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New methodology for facial nerve monitoring in extracranial surgeries of vascular malformations

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HIGHLIGHTS

- We developed a new methodology that allows continuous recording of CMAP by stimulating the facial nerve extracranially throughout surgery.
- Our methodology reduces the incidence of complete facial nerve injury to 1.5% during surgery of vascular malformations.
- This methodology may prevent facial nerve injury during other types of extracranial surgeries where radical excisions are required.

ABSTRACT

Objective: To develop a more reliable methodology for monitoring the facial nerve in surgeries of vascular malformations where the extracranial segment of the nerve is at risk.
Methods: Our methodology comprises: (1) preoperative mapping to identify the anatomical location of the nerve branches, (2) continuous intraoperative monitoring of the compound muscle action potential (CMAP) by stimulating the facial nerve extracranially, in close proximity to where the trunk of the facial nerve exits the skull at the stylomastoid foramen, (3) intraoperative mapping to identify the nerve branches during surgical dissection and quantify the innervating contribution of each branch to the target muscle.
Results: Only three out of 201 surgeries (1.5%) had complete facial nerve trunk injury as a consequence of facial vascular malformation surgery.
Conclusions: We developed a new method to continuously stimulate the facial nerve extracranially eliciting an objective parameter—the CMAP amplitude—to constantly measure changes in the muscle responses throughout surgery, alerting the surgeon before the facial nerve is severely injured. Our methodology notably reduces the complete facial nerve injury during extracranial surgery of facial vascular malformations.
Significance: This comprehensive methodology may also be a valuable tool to prevent facial nerve injury during other types of extracranial surgeries where radical excisions are required.

1. Introduction

The risk of facial nerve (FN) injury during extracranial surgery for facial vascular malformations (FVM) is high and comparable to the risk of FN injury as reported in parotid gland tumors surgery. The percentage of patients with permanent FN paralysis reported in the literature following surgeries for lymphatic malformations are 9.5% (Lee et al., 2008) and up to 7% for parotidectomies (Lowry et al., 2005; Eisele et al., 2010). FN paralysis has a significant impact on the patient's life (Lowry et al., 2005) and rehabilitative efforts have poor results. Additionally, in contrast to malignant parotid tumors, FVM are benign lesions, making it particularly important to preserve the function of the FN in these patients.

The aim of facial nerve monitoring (FNM) is to prevent complete nerve injury by alerting the surgeon when the FN is at risk during surgical manipulations. FNM methods available for

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surgery involving the extracranial segment of the FN do not substantially differ from those involving the intracranial segment of the FN, except for the preoperative mapping. Percutaneous preoperative mapping of FN has been previously described to provide a preview of the anatomical pattern of the FN divisions in surgeries of head and neck where the extracranial part of the FN is at risk (Park, 1998; De Camargo and Deletis, 2002; Park, 2003; Chiara et al., 2009).

Conventional FNM methods include: continuous free-running electromyography (Grosheva et al., 2009; Chiara et al., 2009), recording of facial motor evoked potentials elicited by transcranial electrical stimulation (Dong et al., 2005) and occasional intrafield electrical stimulation of the FN with a probe stimulator and recording of the compound muscle action potential (CMAP) (Delgado et al., 1979; Mamelle et al., 2013). Recently Amano et al. (2011) introduced an innovative method in surgery of vestibular schwannomas that allows continuous recording of CMAP by stimulating the root of the nerve intracranially. But intracranial stimulation of the FN is not a feasible methodology for surgeries involving the extracranial segment of the nerve, where no craniotomy is performed.

In this study, we describe a reliable method for stimulating the FN in its extracranial segment, which has been lacking with other techniques. By stimulating the FN extracranially, in close proximity to where the trunk of the FN exits the skull at the stylomastoid foramen, we are able to record changes in the amplitude of the CMAP continuously throughout the surgery. According to Amano et al. (2011), if the CMAP amplitude is preserved more than 50% at the end of the surgery, the probability of severe FN palsy is very low (<5%). Similarly, our warning criterion by which to judge whether to stop or continue vascular lesion removal in order to prevent further nerve damage was a CMAP amplitude preservation ratio of 50%.

Our approach to FNM in extracranial surgeries of FVM integrates percutaneous preoperative mapping, intrafield intraoperative mapping and a continuous CMAP monitoring throughout the surgery. The greatest advantage of this new method is the ability to detect early signs of nerve stress in response to surgical manipulations by recording decrements in CMAP amplitude and using those values as neurophysiologic warnings to alert the surgeon before the FN is severely injured.

2. Materials and methods

2.1. Patients

We retrospectively analyzed data from 201 surgeries on 161 patients during an 8-year period (2004–2012). All patients presented to the tertiary referral practice of a single surgeon (M.W.) at the Vascular Birthmark Institute of New York. Each patient underwent surgical excision of FVM, involving the head and neck, whereby the trunk of the FN was potentially at risk of being damaged during surgery.

Diagnoses were based on clinical examination, MRI (with and without contrast), ultrasonography, and angiography. Surgery was performed by a surgical team, with the same principal surgeon (M.W.). The surgical approach was a facelift or modified Blair incision for all the patients (Fig. 1).

Some patients underwent multiple surgeries using the same approach for persistent disease or more extensive lesions (Fig. 2). Anesthesia was maintained by inhalational anesthetics without a muscle relaxant unless intubation was difficult. In general, local administration of lidocaine was avoided.

This study was approved by the local Institutional Review Board.

Fig. 1. This schematic shows some of the surgical incisions performed by the surgeon in facial nerve surgery, viewed from the lateral side of the face. The Modified Blair incision is illustrated as a line extended from retro-auricular to pre-auricular region and caudally to the neck (arrows).

2.2. Methodology

Our approach for monitoring the FN in extracranial surgeries of vascular malformations is based on our previously used techniques (De Camargo and Deletis, 2002) and is comprised of three steps: (1) preoperative percutaneous mapping of the FN, (2) continuous intraoperative monitoring of the CMAP by stimulating the extracranial segment of the FN, and (3) intraoperative mapping of the FN.

2.3. Preoperative percutaneous mapping of the facial nerve

We stimulated the FN with a portable stimulator (Digistim III, Neurotechnology; Houston, TX) by delivering stimuli of varying intensities, with a maximum of 40 mA. A handheld ball-tip monopolar probe was used as the cathode electrode, and a disposable surface electrode (Viasys Healthcare; Madison, WI) was used as the anode and placed over the skin of the mastoid process.

Muscle responses were primarily assessed by visualization of muscle twitch (Fig. 3A and B). In very complex lesions or when the muscle twitches were not clearly visible, CMAP responses were assessed instead of visible muscle twitches for mapping the FN branches (Figs. 2A and 3E). For recording CMAP responses, disposable twisted pair subdermal needle electrodes (Viasys Healthcare; Madison, WI) were inserted into the monitored muscles: *orbicularis oculi*, *orbicularis oris*, *nasalis*, *mentalis*, and *frontalis.* Recording muscle electrodes were placed: 0.5 cm lateral to the outer wall of the bony orbit for *orbicularis oculi*; 0.5 cm below the lower border of the lower lip or 0.5 cm above the upper border of the upper lip, close to the angle of the mouth for *orbicularis oris*; 1 cm above the lower border of the nasal ala for *nasalis*; 1 cm lateral to midline of