Reference Values of Facial Nerve Stimulation Using Nerve Conduction Study

[1*]Afraa Musa Mohammed Musa (Afraa Musa)

[2]Ammar Eltahir Mohammed Ahmed (Ammar Ahmed)

[1] Department of Physiology, University of Khartoum, Faculty of Medicine.

[2] Department of Physiology, Nile College.

Abstract:

Background: Electroneurography (ENoG) is an objective electro-physiologic measurement used to assess facial nerve integrity; determine the prognosis of facial nerve injury; and guide management.

Objective: This study aimed at establishing baseline reference values of facial nerve parameters of compound muscle action potential (CMAP) for comparison with abnormal findings of facial nerve disorders.

Methods: This cross-sectional study was conducted at the Physiology Department, Faculty of Medicine, University of Khartoum. It involved sixty healthy volunteers (25 males & 35 females). Their mean age was (34.1±15.98), ranged (15-65years). Pre-auricular stimulation of the facial nerve and recording from Nasalis muscle was done bilaterally using Medelec Synergy Machine.

Results: The distance between stimulating and recording electrodes ±SD was 0.65±٨،٢١ cm (7.56–8.86cm). Nerve conduction study findings showed values of total right & left (120) facial nerves as well as right and left sides values including (minimum, maximum, mean and standard deviation) of latencies, amplitudes, durations and areas of facial CMAP.

Conclusion: The values for parameters of facial nerve stimulation are comparable to that of worldwide literature. The variations observed here were most likely due to many factors such as: stimulating electrode placement (pre-auricular versus post-auricular); recording electrodes placement (using different muscles innervated by facial nerve); skin resistance; and magnitude of stimulus.

***Corresponding Author:** *Afraa Musa (aframusa@gmail.com)**

Interoduction:

Electroneurography (ENoG), an objective electro-physiologic measurement of compound muscle action potential (CMAP), is used to assess the integrity of a peripheral motor nerve [(1)]. It is a quick, relatively painless procedure for assessing facial nerve function [(2)]. Electroneurography (ENoG), also is referred to as evoked electromyography (EEMG) and electroneuronography, involves electrical stimulation of the facial nerve with simultaneous electromyographic (EMG) recording[(3)]. Electroneuronography (ENoG) and electromyography (EMG) are the objective tests of facial function most useful in determining the prognosis of facial nerve disorders and in guiding treatment. They are both electro-physiologic measures that indirectly quantify facial nerve function by recording motor unit action potentials (MUAPs) and/or compound muscle action potentials (CMAPs) [(2)]. EMG showed higher prognostic values than ENoG, especially when repeated during the time course of the facial palsy; but ENoG might be helpful if the EMG result is not classifiable[(4)]. Although stimulation electromyography was introduced by Gilliat and Taylor [(5)] as early as in 1959, it was Esslen [(6)] who pioneered this as a test for facial nerve function.

The technique offers the distinct advantage over previous methods of providing an objective quantitative assessment of facial nerve function. The latency, amplitude and total duration of the CMAP are the important parameters of evoked EMG. The technique relies on comparing these values obtained from the affected side with that from the normal side in unilateral facial palsy.

Many other alternative tests of facial nerve function have been, and continue to be, used [(7)]. These include: the Hilger test; acoustic reflex testing [(8)]; evoked accelerometry; antidromic nerve potentials; MRI and CT radiologic evaluations; maximal nerve stimulation tests; minimal nerve stimulation tests; trans-cranial magnetic stimulation [(9)]; blink reflex tests [(10)] ;and highfrequency ultrasonography (HFUS) as a complementary technique paired with neural electrophysiology was beneficial in the evaluation and prognosis of Bell's palsy disease [(11)]. Blink reflex and ENoG, considered together with clinical findings, could offer a good indication and best predictors of facial function recovery in the first phases of Bell's palsy, while EMG findings did not add any prognostic significance [(12)].

Anatomically the facial nerve is the seventh cranial nerve. It carries motor, secretory, and afferent sensory fibers from the anterior two thirds of the tongue. Its nucleus is located within the central nervous system in the pons. This nerve provides motor innervations to the muscles of facial expression, i.e. all facial muscles except those innervated by the trigeminal nerve (masseter, temporalis and pterygoid muscles). Each facial nerve has some 10,000 fibers. About two thirds of the fibers are motor, while only one third are sensory. The anatomic course of the facial nerve can be separated into an intracranial and extra-cranial portion. Intra-cranially, the seventh nerve arises from the pons and traverses the cerebello-pontine angle (CPA) to enter the facial canal via the internal auditory meatus (i.e. the porus-acousticus). The facial canal consists of the labyrinthine, tympanic, and mastoid segments, of which the labyrinthine is the smallest. The mastoid segment terminates, and finally, exits the skull through the stylo- mastoid foramen to begin its extra-cranial course. As the main trunk of the facial nerve enters the parotid region, it divides into superior and inferior divisions from which five main branches arise (temporal, zygomatic and buccal, mandibular and cervical) just anterior and inferior to the tragus of the ear. It innervates various muscles of facial expression [(1, 3, 7, 13)]. These muscles are relatively easy to evaluate with nerve conduction techniques because of their superficial location.

There are various etiological factors for facial nerve paralysis, the most common of which is Bell palsy, which is unilateral and is considered to be of idiopathic etiology. The other causes are metabolic: (e.g. diabetes mellitus); traumatic; neurologic; infectious; vascular; toxic; neoplastic; iatrogenic; and idiopathic [(3, 7, 14-16)].

The evaluation of facial nerve viability by means of electroneuronography (ENoG) is critically important in the management of facial nerve disorders. Depending on the outcome of the ENoG evaluation, the physician may choose to "watch and wait" or may decide to intervene surgically [(7)]. Hence, this test is usually done in cases of unilateral facial nerve paralysis to compare the neurophysiological responses of the normal facial nerve to that of abnormal one. The idea behind doing this is to determine whether surgical intervention is recommended or not, and also to decide the prognosis. The present study was undertaken in normal subjects to establish the normal parameters of facial nerve stimulation (latency, amplitude, duration and area) among Sudanese population and consider these results as baseline reference or cut- off values for comparison with the abnormal findings in cases of facial nerve dysfunction. Our study is the first to establish reference values of facial nerve stimulation in Sudan. Unavailability of the test in most of our centers makes prediction of prognosis of facial nerve dysfunction extremely difficult leading to deficient management of facial nerve palsies.

Methods:

This prospective cross- sectional study was conducted at the Department of Physiology, Faculty of Medicine, University of Khartoum, during a six months period. The study was carried out on healthy human volunteers who were mainly selected from medical students and workers in the Faculty of Medicine and area around it. Sixty subjects participated in this study of whom 25 were males and 35 were females. Their ages ranged from 15-65 years. Only healthy subjects were included in the study (i.e. they had been subjected to thorough history taking and clinical examination). Individuals with a history of facial paralysis due to any cause, neuromuscular disorders (e.g. Gilllain-Barre syndrome), injury, trauma to the temporal bone secondary to motor vehicle accidents (MVA), recent infections (otitis media, mastoiditis, mumps, chicken-pox, herpes zoster oticus), central nervous system disorders (e.g. Multiple sclerosis, stroke), drugs causing peripheral neuropathy, alcohol consumers and diabetics were excluded from the study. Data collection was performed using questionnaire that was designed taking into consideration the full medical history with reference to age, sex and occupation. General physical and neurological examination was done for all volunteers.

The test was performed using Medelec Synergy Machine. The skin was prepared for application of the stimulating and recording electrodes. The subject was made to sit down on a chair while the test was carried out. The stimulating electrode in this study was placed directly over the facial nerve anterior to the earlobe (pre-auricular). The cathode is placed just anterior and inferior to the tragus of the earlobe. Slight manual superior/inferior movement was required to optimally locate facial nerve stimulation position that generates the best compound muscle action potential. The active recording electrode was placed over the Nasalis muscle belly [17] (lateral mid-nose) 1-2 cm above the external naris; sometimes the subject needed to wrinkle the nose and the electrode was placed on the most prominent bulge of the muscle while the reference electrode was placed in the same position on the other side of the face, or on the tip or bridge of the nose [13, 18]. The ground electrode was placed on the chin. The current intensity was increased from zero to a level sufficient to evoke maximal CMAP. An additional 10%-20% of current was added to produce supra-maximal stimulation [2, 13]. A single supra-maximal stimulus was applied to the facial nerve and an individual(CMAP) response was recorded from Nasalis muscles. The CMAP response was recorded first on the right side and then on the left side. Therefore, measurement was conducted using the same technique and distance. From the trace displayed on the monitor, latency, amplitude total duration and area of the CMAP were measured automatically by the digital machine. Latency was measured in milliseconds from the start of the stimulus artefact to the onset of muscle response. Total duration of the response was measured in milliseconds and area in mv/ ms from the beginning to the end of CMAP. Amplitude was measured in millivolts. Finally, the distance between the cathode stimulating and the active recording electrodes was measured in centimeters [13, 18]. Three trials were made for reproducibility on each side of the face and the best was considered.

Statistical analysis was performed using the Statistical Package for Social Science (SPSS) program. The study was ethically approved by the Ethics Research Committee of the Faculty of Medicine , University of Khartoum. All participants were fully informed about the test. They signed an informed consent to volunteer to the research and they had the freedom to withdraw from the study at any time.

Results:

Sixty normal volunteers were included in the study. Gender distribution showed a percentage of 58.3 females and 41.7 males. Age (mean ± SD) was 34.1 ± 15.98 years. Nerve conduction study findings showed values of total right and left parameters of facial nerve stimulation (120 nerves) including mean and SD of the latencies, amplitudes, durations and areas of the CMAP which were summarized in (table 1). In addition, values of right facial nerves and left facial nerves CMAP parameters were illustrated for each nerve separately in (table 2). The mean distance between stimulating and recording electrodes ± SD was found to be 8.21 ± 0.65 cm, ranged (7.56 – 8.86 cm).

Stimulation of the facial nerve anterior to the ear lobe revealed a mean onset latency of 2.87 ± 0.56 ms (2.31-3.43ms) for total right and left facial nerves; mean value of right side latency was 2.83 ± 0.51 ms and left side 2.91 ± 0.61 ms. The mean amplitude was 2.74 ± 1.12 mv (1.63-3.87 mv) for total right and left facial nerves; mean value of right side amplitude was 2.43 ± 0.98 mv and left side 3.05 ± 1.16 mv. The mean response duration was 11.45 ± 1.89 ms (3.22-27.12 ms) for total right and left facial nerves; mean value of right side unit duration was 12.43 ± 2.15 ms and left side 10.47 ± 1.6 ms. The mean response area was 12.48 ± 2.15 mv/ms (4.17-29.13 mv/ms) for total right and left facial nerves; mean value of right side response area was 12.26 ± 2.68 mv/ms and left side 12.7 ± 1.46 mv/ms.

Table 1. Summary of Reference Values of CMAP **Table 1. Summary of Reference Values of CMAP parameters for total right and left facial nerves (n=120) in healthy individuals**

CMAP parameters of total Rt & Lt facial nerves	N	Mean	SD	minimum	maximum
Rt & Lt Latencies (ms)	120	2.87	0.56	2.31	3.43
Rt & Lt Amplitude (mv)	120	2.74	1.12	1.63	3.87
Rt & Lt Duration (ms)	120	11.45	1.89	3.22	27.12
Rt & Lt Area (mv/ms)	120	12.48	2.15	4.17	29.13

Table 2. Summary of Reference Values of CMAP parameters for individual right facial nerves (n=60) and left facial nerves (n=60) in healthy individuals

CMAP parameters of facial nerve	N	Mean	SD
Rt Latency (ms)	60	2.83	0.51
Lt Latency (ms)	60	2.91	0.61
Rt Amplitude (mv)	60	2.43	0.98
Lt Amplitude (mv)	60	3.06	1.16
Rt Duration (ms)	60	12.43	2.15
Lt Duration (ms)	60	10.47	1.6
Rt Area (mv/ms)	60	12.26	2.68
Lt Area (mv/ms)	60	12.69	1.46

Discution:

Electrical stimulation has been used by neurophysiologists over years to test motor nerve function. In recent years, the precision of such tests has been greatly increased by the recording of compound muscle action potentials as a measure in a number of neuromuscular disorders. Almost every aspect of this type of response might be useful in diagnosis [(19)]. In the present study, individual CMAP from Nasalis muscles were recorded on both sides of the face. Response latency is largely a measure of the time required for a nerve action potential to travel down the nerve plus neuromuscular transmission time and muscle fiber depolarization time. Since the latter two are relatively constant, changes in latency reflect changes in nerve conduction time [(13, 20)]. Amplitude of the CMAP is roughly proportional to the number of muscle fibers that respond to the nerve impulse, which in turn correlate with the number of intact motor neurons [(13)]. The duration of CMAP, measured from the beginning to the end of CMAP, is related to the difference in conduction time in the various axons and muscle fibers. It reflects the synchrony of contraction of the muscle fibers contributing to the response [(13)].

In this study stimulation of the facial nerve anterior to the ear lobe (pre-auricular) showed mean values for CMAP parameters (latency, amplitude, duration & area) using distance that ranged between (7.56-8.86 cm). Our mean latency of **2.87 ± 0.56** msec which ranged (2.31 -3.43) was lower compared to 3.57 ± 0.35 msec (2.8-4.1) in which facial nerve stimulation was pre-auricular [(18)]. Again it was lower than 3.880.36± msec (3.2-4.4) in which facial nerve stimulation was post-auricular [(18)]. Another study reported mean latency of 3.5 ± 0.4 msec in which post-auricular stimulation of the facial nerve was carried-out [(13, 21)]. These variations might reflect differences in the placement of stimulating and recording electrodes. In a similar Indian study done in 2003 on 45 normal subjects in the age group of 20–30 years, a mean value of latency on the right side was found to be 3.51 ± 0.38 msec and on left side 3.45 ± 0.49 msec [(22)]. Their latencies were greater than ours (**2.83 ± 0.51** ms in the right and **2.91 ± 0.61** ms in the left side). That could be explained by their longer distance between stimulating electrodes (stylo-mastoid foramen behind the ramus of the mandible) and recording electrodes (alae-nasi) used in that study [(22)]. An increase in distance of 1 cm between the stimulating and recording electrodes results in an increase in latency of 0.23 msec [(23)].

The mean CAMP amplitude of the current study was found to be **2.74 ± 1.12,** and ranges between (**1.63 - 3.87** mv) which is in agreement with other reported reference values range from (1-4 mv) [(13)]. The Indian study findings of facial nerves amplitudes of the right side (2829.26 ± 918.07 μv) and the left side (2989.13 ± 1073.62 μv) were comparable to ours (**2.43 ± 0.98** mv on the right side & **3.05 ± 1.16** mv on the left side) because of the use of similar stimulation techniques [(22)]. Electro-diagnostic evaluation of the temporal branch of the facial nerve and establishment of normative values was done by Silva et al [(24)]. They studied 150 healthy volunteers stimulating the facial nerve at two points along the nerve course, distal: (on the temple, over the temporal branch) and proximal: (in retro-auricular region) on both sides of the face and recording from the ipsilateral Frontalis muscle. Their variable amplitudes obtained [ranging from 0.20 to 3.20 mV for the distal stimulus, and 0.20 to 2.7 mV for the proximal stimulus] were slightly lower compared to our range (**1.63-3.87** mv) of 120 CMAP amplitudes.

Our results of mean CMAP duration were **11.45 ± 1.89** ms for total right and left facial nerves, **12.43 ± 2.15** ms for the right side and **10.47 ± 1.6** ms for the left. These values were greater than those reported by the Indian study [(22)] for total duration of right side CMAP (5.03 ± 1.48 msec) and left side CMAP (5.22 ± 1.54 msec). The duration of CMAP is related to the conduction velocities of large diameter motor nerve fibers and reflects the synchrony of discharge of individual muscle fibers [(13, 25)]. CMAP duration is measured either from beginning to end of the response (total duration) ,or from the initial onset to the final return of the negative deflection (negative–

peak duration) ;and usually the peak duration is about 30% of the total duration in normal control. This fact may explain our longer total duration compared to the Indian study duration [25]. The use of different muscles for recording (Frontals vs. Nasalis) might had partially contributed to this variation as well as different electrode placement would result in different waveforms [26].

Conclusion:

Facial electroneuronography can be performed reliably in the clinic and is usually well tolerated and is of great value in assessing facial nerve's functional integrity. The values for parameters of facial nerve stimulation in our study are comparable to those of world-wide literature. The variations observed were most likely due to many technical factors such as: electrode placement of both stimulating electrodes (pre-auricular vs. post-auricular) and recording electrodes (different muscles innervated by facial nerve); skin resistance ;and magnitude of stimulus intensity.

Recommendation:

Since this is the first study in Sudan establishing nerve conduction studies normal values of facial nerve stimulation, we recommend doctors and neuroscientists to use these normal parameters in the evaluation of patients with facial nerve dysfunction.

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