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Original Article

Midline Facial Nerve Monitoring: Single-Center Experience and Review of Literature

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BACKGROUND: Facial nerve monitoring system has enabled facial muscle activity detection using electrodes placed over the target muscles. In an effort to enable the best and minimally invasive surgical approach, a midline facial nerve monitor was applied during bilateral cochlear implantation surgical intervention in our center and the feasibility of placing midline facial nerve monitor electrodes during bilateral cochlear implantation operations was evaluated.

METHODS: The medical records and operative notes of all patients who underwent bilateral cochlear implantation surgery between January 2017 and April 2018 in a quaternary care center were retrospectively reviewed and divided into 2 groups based on the facial nerve monitoring methods: facial nerve monitoring with the midline (midline facial nerve monitor) or bilateral (bilateral facial nerve monitor) electrode placements. Basic demographic information, comorbidities, and facial nerve status (pre- and postoperatively) were collected from patient electronic medical charts. The operative notes were reviewed for abnormal facial nerve findings, as well as for any reported difficulties with the identification or stimulation of facial nerve. The primary outcome was facial nerve identification postoperative function.

RESULTS: Seventy-eight patients met our inclusion criteria. Midline facial nerve monitor was used in 49 patients and bilateral facial nerve monitor was used in 29 patients. No documented difficulty was identified at the step of facial nerve identification in either group, and none of the patients developed facial nerve weakness postoperatively.

CONCLUSION: Midline facial nerve monitor is a safe and reliable method that can be used in bilateral cochlear implantation surgeries and other surgeries requiring facial nerve monitoring.

KEYWORDS: Cochlear implantation, facial nerve, facial nerve injuries, neurotology, physiologic monitoring

INTRODUCTION

The concept of facial nerve (FN) monitoring dates back to 1898, when Krause described the use of monopolar electrode stimulation during cochlear nerve transection for a patient with tinnitus to identify the course of the nerve and differentiate it from other cranial nerves, including the FN.[1] After that, intraoperative FN monitoring underwent multiple stages of development and refinement, including in the form of direct visual inspection of facial movements[2] and facial motion detection devices[3] until the advent of intraoperative electromyography in 1979. The latter was used by Delago et al[4] during cerebellopontine angle (CPA) tumor resection using surface electrodes. After that, this technique was modified multiple times to improve the detection of facial muscle movement in response to electrical and mechanical stimulation with the integration of acoustic feedback.[5,6]

The use of FN monitoring intraoperatively during ear and skull base surgery was found to be useful and contribute to improving FN function postoperatively, as reported by multiple studies.[1] Currently, the standard of care is to use FN monitoring during CPA tumor surgeries, and the National Institutes of Health has recommended its routine use in all cases.[7] Similar recommendations were recently made by the Congress of Neurological Surgeons.[8] For middle ear and mastoid surgeries, despite conflicting opinions with

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regard to its routine use, most centers nowadays adopt its use as the standard of care,[9] as it was found to be cost-effective and of great importance, especially for complicated cases or in cases in which abnormal FN anatomy is anticipated.[10] Intraoperative FN monitoring has many advantages as it helps the operating surgeon identify and map the course of the FN and notifies the surgeon when dissection or drilling gets too close to the FN, thus minimizing mechanical/thermal trauma to the FN trunk, and predicting the prognosis of FN function if it is inadvertently injured during the surgical procedure.[1]

Multiple neuromonitoring techniques have been described in previously published literature[1] with multiple commercially available systems such as Medtronic® Nerve Integrity Monitor (NIM-RESPONSE 3.0; Medtronic Xomed INC, Jacksonville, USA) and the Neurosign® system. These systems provide real-time continuous monitoring of neural activity, which is detected by electrodes attached to the target muscles (facial muscles) being monitored. Different types of electrodes can be used including wire, subdermal, and surface electrodes, each with its own advantages and disadvantages.[1] Subdermal electrodes are most commonly utilized due to their specificity in detecting target muscle activity as compared to surface electrodes and their low insertion-associated complication rates compared to wire electrodes.[1]

Facial nerve monitoring has been widely performed by placing the recording electrodes on the lateral edges of facial muscles (Orbicularis oculi and Orbiculais oris) in the side ipsilateral to the surgical procedure.[11,12] However, the exact location and configuration of the electrodes at the vicinity of these muscles providing optimum monitoring have not been standardized yet.[13] For bilateral simultaneous ear surgeries, such as bilateral simultaneous cochlear implant (BSCI) surgery, 2 sets of electrodes are utilized to monitor the FN on each side. However, both theoretically and based on anatomical studies, it is possible to monitor the activity of the FNs on both sides by placing the FN monitor electrodes at the midline.[14,15] The midline facial nerve monitoring (MFNM) method for BSCI has been described in previously published literature, but this technique's safety and its effects on FN function have not yet been reported.[16]

Our aim in this study is to assess the impact of FN monitoring with electrodes placed in the midline, compared to the method in which they are placed bilaterally, on FN function and ease of stimulating the FN intraoperatively during BSCI surgery.

METHODS

This is a retrospective case–control study involving all adults and children who underwent simultaneous bilateral cochlear implantation (CI) surgery with the use of an FN monitoring system using midline or bilaterally placed electrodes under general anesthesia between January 2017 and April 2018 at a quaternary care center. Ethical approval was obtained from King Saud University, Protocol No. (KSU IRB No. E-18-3510), and informed consent was waived as the study does not involve revealing of participant identity and lack of risk to included patients. Patients with pre-existing FN deficits, facial deformity, cleft lip, a neuromuscular disorder, history of Botox injection, having undergone revision surgery, or having undergone surgeries terminated due to operative risks were excluded from the study. The primary outcome assessed was intraoperative FN identification and postoperative function.

Data Collection

Data were collected from the medical records and operative reports of each patient. Variables collected included basic demographic information (age and gender), medical comorbidities, syndrome, FN status (pre- and postoperatively), and electrode placement-related complications (ecchymosis, swelling, pain, or facial twitching). All data were recorded in an Excel sheet (Microsoft® Excel for Mac V16.19, 2018, Microsoft Corp., Washington, USA).

Facial Nerve Monitoring

All surgical procedures were performed under general anesthesia with the use of a short acting muscle relaxant for induction and endotracheal intubation. The same FN monitoring system (NIM-RESPONSE 3.0; Medtronic Xomed Inc, Jacksonville, USA) was used for all surgical procedures. After induction of anesthesia, the FN monitoring electrodes (Paired Subdermal electrodes, Medtronic Xomed Inc) were put in place (midline or bilaterally) after cleaning the skin with an alcohol swab.

For the midline electrode placement, 1 electrode was placed in the midline of the forehead at the glabellar region in a vertical orientation, and the other electrode was placed at the midline of the philtrum (midway between subnasale and labrale superius) in a transverse orientation (Figure 1). The ground (reference) electrodes were placed over the sternum with a minimum of 5 mL between the 2 electrodes. All electrodes were fixed in place using adhesive tape (3M™ Steri-Strip™, Minnesota, USA.

For the bilateral electrode placement, the first electrode was placed on the lateral rim of the orbicularis oculi muscle (1 cm above lateral cantus) and the second electrode on the lateral part of the orbicularis oris muscle (into the upper lip through the nasolabial fold) (Figure 2).

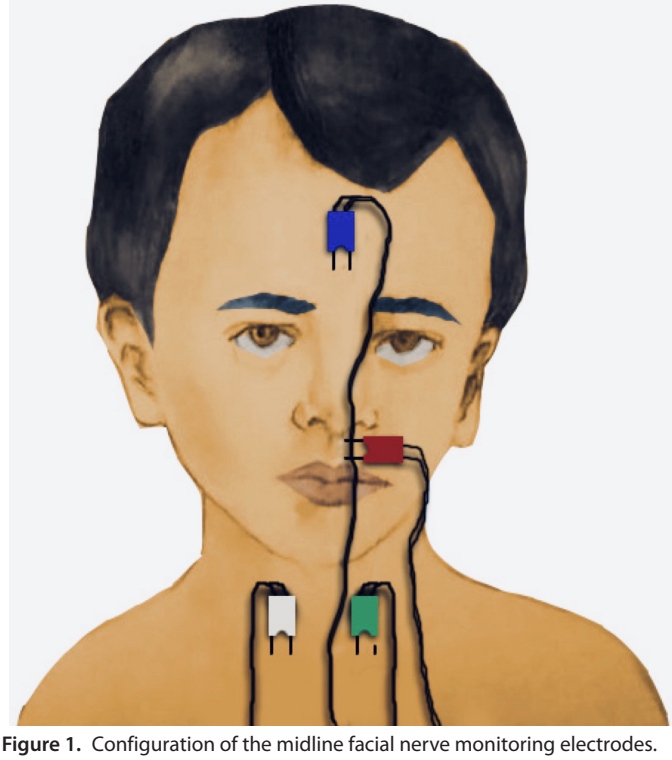

Figure 1. Configuration of the midline facial nerve monitoring electrodes.

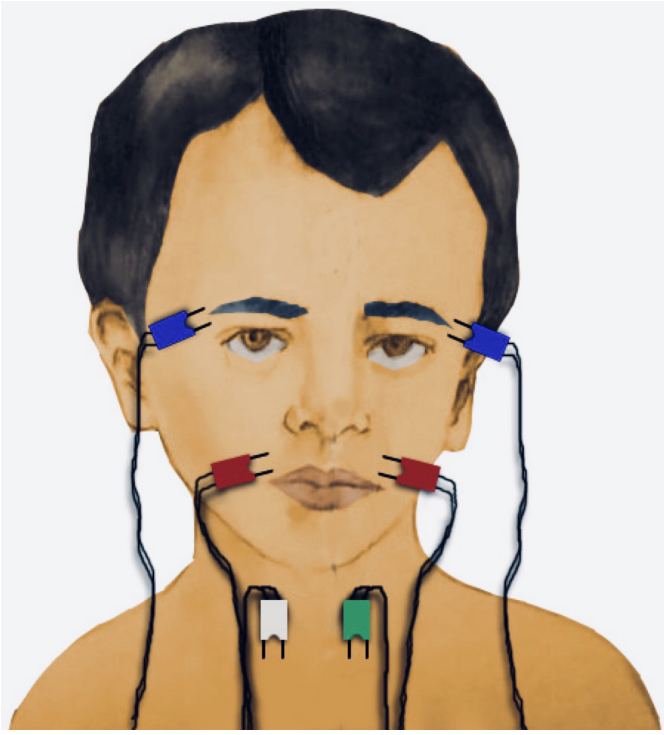

Figure 2. Configuration of the bilaterally placed facial nerve monitoring electrodes.

Electrodes were then connected to the NIM 3.0 device, and their function was tested by tapping over the electrode inserted over the orbicularis oculi (frontalis for midline) and orbicularis oris muscles. Waves on the monitor and audible sounds were observed in order to confirm their proper placement and function before draping the patient. The FN monitor was set to mastoid surgery settings, turned on at all times during the surgical procedure, and muted when using monopolar electro-diathermy to incur a skin incision or superficial hemostasis.

Surgical Method

The same surgical steps were applied in every case. A 3 cm postauricular incision was made on each side, after which the anteriorly based Palva flap was elevated and the internal device pocket was created. A cortical mastoidectomy was performed until the antrum was exposed and the landmarks were identified (lateral semicircular canal and incus).

Once the anatomical landmarks were identified, the facial recess was opened with respect to the FN and chorda tympani. The probe of the FN stimulator (Standard Prass Flush-Tip Monopolar Stimulator Probe Medtronic Xomed Inc) was used during facial recess opening to confirm the FN position. Stimulation of each point along the mastoid segment of the FN started at 0.8 mA, decreasing in a stepwise manner to 0.5 mA, at a frequency of 3 Hz, until FN skeletonization was achieved. After opening of the facial recess, the CI electrode was slowly inserted into the scala tympani through the round window after drilling the overhanging niche. The wound was then closed in 3 layers, and no dressing was applied.

Statistical Analysis

IBM SPSS Statistics for mac, version 23 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses. Parametric variables were compared between the 2 groups using an independent sample *t*-test. Non-parametric variables were compared between the 2 groups using a Mann–Whitney *U* test.

RESULTS

Seventy-eight patients were included in the study. Forty-nine patients were in the midline group and 29 in the bilateral group. The basic demographic information for both groups is presented in Table 1. No statistically significant difference was found in age, gender, or comorbidities between the 2 groups.

All of the patients had intact preoperative FN function. Facial nerve monitoring was used in all cases, with no documented technical issues or loss of the monitor signal. There was no difficulty intraoperatively identifying the FN on either side, and none of the patients developed any FN deficits postoperatively in either group. There were no subdermal electrode placement-related complications in any patients in either group.

DISCUSSION

Our results suggest that the use of FN monitoring with midline-placed electrodes can provide equally adequate and safe intraoperative FN monitoring as the bilateral configuration method during BSCI. No difficulty was encountered during identification of the FN in any of the patients using either configuration method. However, due to the retrospective nature of the study and the lack of documentation, we were not able to compare the levels of stimulation required in each group for a more objective comparison. The majority of patients in our study were in the MFNM group, and none of the patients in either group developed any FN deficits postoperatively, which further supported the safety of our innovative MFNM method.

To our knowledge, this is the second study to investigate the role of MFNM in BSCI.[16] We sought to conduct this study since we found that there is a paucity of studies investigating the value of FN monitoring

Table 1. Basic Demographic Information of the Included Patients

Group	Age*, Mean (SD)	Sex**		Comorbidities***		Syndromic***	
		Male, No. (%)	Female, No. (%)	Yes, No. (%)	No, No. (%)	Yes, No. (%)	No, No. (%)
Midline N = 49	4.4 (5.03)	29 (59%)	20 (41%)	7 (14%)	42 (86%)	2 (4%)	47 (96%)
Bilateral N = 29	2.9 (2.06)	14 (48%)	15 (52%)	2 (7%)	27 (93%)	3 (10%)	26 (90%)
P-value	.065	.349		.471		.355	

*Independent samples Student's *t*-test, **chi-square test, ***Fisher exact test.

during CI surgery in general. In our center, which is one of the biggest centers in the world for CI, we adopted a philosophy of minimalism in order to simplify the surgical procedure and provide the patient with a safe and less invasive surgical intervention. Using FN monitoring with midline-placed electrodes is an important minimalistic measure with regard to the number of traumatic subdermal needle insertions. This will help reduce pain at the needle insertion site, risk of ecchymosis development, infection, and risk of muscle fiber injury.[11,17] Moreover, during bilateral simultaneous CI surgery, head movement during repositioning of the patient to operate on the other side may result in the accidental displacement of the electrodes; midline fixation of the electrodes may help minimize this risk.

Facial nerve monitoring is an essential tool, when available, that provides the otologist with valuable information that greatly contributes to safe surgical procedures. This is of heightened importance in surgical procedures that involve close dissection around the FN such as skull base and middle ear/mastoid surgeries including CI. In addition to meticulous surgical techniques and adequate anatomical knowledge, FN monitoring can help the surgeon more accurately identify the nerve course, thus minimizing the risk of injury.[11,18] Currently, CI is considered a safe surgical procedure with minimal risks. However, like any other surgical procedure, it can lead to certain complications.[19,20] One of the rare but serious sequels is the potential for FN injury.[18,21,22] While multiple studies have reported on the rate of FN injury following CI surgery, only 1 has looked into the effect of FN monitoring on FN function.[11,21,22] A recent retrospective case series study was conducted by Hsieh et al[11] to assess the rate of FN injury with and without FN monitoring use during CI surgery. The authors compared the incidence of FN paralysis between 2 groups consisting of group 1 (FN monitor group) (n = 273) and a control group (without use of FN monitor) (n = 372). There were 4 cases out of 645 patients who developed immediate onset FN paralysis, with 2 patients in each group. Although the difference in incidence of FN paralysis among the 2 groups was not statistically significant, the authors found a great value for FN monitoring for the identification of dehiscent FN and the maintenance of its integrity. Other previously published studies have reported on the FN status following CI, but none of them studied the impact of FN monitoring use on nerve function postoperatively.[21,22] In contrast, multiple reports have shown the great value of using FN monitoring in middle ear and mastoid surgery, alongside its usefulness in tracing the FN.[23,24] Currently, most centers, including ours, have adopted the use of FN monitoring as a standard of care during CI surgery. Based on our experience, we found FN monitoring to be a great adjunct since none of our patients developed FN weakness postoperatively.

The use of FN monitoring and the configuration of placement of the electrodes at facial muscles during the middle ear/mastoid or CI surgery have not received enough attention. Subdermal needle electrodes were mostly placed with one electrode over the orbicularis oris muscle and another over orbicularis oculi muscles on the ipsilateral side, with the reference electrode placed at the vertex or sternum, as described by Kartush et al[12] Guo et al[13] evaluated the optimal monopolar needle electrode placement during various otological surgeries by measuring the maximum compound muscle action potential (CMAP) recorded using different ipsilateral electrode placement configurations. The authors found that placing one monopolar electrode within the lateral canthus and one toward the upper eyelid generated the highest CMAP, while no difference was found for the orbicularis oris between of the electrode on the upper or lower lips. Despite frequent ipsilateral electrode placement in the orbicularis oculi and orbicularis oris, there remains no standardized configuration method.

Midline electrode placement for assessing FN function was previously reported in the literature.[14,16,25] In a recent study, Wada et al[25] compared CMAP recorded with surface electrodes placed at the midline (at philtrum for orbicularis oris) and on each side during electroneurography in patients with facial paralysis. They reported that midline electrode placement was simple and could provide results comparable to the bilateral electrodes configuration. The idea behind using MFNM in our study was based on the anatomical configuration of the facial muscles and their FN supply. The FN has a variable branching pattern and, reportedly, multiple interconnections exist between the different branches and their muscular targets.[26-28] Most studies reported that the frontalis muscle and superior portion of the orbicularis oculi are supplied by the temporal branch mainly in addition to the zygomatic branch or the interconnection of these.[15,26,27,29,30] The superior portion of the orbicularis oris muscle is mainly innervated by the buccal branch of the FN, which itself is frequently found to have interconnections with the zygomatic and marginal mandibular nerves.[26,27] The procerus muscle is supplied by the buccal branch of the FN,[26] although it has been reported to be supplied by temporal and zygomatic branches as well.[15] The terminal branches of the FN entered their target facial muscles at the posterolateral aspect of each muscle on each side,[26,30,31] but histological studies of facial muscles revealed a diffuse motor end plate distribution over the muscle fibers.[28] The terminal FN branches were found to be confined to one side of the face without crossing the midline to the contralateral side,[31] but crossing FN fibers to the contralateral side have been reported in an experimental animal electrophysiological study.[32] Anatomical studies have revealed several characteristics of the orbicularis oris muscle. This muscle is composed of 8 distinct segments with fibers interlacing each other. At the midline near the nasolabial sulcus, the muscle is bulkier and thicker than at the periphery, with muscle fibers from each side crossing to the contralateral side.[15] Therefore, the midline part of the orbicularis oris muscle receives dual innervation from FNs on each side,[15] and electrodes placed in this region can better detect muscle activity. For the forehead, there exist multiple muscles including the frontalis, procerus, corrugator supercilii, and medial parts of the orbicularis muscle, all of which were found to intermingle with each other,[15,30] meaning that electrodes placed at the midline of the forehead are able to simultaneously detect the electrical activity of multiple facial muscles, from both sides. These anatomical and neurophysiological findings support the feasibility of MFNM, as an alternative to BFNM, as a method for monitoring FN activity from both sides.

We propose that future studies be conducted to study MFNM in cases of unilateral ear surgery, as well as to compare MFNM to classical bilaterally placed electrodes for the identification of the FN. In addition, we suggest investigating whether there is any difference in the threshold of stimulation between the 2 techniques.

CONCLUSION

Midline facial nerve monitor is a reliable method for FN monitoring during simultaneous bilateral ear surgery. Future studies are needed

to compare the advantages of using the midline configuration over bilaterally placed electrodes and assess the different levels of facial monitor stimulation between the 2 configurations.

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