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Research Paper

# Assessment of axonal excitability properties in two branches of the human facial nerve

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## HIGHLIGHTS

- A new method for determining facial nerve excitability properties is proposed.
- The method uses surface stimulation and recordings for two distinct branches of the facial nerve.
- Normal control data demonstrates consistency of excitability properties between the two branches.
- Age and gender differences and comparison with median nerve recordings are explored.

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## ABSTRACT

*Background:* Axonal excitability methods have an established role in determining the biophysical properties of human axons in the clinical setting. The translation and refinement of these techniques for application to the facial nerve is important for advancing the pathophysiological understanding of facial nerve disorders. Facial nerve disorders are common and debilitating, yet in most cases diagnosis is based on clinical judgment alone. The pathophysiology of most causes of facial palsy remains unclear.
*New method:* Novel techniques for the acquisition of facial nerve excitability properties were developed based on anatomical and surgical landmarks for two facial nerve branches. Zygomatic branch stimulation with nasalis recording and marginal mandibular branch stimulation with depressor angularis oris (DAO) recording were used. Comparisons were made between the two branches and with the median nerve, and the relationship between gender, age and nerve properties was explored through subgroup analysis.
*Results:* A full set of recordings were obtained in all participants across a wide age range. 27 nasalis recordings and 19 DAO recordings were completed and analysed. The studies were well tolerated in all participants. Excitability parameters were found to be similar for both branches of the facial nerve.
*Comparison with existing method:* Axonal excitability has proven to be of significant value in the study of motor and sensory neuropathy, however previous experience with facial nerve techniques has been limited. This study establishes normative data and a consistent technique for the application of axonal excitability testing to the study of facial nerve properties.



## 1. Introduction

In the clinical setting, facial nerve disorders are common, disabling and are a frequent cause of diagnostic and prognostic uncertainty for clinicians (Hohman and Hadlock, 2014; Eviston et al., 2015). Traditional neurophysiological methods such as nerve conduction studies (NCS) are of only limited clinical value due to poor sensitivity for early nerve injury and an inability to determine axonal properties beyond the speed of conduction and amplitude of response (Krishnan et al., 2009).

There are a broad array of facial nerve pathologies (Hohman and Hadlock, 2014) yet there are few objective measures which clinicians and researchers can use to determine underlying facial nerve functional properties in disease groups. Controversy still exists regarding the pathophysiology of common causes of facial palsy, including Bell's palsy (Kennedy, 2010; Greco et al., 2012; Eviston et al., 2015). There is a distinct clinical and research need for methods which allow better insight into facial nerve disorders in the human setting. The aim of this study is to establish and standardise methods for determining axonal excitability proper-

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ties of the human facial nerve using threshold tracking techniques in two separate branches of the facial nerve. A range of facial nerve pathologies including tumours, trauma, iatrogenic injury and congenital conditions, may selectively affect individual branches of the facial nerve. For this reason it is important to have the ability to measure nerve function at more than one site and enable branch comparison in the setting of disease.

The peripheral human facial nerve is a complex cranial nerve with motor, sensory and parasympathetic components. It is responsible for all facial muscle movement, facial expression and is critical to interpersonal communication and emotional expression (VanSwearingen and Brach, 1996). Functionally, the facial nerve enables eye closure and eye protection, lacrimation, nasal patency through supporting the lateral alar cartilage and oral competency through enabling lip closure. Loss of these functions causes social and physical disability for those affected with facial palsy and is a primary concern for treating clinicians. Difficulties with eye closure, in particular, risk corneal exposure and predispose to keratitis, erosions and the risk of permanent visual loss.

Measures of axonal excitability provide information on voltage-gated ion channels, pump and exchangers that are located on the axonal membrane (Krishnan et al., 2009). Studies of excitability in upper and lower limb nerves have provided critical insights into the underlying pathophysiology of degenerative, inflammatory and metabolic peripheral neuropathies (Krishnan et al., 2008, 2009). To date the application of this technique to the study of the facial nerve has been limited to a single small study (Krishnan et al., 2007). The facial nerve presents a number of unique challenges for translating this technique due to its complex anatomical arrangement, with many nerve branches intercommunicating and subdividing to form a highly variable network in the confined space of the face. Using anatomical information gleaned from the surgical literature (May, 2000; Captier et al., 2005; Dorafshar et al., 2013) the present study was designed to assess facial nerve excitability properties in two different braches of the nerve, namely the marginal mandibular branch and zygomatic branches and in a wide age range of participants. As many facial nerve pathologies, including congenital, infectious, traumatic and malignant causes, may selectively affect individual branches (Croxson, 1990), a method of testing more than one branch may increase the utility of this technique in studies of facial nerve injury.

## 2. Methods

Participants were recruited from research sites at Prince of Wales Hospital, Chris O'Brien Lifehouse and Liverpool Hospital, Sydney, Australia. The study was approved by institutional ethics committees and written informed consent was obtained from all participants. All participants were screened prior to undergoing study procedures. Screening consisted of clinical neurological assessment and specific questioning for present or past disorders of the facial nerve or neurological system including conditions and treatments known to alter axonal excitability properties (e.g. diabetes, kidney disease, active malignancy, previous chemotherapy, hereditary neuropathy, undiagnosed peripheral neuropathy symptoms, pregnancy, medications).

In total, 27 participants (11 M: 16 F; age range 20–64 years; mean 36.1 years) underwent facial nerve excitability studies of the zygomatic branch. Of this group, 19 had studies performed in two branches (zygomatic and marginal mandibular branches) in the same sitting. Factors limiting marginal mandibular testing in some subjects included the presence of facial hair and participant preference. A full set of excitability parameters was obtained in each recording.

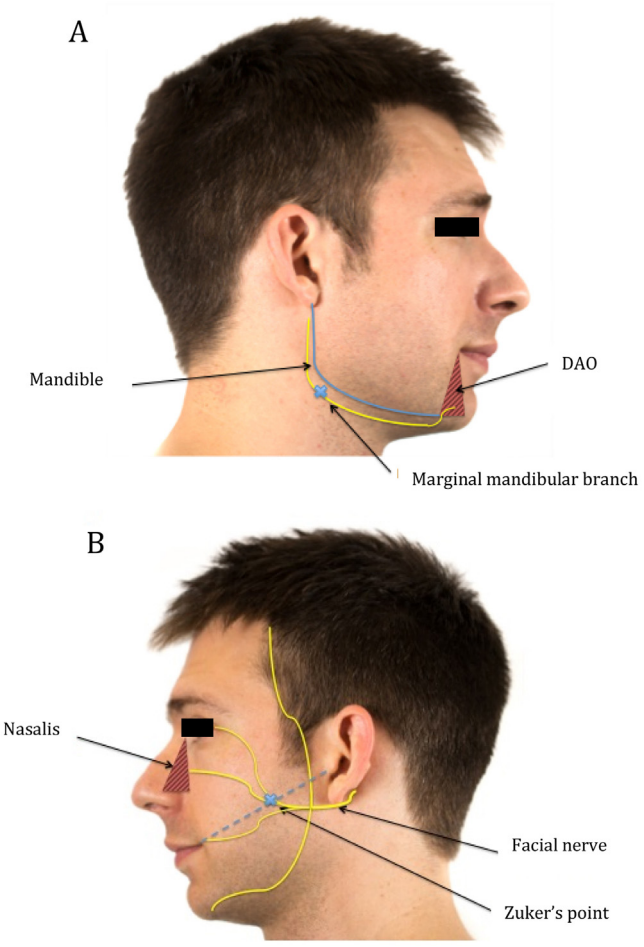


**Fig. 1.** Anatomical representations of marginal mandibular (A) and zygomatic branch (B) landmarks used for recording facial nerve excitability properties.

### 2.1. Threshold tracking

Facial nerve excitability properties were acquired using QTRAC software (©Prof Hugh Bostock, Institute of Neurology, London). The software's TROND protocol enables the automated acquisition of multiple excitability parameters. Initially a stimulus response curve is generated using 1 ms test impulses until a maximal compound muscle action potential (CMAP) is reached. A target response of 40% of maximal CMAP amplitude is then tracked during the course of a defined protocol of conditioning currents. This protocol includes an automated sequence of four testing phases to determine the properties of strength-duration time constant (SDTC), Threshold electrotonus (TE), Recovery cycle (RC) and Current threshold relationship (I/V). Detailed descriptions of the TROND protocol, the testing equipment configuration and the underlying axonal properties which contribute to each variable are described elsewhere(Kiernan et al., 2000).

To attain facial nerve recordings, participants were seated upright for the duration of assessment. Skin preparation was performed routinely and makeup was removed where required. Skin temperature was maintained above 32° C for the duration of testing. Non-polarisable, solid gel surface electrodes (WhiteSensor® WS, Ambu A/S, Ballerup, Denmark) were placed according to pre-determined anatomically optimised sites for testing the mid-face (zygomatic) branches and lower face (marginal mandibular) depressor branch respectively. The anatomical placement for the recording protocols is as follows: