular blockade*, *otology*, *surgery*.

INTRODUCTION

Intraoperative monitoring of the facial nerve during neurotologic procedures is a well-accepted helpful adjunct for preservation of facial nerve function (1–4). However, there have been few published reports concerning the utility of facial nerve monitoring in otologic surgical procedures (4–7). The role of facial nerve monitoring in middle ear and mastoid surgery has been promoted recently (8). Iatrogenic facial nerve injury occurs in ≈ 0.6–3.6% of primary and 4–10% of revision otologic surgeries (9). Prevention is obviously the preferred management strategy for iatrogenic facial nerve paralysis (10). Intraoperative facial nerve monitoring has been shown to reduce the rate of iatrogenic facial nerve injury during ear operations (2, 11).

In otologic surgery the routine procedure of anesthetic management has typically excluded the use of neuromuscular relaxants to avoid any compromise of facial electromyographic (EMG) monitoring capability (12). The use of neuromuscular blockade (NMB) can make the facial muscles unresponsive to nerve stimulation (13). Therefore, after a single dose of muscle relaxant is administered at the beginning of an operation for induction purposes, large doses of narcotics and high levels of volatile anesthetic agents are required in order to keep the patient immobilized (12, 13). However, these high levels of anesthetic agents are not well-tolerated by some patients (12). Advances in neuromonitoring technology and progress in anesthetic management currently allow the use of controlled levels of NMB, avoiding potential ablation of EMG responses to nerve stimulation. The aim of this study is to investigate the effects of partial peripheral NMB on facial nerve EMG activity in response to electrical stimulation during otologic surgery.

MATERIAL AND METHODS

Twenty-nine consecutive patients with advanced middle ear disease undergoing otologic surgery participated in this study. All patients were monitored by means of electrocardiography, sphygmomanometry, pulse oximetry and an esophageal temperature probe. None of the patients were premedicated. Anesthesia was induced with thiopental sodium (5 mg/kg), fentanyl citrate (1 μg/kg) and lidocaine (1 mg/kg). Tracheal intubation was facilitated with an i.v. bolus administration of atracurium (0.5 mg/kg). Mechanical ventilation was initiated immediately after endotracheal intubation. Anesthesia was maintained with a mixture of 50% nitrous oxide in oxygen and 2% sevoflurane. After complete recovery of peripheral neuromuscular functions and exposure of the facial nerve, the baseline stimulation threshold level was

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determined. The atracurium drip infusion was initiated with an initial dose of 3 μg/kg/min and the dose was then adjusted according to the hypothenar muscle activity.

The Neurosign 800® system (The Magstim Company Limited, Whitland, UK) was utilized for intraoperative facial nerve monitoring. It consists of a main unit, a pre-amplifier pod and a stimulator probe tip. The main unit contains eight channels, each of which have separate monitoring capability with both oscilloscopic and auditory stimulation responses. After the patient was anesthetized, sterile needle electrodes were inserted into the orbicularis oris and orbicularis oculi muscles on the operative side. The reference electrodes were placed in the contralateral frontalis muscle. In order to determine non-specific EMG activity (e.g. light anesthesia), additional electrodes were also placed in the contralateral orbicularis oris muscle. The wires were plugged into the pre-amplifier which was attached to the operating table on the other side of operation field and were then connected to the main unit, which was kept near the patient's feet. A constant-current bipolar stimulator was used for facial nerve stimulation.

Peripheral NMB levels were assessed by recording the hypothenar muscle action using a commercially available TOF Guard® instrument (Organon Teknica NV, Turnhout, Belgium). The contralateral ulnar nerve was stimulated using surface electrodes with a supramaximal 2 Hz constant current (4 twitches at 60 mA). The hypothenar muscle movements were assessed by an accelerometer.

During the operation, the location of the facial nerve was confirmed by the stimulations given via a bipolar electrode using a constant current of 0.05–1 mA directly or 2 mA in the close vicinity of the facial nerve. Following complete recovery of peripheral neuromuscular functions from the muscle relaxant used for induction, measurement outcomes of facial electrical stimulation were determined as baseline records. Stimulation thresholds were determined by stimulating in increments of 0.05 mA until recordable EMG responses were obtained. A bipolar stimulator was placed momentarily over the facial nerve. Various NMB levels were obtained by adjusting the infusion rate of atracurium. Minimal stimulation levels of the facial nerve causing just recordable EMG activity were obtained at varying NMB levels, namely 0%, 25%, 50%, 75% and 100% (full). The facial nerves were not exposed to maximal stimulation causing maximal EMG activity.

The stimulations were applied through the defective areas in patients who had Fallopian's channel dehiscence or otherwise over the non-dehiscent area of the tympanic segment. EMG recordings were obtained from the orbicularis oris and orbicularis oculi muscles. One of the authors (I. A.) monitored all the patients and observed visual and auditory signals meticulously during the operative procedures.

The study protocol was approved by the local Institutional Review Committee and written informed consent was obtained from all patients. Analyses were performed using SPSS software. Average values and standard deviations were calculated for the whole group and ANOVA and Kruskal–Wallis tests were employed to assess the correlation of facial monitoring results from the baseline and different NMB levels.

RESULTS

The patients included 18 females and 11 males (average age 30 years; range 11–57 years). Twenty-three cases were primary surgeries and the other six were revisions. Seventeen surgeries were performed on the right ear and 12 on the left. The pathologies of the patients and details of the procedures performed are summarized in Table I.

Pre- and postoperatively, all 29 patients demonstrated clinically normal facial nerve function. In all cases, the facial nerve could be identified and clearly visualized during surgery. In the operative field, the facial nerve was found to be exposed in 12 of the cases (41%).

Intraoperative facial and ulnar nerve monitoring was accomplished simultaneously. During full recov-

Table I. *Pathology of the patients and details of the procedures performed*

Type of surgery	*n*	Pathology	*n*	No. of revisions
Radical mastoidectomy	11	Cholesteatoma	11	3
Open cavity tympanoplasty	9 (type II)	Cholesteatoma	10	
	4 (type III)	Chronic otitis media	2	
		Keratosis obturans	1	
Canal wall-up tympanoplasty	3	Cholesteatoma	3	2
Partial petrosectomy	1	Cholesteatoma	1	
Explorative tympanotomy	1	Cholesteatoma	1	1
Total	29			

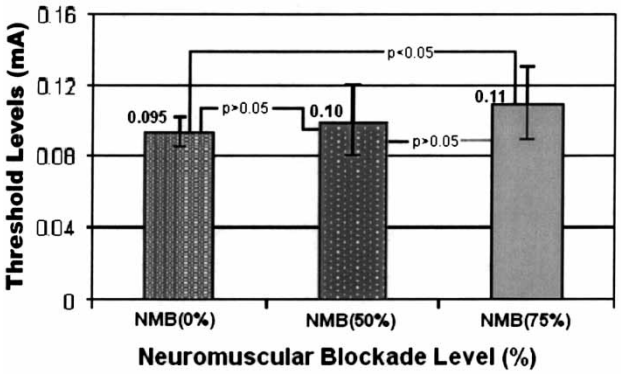

Fig. 1. Mean stimulation threshold levels (with standard deviations) at different NMB levels.

ery of neuromuscular function the mean stimulation threshold of the facial nerve was 0.095 ± 0.01 mA (baseline). When the levels of peripheral NMB were 50% and 75%, all of the patients had recordable EMG responses of facial musculature with mean current threshold levels of 0.10 ± 0.02 and 0.11 ± 0.02 mA, respectively. There was no statistically significant difference in thresholds between the baseline condition and 50% peripheral NMB ($p > 0.05$), whereas the facial nerve stimulation threshold at 75% peripheral NMB was found to be significantly higher ($p < 0.05$) than the baseline status. The stimulation threshold of the facial nerve at 50% NMB was not statistically different from that at 75% NMB ($p > 0.05$). The recordings of facial nerve stimulation thresholds for different NMB levels are shown in Fig. 1. When the level of peripheral NMB was 100%, no response to facial nerve stimulation was measured in 9 patients (31%), 5 of whom had an overtly dehiscent facial nerve. The results obtained at 25% NMB were disregarded, owing to their close similarity to the baseline findings. Additionally, stimulation thresholds of the facial nerve were to be found statistically indistinguishable in dehiscent and intact facial nerves when the level of peripheral NMB was 50% ($p > 0.05$).

DISCUSSION

Postoperative facial nerve paralysis is a devastating complication for both the patient and the surgeon, and thus prevention is clearly the desired management strategy. In an attempt to decrease the occurrence of postoperative facial nerve palsy, intraoperative facial nerve monitoring has been used to identify and map the course of facial nerve fibers (10). The effectiveness of EMG monitoring systems for the detection of injury to the nerve is related to facial muscle responsiveness. The use of neuromuscular blocking agents can make the facial musculature unresponsive to electrical and mechanical stimulation (13, 14). For this reason, anesthetists are asked to avoid the use of neuromuscular blocking agents when maintaining anesthesia during otologic surgery (12).

The anesthetic management of otologic patients should ensure both optimal general anesthesia and a safe environment for EMG monitoring. NMB, as part of a general anesthetic, is given in order to keep the patient immobilized during surgery. In the absence of NMB, large doses of narcotics and volatile anesthetic agents are used to keep the patient immobilized (12, 13). These high levels of anesthetics may cause detrimental effects in some patients with severe hemodynamic instability. Patients who move or are aroused during particular surgical procedures may present a serious risk to the surgeon by causing complications. Sometimes delicate microsurgical interventions necessitate the absolute immobility of the patient (14). Thus, we have investigated the effects of partial NMB on facial EMG monitoring in otologic surgery. The facial nerve was sequentially stimulated at various NMB levels to determine the adequacy of partial NMB for providing suitable facial EMG recordings. Facial nerve stimulation thresholds at various NMB levels were correlated with baseline measurements. The stimulation threshold of the facial nerve at 50% NMB was statistically indistinguishable from that at 75% NMB. The stimulation threshold of the facial nerve at 75% NMB was significantly higher than that at the baseline level of peripheral NMB. A 50% level of peripheral NMB with atracurium provided sufficient NMB with reliable facial nerve monitoring. Maximal stimulation was not applied to the facial nerve for fear of causing fatigue or neuropraxia.

The anesthesia literature indicates that there is a difference in sensitivity between the facial and ulnar nerve responses to non-depolarizing NMB agents (15). The facial musculature seems to be less sensitive than the hypothenar muscle to the NMB effect of non-depolarizing agents (15, 16). This knowledge allows us to speculate that intraoperative monitoring of the facial nerve can be regarded as a reliable method in conditions of partial NMB.

In an animal model, it was found that high levels of NMB do not preclude safe facial EMG monitoring during cerebellopontine angle surgery (12). In clinical studies of acoustic neuroma surgery, controlled NMB with atracurium with a 50% decrease in hypothenar muscle activity allowed safe facial EMG monitoring, in addition to effective peripheral NMB (14, 17). Although there are several differences between the otologic and neurootologic approaches and the condition of the facial nerve within the temporal bone

also differs, there have been no reports regarding the role of partial NMB in otologic surgery in terms of providing satisfactory facial nerve monitoring. The operative management of acoustic neuroma differs from conventional otologic surgery. The condition of the facial nerve generally differs in acoustic neuroma surgery and tympanomastoid surgery. Also, the facial nerve is histologically different in the cerebellopontine angle and labyrinthine segment than in its distal extension, where it is surrounded by a dense epineurium. Despite these differences, the results of the present study corroborate previous reports (12, 14, 17) with similar objectives in the domain of neurootology.

In conclusion, this study suggests that a regulated 50% level of peripheral NMB provides reliable intraoperative EMG monitoring of the facial musculature in response to electrical stimulation and adequate anesthesia, with full immobilization of the patient.

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