The role of transcranial magnetic stimulation in acute Bell's palsy

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This review discusses the reported data in studies using transcranial magnetic stimulation (TMS) in acute Bell's palsy (BP). These studies displayed the role of TMS in confirming the diagnosis and providing prognostic information about outcome of acute unilateral BP. In summary, two TMS roles have been discussed in these reviewed studies when employing TMS in patients with BP: first, the role of TMS as a diagnostic tool for BP when a lesion is of peripheral and lower motor in nature either applied over the ipsilateral parieto-occipital region (canalicular stimulation) or over the contralateral facial area of the motor cortex (cortical stimulation), and the second role of TMS is providing data about its prognostic value in recovery and BP outcome. The overall TMS studies are valuable in prognosis of BP regarding recovery and sequelae.

Keywords:
Bell's palsy, diagnosis, onset of symptoms, outcome, prognosis, transcranial magnetic stimulation

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Introduction

Bell's palsy (BP) is an acute, peripheral facial paresis of unknown cause [1]. It is the most common form of peripheral facial palsy in adults [2,3], with annual incidence range of 20–30 per 100 000 in most epidemiological studies [3–5]. However, other studies recorded higher incidence rate ranged from 51.89 to 107/1 000 000 [6–8].

In at least 85% of affected cases, a complete or near-complete recovery can occur within 5 months without treatment [2]. Up to 30% of patients with BP fail to completely recover of facial function, with the result that thousands of these patients had permanent, potentially disfiguring facial weakness each year [9]. Therefore, these patients want to know the probability and duration of recovery [10,11].

Neurophysiological methods such electrical stimulation (ES) and transcranial magnetic stimulation (TMS) of the facial nerve are presumed to be tools to confirm the diagnosis and obtain information concerning the prognosis of the palsy at the onset of symptoms [12–14].

The role of conventional electroneurophysiological tests in Bell's palsy prognosis

Electroneurography (ENoG) is the most frequently used test and has been claimed to be the most reliable test to assess facial nerve degeneration in BP [15–19]. During ENoG study, the nerve is stimulated percutaneously over the stylomastoid foramen and the compound muscle action potential (CMAP) is recorded in the affected facial muscle and reported as a percentage of the CMAP amplitude nonaffected side. Facial nerve degeneration of more than or equal to 90% has been shown to predict long-term outcome of facial weakness [20,21]. Recently, Khedr *et al.* [22] reported that when the degeneration rate of affected frontalis muscle exceeds 50% of unaffected side, it indicates poor predictors of recovery in BP.

However, the ENoG test cannot be used in the early stage of BP as Wallerian degeneration of nerve fibers takes at least 72 h to become apparent after an acute injury to the facial nerve. It is therefore recommended that ENoG should not be performed until at least 3 days after the onset of facial palsy [23]. Others choose ENoG as a prognostic test between 5 and 14 days after onset [24,25].

Prognostic procedures in objective electrophysiologic examinations include the nerve excitability test, ENoG, electromyography, and stapedial reflex measurements. Each of these has advantages and limitations in practice, but nerve excitability test and ENoG are the most widely used. The facial nerve conduction test

has been used for the prognosis of the disease. The recovery rate varies with the degree of denervation or degeneration rate [11,22,26,27]. However, ENoG responses are variable based on the branch of the facial nerve and electrode placement in patients with BP, even within the same patient [11].

The blink reflex is an another neurophysiological test that allows assessment of the entire efferent peripheral pathway of the facial nerve [28], but the specificity and sensitivity of this parameter increases over time after BP onset, not in early onset [29].

The role of transcranial magnetic stimulation in Bell's palsy

The distal part of the facial nerve is accessible to ES but a large part of the nerve is located within the cranium. In a series of reports, TMS can excite the facial nerve and the facial representation in motor cortex painlessly [12,30–33]. TMS can be applied over the ipsilateral parieto-occipital region, with the base of the coil over the mastoid (canalicular stimulation) or at labyrinthine segment and performed over the contralateral facial area of the motor cortex (cortical stimulation) [30–33].

In BP, evoked response of the labyrinthine segment of the facial nerve by TMS is significantly reduced or even completely absent within hours after symptom onset [34,35], where conduction block within the canalicular proportion to TMS within 3 days from symptom is thought to be specific for BP diagnosis [30,34–36]. Therefore, after 3 days from symptom onset, the diagnostic value of TMS vanishes owing to progressive axonotmesis [37,38]. Thus, TMS allows identification of a conduction failure at the canalicular portion of the facial nerve which is not accessible by ES, and thus helps to identify the location of the lesion [39].

The facial muscles are considered to have bilateral cortical innervation [40]. There are controversial observations in old studies with TMS, where some authors recorded responses in the upper and lower facial muscles with TMS of the facial M1 area. The central delay is significantly longer for facial muscles compared with that of limb muscles or muscles innervated by other cranial nerves [41,42]. However, another study found no contralateral upper facial responses from stimulation of the facial M1 area but there were low amplitude responses from stimulation of the mesial frontal region, suggesting that the upper facial movements are controlled by the medial frontal cortex rather than by the M1 [43].

Transcranial cortical magnetic stimulation (TCMS) of the motor cortex can be used to evaluate corticospinal excitability and function [44,45], whereas the intracranial course of the facial nerve prevents more proximal stimulation by ES. With the introduction of TMS, it became possible to excite the intracranial segment of the facial nerve and its cortical motor representation area, and thus conduction measurements can be performed across the entire peripheral and central facial motor pathways [46].

The topographic presentation of the motor area to facial muscles was reported in the study by Rimpilainen *et al.* [47]. The cortical motor evoked potential (MEP) recording response was differentiated from the magnetic peripheral motor responses, as the later had shorter latencies, constant shape, and appeared only at high stimulation intensities as previously reported [12,30,35]. In addition, the intensity of TMS on the motor cortex to evoke cortical response was never strong enough to stimulate peripheral facial nerve [32,48].

Many studies [13,33,47,49–58] using TMS early in acute BP within the first week of onset from the presenting symptoms are illustrated in Table 1, which confirm the diagnosis of BP as a peripheral lesion of facial nerve and provide valuable information about prognosis for BP recovery either used alone as investigatory tool or combined with ENoG studies. Most of these studies reported that good prognosis with better and early recovery among patients with BP who were giving a positive response early within the first week of symptoms to TMS than those who were eliciting no response to TMS (Table 1).

Alternatively from another aspect, the evoked cortical (MEP) response of affected facial muscles by TCMS in BP is confirming that the lesion is peripheral and lower motor in nature and intact central pathway as observed by Rosler *et al.* [30,35]. Therefore, according to the aforementioned data, TMS to the facial nerve could be used to conduct impulses along the whole of its course following transsynaptic excitation of the motoneurons, although its proximal segment could not be excited directly by ES. The decreased magnetic excitability by canicular stimulation at labyrinthine segment had been proved to be one of the most sensitive indicators for inflammation or compression of the facial nerve in BP.

Similarly, investigation of patients with BP using TCMS technique (cortical stimulation of facial muscles) could provide a useful assessment tool in confirming the diagnosis and providing prognosis as previously reported by others [34,48]. However, Rosler *et al.* [30] concluded that patients with BP who evoked cortical MEP response by TMS early in the first week

Table 1 Transcranial magnetic stimulation studies in Bell's palsy

References	Study sample/ assessment time	Aim of the study	Study design	Findings and conclusion
Gao [49]	30 normal participants and 20 patients with facial nerve palsy owing to BP, RHS, or trauma[a]	Measure CMAPs response evoked by TMS and EMG instrument	Using magnetic stimulator and EMG instrument	The latencies on the affected sides were longer and the amplitudes much lower than those in normal ones. TMS can detect conduction block or early axonal degeneration of facial nerve intracranially, and can confirm the diagnosis and evaluate the prognosis
Gao [50]	30 normal participants, and 20 patients with unilateral facial nerve palsy owing to BP, RHS, or trauma[a]	To test TMS in unilateral facial palsy	Measurement of CMAPs from the orbicularis oris and frontal muscles	1. In normal participants, the recorded longer CMAPs latency by TMS than those obtained with ENoG. 2.Longer latencies and lower CMAPs amplitudes on the lesion sides in patients than in normal ones
Rimpilainen *et al.* [47]	51 patients with acute BP/the first 4 days, followed by TMS on 5-8 and 9-14 days	Investigate TMS technique to stimulate the intracranial part of the facial nerve	TMS was performed, and the responses were compared with those elicited by EES, and clinical recovery was evaluated at 258-539, mean 410 days from the onset	The patients with elicitable TMS MEPs during the first 4 days of the palsy had significantly better recovery than those without response and no significant difference in recovery between patients with or without elicitable TMS responses on 5-8 and 9-14 days
Yamakawa *et al.* [51]	10 normal controls and 2 patients with BP[a]	Investigate CMAPs and the Blink reflex, in response to TMS	CMAPs were elicited in the orbicularis oris muscle by TMS at the parieto-occipital skull and stylomastoid foramen	Recordable CMAP with TMS had longer latencies of CMAPs at the parieto-occipital skull than those at stylomastoid foramen in normal. Low amplitude with normal latency were elicited by TMS in patients with BP
Kotterba *et al.* [52]	33 patients with BP; of them 13 patients were followed up[a]	Investigate BP by magneto-electrical stimulation to evaluate the usefulness of TMS for prognostication	In each examination the facial nerve was electrically stimulated, and an orbicularis-oculi-reflex was elicited. Follow-up with investigations were done in 13 patients	In TMS, pathological long- and short-latency responses at the first examination were observed at the first examination in all patients, whereas in ES, pathological response was recorded in 35% of patients. The increase of amplitude and the decrease of latency of the long-latency response correlated with a complete recovery, whereas the decrease of amplitude and the increase of latency correlated with a partial recovery
Wolf and Schneider [53]	31 patients with BP were reviewed in 2-25 days after the onset of palsy at the time of first examination	Evaluate TMS in BP patients' prognosis in follow up of cases clinically	TMS was applied to the facial nerve by parieto-occipital, ipsilateral coil placement	11 of 31 nerves on the affected side were excitably by TMS and showed complete recovery of motor function within a median period of 7 weeks (only one experienced 'crocodile tears' syndrome). One year after in patients with unresponsive nerve function following TMS, 17 recovered without sequelae (median, 11 weeks), whereas 3 of 20 (15%) developed deficits of motor function (2 of them showed synkinesis)
Kohsyu [54]	15 normal participants and 108 patients with peripheral facial palsy/in the first 7 days	To obtain an early prognostic diagnosis of patients with peripheral facial palsy	Compared CMAPs of the orbicularis oris muscle elicited by TMS with CMAPs elicited by ES at stylomastoid foramen	Magnetically evoked CMAPs within the seven days after the onset of palsy were recovered almost 2 months after the onset of palsy, and with significant better recovery rates than patients with no recordable magnetically evoked CMAPs
Laranne *et al.* [55]	86 patients with BP/ first 5 days	To compare the ability of ES and TMS to predict clinical recovery in BP	Examination of the neuronographic findings of the facial nerve in ES and TMS for 1-6 times with time interval of 2-7 days for each patient with BP with median follow-up period of 13 months	Relative amplitude differences of ENoG and TMS during the acute phase were correlated with clinical outcome as; TMS response elicitable during the first 5 days of the palsy was correlated with a good prognosis. ENoG results correlated with clinical outcome at a later time from onset of symptoms
Rimpiläinen *et al.* [56]	137 patients with unilateral BP/0-4 days	Evaluate the prognostic capability of TMS	Compared the TMS results with ENoG	Early elicitable motor response with TMS predicts good prognosis

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References	Study sample/ assessment time	Aim of the study	Study design	Findings and conclusion
Nowak *et al*. [13]	65 patients with BP, 5 patients with Zoster oticus, one patient with neuroborreliosis, and one patient with multiple sclerosis/first 3 day	Investigate that is TMS sensitive and had potentially specific finding in BP diagnosis, differentiating it from other etiologies of facial palsy	Stimulation of the facial nerve was performed electrically at the stylomastoid foramen and magnetically at the labyrinthine segment	Absence or decreased amplitudes of muscle responses to early TMS was not specific for BP, but TMS seems capable of localizing the site of lesion within the Fallopian channel
Aoyagi [57]	116 patients with BP and 31 with RHS/in the first 3 days	Estimate the accuracy, sensitivity, and specificity of electrophysiology tests; the scoring system of facial movement (40-point method), NET, ENoG, TMS and SR	Calculation of sensitivity and specificity of these tests according to the findings	Good prognosis, if scoring system of facial movement>10, a positive response to TMS, and a positive response to SR
Happe and Bunten [58]	216 patients with the diagnosis of peripheral facial palsy (193 patients with BP)/first 3 days	Identification of a conduction failure at the level of the canalicular portion of the facial nerve by TMS	Assess the diagnostic relevance of the electrophysiological investigations, including the blink reflex, preauricular electrical stimulation, and the response to TMS at the labyrinthine part of the canalicular proportion of the facial nerve	Reduction or loss of the TMS amplitude of the affected side A conduction block in TMS supports the diagnosis of peripheral facial palsy without being specific for BP diagnosis
Hur *et al*. [33]	42 patients with BP and 14 patients with RHS/first 7 days	Examine the neurophysiologic status in patients with BP and RHS	Comparing the amplitude of CMAP of facial muscles in ENoG and TMS	The DR in TMS was significantly greater than DR in ENoG. The difference of DR between ENoG and TMS was significantly smaller in patients with RHS than in patients with BP

[a]No mentioned assessment time. CMAP, compound muscle action potential; DR, the denervation ratio; EES, extracranial electrical stimulation; EMG, electromyography; ENoG, electroneurography; ES, electrical stimulation; MEP, motor evoked potential; BP, Bell's palsy; NET, nerve excitability test; RHS, Ramsay Hunt syndrome; SR, stapedial reflex; TMS, transcranial magnetic stimulation.

were suspected to have better prognosis and recovery than who did not elicit MEP response with TMS of facial muscles.

In practice, Rimpilainen *et al*. [47] found that the degeneration process in facial nerve had an effect on MEPs amplitude to TMS, and it was progressively more difficult with time, and after the first 4 days became impossible, to predict clinical outcome and recovery from the BP with this method [47]. However, conduction time (CT) is a valuable parameter in the detection of conduction along the whole facial nerve pathway up to corticomotor areas of facial muscles, including measurement of peripheral and central motor CT by the prolongation or side difference of CT [59].

From another point of view, Glocker *et al*. [34] observed a relationship between cortical MEP amplitude of affected facial muscle and CMAP of amplitude of affected to unaffected muscle amplitude ratios of facial nerve in ENoG studies. When they performed stimulation of the facial nerve electrically, and magnetically in the labyrinthine segment, as well as the face-associated motor cortex magnetically stimulated in patients with facial palsy, they found a marked reduction of the amplitudes of MEP evoked by magnetically in the labyrinthine segment, which was more pronounced than the amplitude reduction to stimulation of the facial nerve electrically early during the disease at the first 4 days. These changes persisted for several months, although facial nerve function had recovered to normal. Inspite of having an inflammatory lesion and lower motor neuron in nature, these data suggest that the cortical areas of facial muscles had a role in BP recovery. This hypothesis was investigated recently in the study Lee *et al*. [60]. However, they considered that severity of BP in acute phase and duration for recovery might have an influence on the cortical reorganization based on findings of the study by Klingner *et al*. [61], using fMRI in follow-up of patients with BP for recovery.

Conclusion

In this review, we presented the reported data of different studies that have used TMS as a diagnostic tool for acute BP within the first week of presenting symptoms from the onset and providing valuable

information about prognosis of BP recovery. These reported data are promising to conduct future studies that should address many questions, including (i) the optimum timing of TMS assessment in acute BP and follow-up and (ii) comparison between magnetic excitability parameters evoked at labyrinthine segment and cortical segment at faciomotor cortex of facial nerve and its prognostic value.

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Conflicts of interest
There are no conflicts of interest.

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