Nerve conduction study in rehabilitation of patients with residuals and complications of long-standing Bell's palsy

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From every 100 cases of Bell's palsy (idiopathic peripheral facial palsy) from 15 to 30 will not recover completely. Some residuals will remain, and some complications will develop. As residuals, one can name weakness of facial muscles, asymmetry of facial expressions, distortion of taste, hyperacusis, dry eye. Possible complications of long-standing Bell's palsy (BP) are also numerous: contractures of facial muscles, pathological synkinesis, mass movements, crocodile tears, facial pains, headaches, emotional disbalance etc.

Unresolved cases of Bell's palsy require rehabilitation programs that will address both the issues of general nerve regeneration, complications and irregularities in mimetic movements, and psycho-emotional state of long-standing Bell's palsy patients. There are several methods and systems to assess the condition of facial nerve and functioning of facial muscles. These scales and systems are either therapist- or patient-graded: House-Brackmann Facial Grading system, Sunnybrook Facial Grading system, Facial Clinimetric Evaluation Scale (FaCE Scale), Synkinesis Assessment Questionnaire (SAQ) and several others.

At the same time, to compose a well-balanced and focused rehabilitation program, next to subjective assessments and test-photos of standard facial expressions, it is important to have an objective, instrumentally-measured picture of facial nerve recovery, as well as of the physiological ability of mimetic muscles to perform facial movements, to reflect emotions and to produce articulated speech.

In that respect, the surface EMG or Nerve Conduction Study (NCS) is the modality of choice. NCS-examination is non-invasive and is relatively easy to perform. It records Compound Muscle Action Potentials (CMAPs) in response to external stimulation. The analysis of recorded graphs allows to evaluate the level of regeneration and maturity of recovering axons in main branches of the facial nerve.

At the same time, the standard protocol of NCS does not offer a detailed assessment of each particular muscle of facial expression. It also requires additional time to swap the active electrode position when changing stimulation side from right to left and vice versa.

At Crystal Touch Bell's palsy clinic, we have developed an amended NCS protocol that addresses all mentioned issues. To allow a more detailed assessment of facial muscles, we have added mm.zygomatici (major et minor) and m.depressor anguli oris to the list of measured facial muscles.

In order to perform a more focused stimulation and to receive a more "clean" motor responses from facial muscles, we changed the position of stimulating electrode. In the standard protocol, stimulating electrode is placed either pre- or post-auricularly. In Crystal Touch protocol, we position the stimulating electrode above each particular nerve branch that innervates the measured muscle. Therefore, we use six positions of stimulating electrode that correspond to the six measured facial muscles: m.frontalis, m.orbicularis oculi pars superioris, m.nasalis et m.levator labii superioris, mm.zygomatici (major et minor), m.orbicularis oculi pars superioris, m.depressor anguli oris et m.mentalis.

To save time required for the examination, instead of placing reference electrode on the nasal bridge (standard protocol), we use contralateral electrode over the same as measured muscle, as a reference electrode. As there are no anastomoses between left and right facial nerves, stimulation of facial nerve on one side will not evoke CMAPs in contralateral facial muscles. This simple amendment allows to save about 15% of total time required for the examination.

In this article we also briefly touch the following issues: distortion in reciprocal inhibition of facial muscles-antagonists, forming of the pathological mimetic patterns in the motor cortex due to lack of proprioceptive feedback during long recovery, and the necessity to further investigate from the electrotechnical, engineering and functional point of view the hypothesis of aberrant regeneration as possible cause of facial synkinesis.

Keywords: Bell's palsy; facial palsy; synkinesis; contractures; facial pains; nerve conduction study.

Introduction

Patients with acute peripheral facial palsy lose both emotional and volitional control over their facial muscles on the affected side. Patient cannot move his or her face, blink, adequately express emotions, or speak clearly. Many have difficulty with eating and drinking and suffer from dryness or excessive tearing of the affected eye. Some patients may experience taste distortion, dry mouth and hyperacusis. Although during peripheral facial palsy all brain structures remain intact and continue to function normally, the mimetic signals nevertheless cannot reach facial muscles due to lesion in the very last link of mimetic transmission chain – facial nerve.

There are various possible causes of damage to the facial nerve, and respectively several possible diagnoses.

- Tumors of cerebellopontine angle (CPA) and parotid gland
- Post-operational palsy
- Post-traumatic palsy
- Ramsay Hunt syndrome (herpes zoster virus)
- Otitis media
- Lyme disease
- Guillain-Barré syndrome
- Bell's palsy (idiopathic facial palsy)
- Other

If the trunk of the facial nerve had not been severed or crushed because of trauma or from surgical intervention, then its internal structures (endoneurium and perineurium) in majority of cases will remain intact, which allows unobstructed axonal regeneration and reconnection of regenerating axons to their respective muscles – aims. Discussion about possibility of aberrant regeneration (miswiring) of facial nerve fibers in suchlike cases, lies outside the scope of this article.

In majority of Bell's palsy cases patients achieve full spontaneous recovery within 3-5 weeks with or without treatment. In such cases damages to the nerve fibers (motor neurons) are usually only superficial and limited to myelin sheath, which serves as an electrical insulation and as internal mechanical protection of the axons. Such damages can be repaired by the human body rather quickly and mimetic movements are fully restored within several weeks.

In about 15-30% of cases the recovery takes considerably longer time (3 to 6 months, sometimes longer)

and is usually incomplete. If the damaging factor was affecting the nerve trunk longer than 4-5 days, then the fibers of facial nerve sustain severe damages and axonal degeneration takes place between the site of lesion and facial muscles. After the incomplete recovery of Bell's palsy, some residuals remain, and complications usually develop. Those can include weakness of facial muscles, facial asymmetry in both neutral expression and with facial movements, pathological synkinesis, contractures of facial muscles, crocodile tears, facial pains etc.

If the clinical picture of acute facial palsy is unclear, MRI scan is usually performed to exclude stroke, tumor or transient ischemic attack. In some countries EMG is customarily performed (including needle EMG, blink reflex study and nerve conduction study) to assess the condition of facial nerve, determine the scale of damage and conduction capacity of its branches.

In most of Western countries, once stroke, tumors and other potential damages to the brain had been excluded, it is not customary to perform EMG or Nerve Conduction Study during the acute phase and recovery period. To evaluate the condition of facial muscles and to assess facial movements, various specialist-graded and patient-graded methods and systems are being used:

1. House-Brackmann Facial Grading System. Therapist-graded.
2. Sunnybrook Facial Grading System. Therapist-graded.
3. Glasgow Facial Palsy program. Video recording-based software, automated (returns values of House-Brackmann scale)
4. Face Assessment by Computer Evaluation System (F.A.C.E.S) Video recording-based software, Semi-Automated
5. Facial Clinimetric Evaluation Scale (FaCE Scale). Patient-graded
6. Synkinesis Assessment Questionnaire (SAQ). Patient-graded.

Although these methods and systems provide time- and cost-efficient and comparatively simple ways to assess the condition of the patient's facial nerve and functioning of his/her facial muscles, these methods do not offer visualization aids to demonstrate both to the therapist and to the patient how well facial nerve is recovering, which of nerve branches had regenerated and how well, which facial muscles had regained their connection with the brain and which are still recovering. Based on those conclusions

certain adjustments to the rehabilitation programs may be required.

From our experience at Crystal Touch Bell's palsy clinic, Nerve Conduction Study (NCS), if performed at regular intervals during rehabilitation program, is indispensable for maintaining patient's motivation, for keeping positive attitude towards the recovery and for providing an objective, instrumental evidence of patient's achievements in the course of rehabilitation program.

Nerve Conduction Study (NCS) may sometimes appear to rehabilitation professionals as a complex, sophisticated and time-consuming procedure. However, it is a rather easy-to-learn and straightforward method that, once mastered, does not take much time to perform. Usually it only takes 20 minutes, including explanations to the patient. It offers both to the patient and to the rehabilitation specialist an objective, instrumental way to "see" the condition and the recovery level of facial nerve. NCS allows to relate dynamic changes in patient's mimetic patterns to the objective graphs on the screen and to visualize instrumentally the clinical picture of regeneration and maturation of recovering motor neurons of the facial nerve.

At Crystal Touch Bell's palsy clinic, we have developed an optimized method to perform Nerve Conduction Study for patients with residuals and complications of long-standing Bell's palsy. This method allows to assess functionality and reinnervation levels of most of the facial muscles. On the other hand, thanks to the optimized procedure and adjusted placement of electrodes, it allows to save time, compared to the classical protocol.

Background

During Nerve Conduction Study at Crystal Touch Bell's palsy clinic, we measure motor responses on both healthy and affected sides from six pairs of facial muscles that provide for most of the facial expressions (FIG.1).

- *m.frontalis*
- *m.orbicularis oculi (pars superioris)*
- *m.nasalis et m.levator labii superioris*
- *mm.zygomatici (major et minor)*
- *m.orbicularis oris (pars superioris)*
- *m.depressor anguli oris et m.mentalis*

Figure 1. Symmetrical placement of 6 electrodes (Active-Reference)

In addition to the "classical" protocols of NCS, we measure motor responses from zygomatic muscles (major and minor) and from depressor anguli oris muscle. The reason is that for the long-standing Bell's palsy patients, asymmetry of smile is the most disturbing aspect of their appearance. For many patients it has higher importance than reduction of synkinesis. Zygomatic muscles produce smile, and in patients with long-standing facial palsy, *m.depressor anguli oris* often contracts spontaneously together with *mm.zygomatici* and pulls down the mouth corner. This results in asymmetry of the smile and leads to forming dimples in the chin. (FIG.2)

From our point of view, the involuntary contraction of

Another amendment to the protocol of NCS that we propose instead of a separate reference electrode (usually placed on the nasal bridge), to use as a reference electrode the contralateral electrode connected to the same as measured muscle. There are usually no anastomoses between branches of the left and right facial nerves, therefore, stimulation of facial nerve on one side does not evoke CMAPs in contralateral facial muscles. This amendment allows to save about 15% time, as there is no need to change each time the position of clips when changing the stimulation side. After having recorded motor responses of the muscle on the right side, we proceed directly to stimulation on the left side without changing

Figure 2. Electrodes on *mm.zygomatici* et *m.depressor anguli oris*, contraction vectors of muscles, asymmetrical smile of a long-standing BP patient, with forming dimples in the chin

m.depressor anguli oris during smiling is not a result of aberrant regeneration, but is caused by disruption in the mechanism of reciprocal inhibition of muscles-antagonists on the affected side of the face. This hypothesis needs further investigation, and further research on this subject is welcome.

polarity of receiving wires and receive an inverted trace on the screen. Instead of spending time each time on changing the clips, we invert the trace just by pressing a pre-programmed shortcut button. (FIG.1, FIG.3)

Figure 3. Non-inverted and inverted traces taken from the left *m.orbicularis oris*

The third amendment to the standard NCS protocol is the adjusted positioning of stimulating electrode. Standard position of stimulating electrode is either pre- or postauricular. We use specific positions for stimulating electrode to receive motor responses from each of the measured facial muscles. Stimulating electrode is placed on a

specific branch of facial nerve, depending on the measured muscle. This allows to imitate (although very roughly) the mimetic signals that arrive to the specific facial muscle from the brain via the facial nerve branch during articulation or reflection of emotions. (FIG.4)

Figure 4. Positions of stimulating electrode (Anode-Cathode), depending on the measured muscle

Discussion

Application of the proposed method allows to assess the condition of facial muscles in a comprehensive and time-efficient way. The study usually takes about 20 minutes, including explanations to the patient. The analysis of results of nerve conduction study allows to evaluate the ability of nerve branches to conduct mimetic signals and the ability of facial muscles to contract in response to those signals. We must realize however, that by themselves, even normal or

close to normal CMAPs do not necessarily indicate the symmetry of facial movements and do not guarantee the ability of the patient to produce adequate muscle contractions to properly reflect the intended emotion or to produce sufficient articulation during speech.

The symmetry of facial movements and adequacy of facial expressions to the underlying emotions in long-standing Bell's palsy patients, depends not only on the functioning of the facial nerve and facial muscles, but a great deal on the finely-coordinated and finely-differentiated

management of mimetic signals by the human brain. We may observe a good recovery of the facial nerve, yet the symmetry of facial expressions may be far from ideal.

Possible reason for this phenomenon, in our opinion, could be the following: during long recovery period, due to poor proprioceptive feedback to the sensory cortex from facial muscles on the affected side, new, pathological mimetic patterns form in the motor cortex that is responsible for volitional facial movements. Those new patterns suppress the well-balanced emotional mimetic patterns that arrive to the nucleus of facial nerve from the limbic system. As a result, facial muscles receive over-amplified, poorly differentiated spectrum of contraction signals, which leads to mass movements, simultaneous contraction of muscles-antagonists and involuntary engagement of facial muscles that under normal circumstances do not participate in the intended facial expression.

Pathological synkinesis, in our opinion, is one of manifestations of disruption in "management" of coordinated contractions and relaxations of facial muscles by the brain. We are planning to address the issue of aberrant regeneration as probable cause of synkinesis in a separate study.

Frontal muscle, for example, may show adequate amplitude, shape and latency of CMAP on affected side, and yet the patient may not be able to lift the eyebrow. This phenomenon could be a result of either "learned helplessness" during long recovery period, or lack of reciprocal inhibition of the upper part of circular muscle of the eye (antagonist of frontal muscle) or to some other factors that yet need to be identified.

Zygomatic muscles may demonstrate motor responses that are very close to those on the healthy side, yet the movement of mouth corner during smiling in most cases will be considerably reduced due to involuntary involvement of the depressor anguli oris muscle. This will result in asymmetric smile and most probably, will be accompanied by synkinetic narrowing of the eye fissure.

In a majority of cases of long-standing Bell's palsy, when there is a difference in CMAP amplitudes of circular muscle of the mouth between healthy and affected side, there will be a certain degree of oral-ocular synkinesis. When the patient puckers the lips or blows the cheeks, the eye fissure on the affected side will narrow, because of involuntary contraction of the circular muscle of the eye.

Likewise, when there is a difference in CMAP amplitudes of circular muscle of the eye between healthy and affected side, there will be a certain degree of ocular-oral synkinesis. When the patient closes the eye, squints the eye or blinks, there will be an involuntary contraction of other facial muscles that are normally not engaged: zygomatic muscles, *m.levator labii superioris*, *m.depressor anguli oris*, *m.platysma* or their combinations.

In order to maintain patient's motivation and to improve his or her quality of life, it is necessary to provide a visual,

easy-to-understand criteria for evaluation of the progress. The time and efforts invested by the therapist in an extended NCS and in explanation of its results to the patient (especially during intake-meeting), are worth every minute spent. It helps to establish good report with the patient and to gain his or her trust, it facilitates patient's understanding of the recovery process, confirms already achieved improvements, helps to set goals and maintains the important feeling of patient's own involvement in the rehabilitation process.

For the therapist, the detailed analysis of NCS results allows to closely follow the rehabilitation progress of a patient, to determine correlations between certain measured parameters and to relate changes in those parameters to improvements in patient's condition. If needed, the rehabilitation program can be adjusted based on the results of instrumental measurements and other tests.

Conclusions

Nerve Conduction Study is a valuable tool in rehabilitation of the long-standing Bell's palsy, as well as of other kinds of peripheral facial palsies. It provides objective, instrumental assessment of the functional capacity of the facial nerve and functioning of the facial muscles. It offers to the therapist an opportunity to establish report with the patient, gain his trust and to obtain important data that will allow to monitor closely not only the changes in patient's appearance and in symmetry of his or her facial expressions, but also to relate those changes to the improvements in objective parameters that reflect the regeneration of the facial nerve.

Amended protocol of NCS proposed in this article will allow rehabilitation specialists to assess in more detail and with better precision the functioning of most mimetic muscles and save time nonetheless.

In this article we have mentioned several important issues that in our opinion, require further research and, if confirmed, may lead to the paradigm shift in rehabilitation of long-standing peripheral facial palsies, and Bell's palsy in particular.

First, it is the issue of disrupted reciprocal inhibition of facial muscles-antagonists that results in their simultaneous contractions during facial movements. Like, for example, zygomatic muscles and muscle depressor anguli oris, or the frontal muscle and circular muscle of the eye. Second, it is the issue of forming of new, pathological mimetic patterns in the motor cortex due to lack of proprioceptive feedback from facial muscles during long recovery, and their role in manifestations of synkinesis. Third issue that in our opinion may require revisiting is a hypothesis of aberrant regeneration as the main cause of synkinesis. There are several assumptions in this theory that may need further study from the electrotechnical, engineering and physiological points of view.

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