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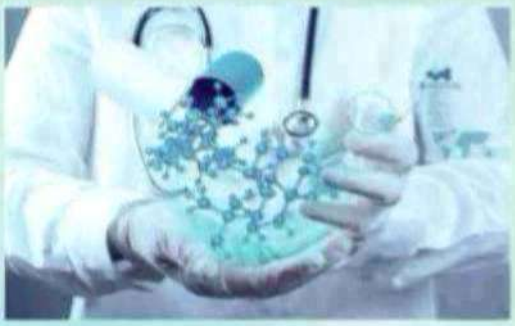

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NEW DAY IN MEDICINE

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TOWARD A PERSONALIZED RTMS ALGORITHM FOR FACIAL NERVE NEUROPATHY: INTEGRATION OF CLINICAL SCORES, IMMUNE MARKERS AND ENMG

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✓ ***Resume***

Objective: To develop and expand a personalized rehabilitation algorithm for facial nerve neuropathy by integrating clinical scales, immune-inflammatory biomarkers and electroneuromyographic (ENMG) markers. Methods: A comparative dataset of 103 patients treated with 1 Hz rTMS, 10 Hz rTMS or conventional therapy was synthesized into clinically usable decision points. Results: The 10 Hz protocol demonstrated the most consistent superiority across the clinical, immune and ENMG domains: House–Brackmann improvement 86.5%, Sunnybrook gain approximately 100%, more pronounced Yanagihara recovery, IL-6 reduction by 33–35%, CRP reduction by about 30% and M-response amplitude increase by 53%. The 1 Hz protocol also outperformed conventional therapy and appeared more relevant when excessive activity, hypertonus or synkinesis risk dominated. Conclusion: A personalized algorithm can reduce empiricism, support more rational rTMS selection and improve the targeting of neurorehabilitation.

Keywords: personalized rehabilitation, rTMS algorithm, facial nerve neuropathy, IL-6, CRP, ENMG, neurorehabilitation, Bell's palsy.

К РАЗРАБОТКЕ ПЕРСОНАЛИЗИРОВАННОГО АЛГОРИТМА рТМС ПРИ НЕВРОПАТИИ ЛИЦЕВОГО НЕРВА: ИНТЕГРАЦИЯ КЛИНИЧЕСКИХ ШКАЛ, ИММУННЫХ МАРКЕРОВ И ЭНМГ

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✓ ***Резюме***

Цель исследования: разработать и расширить персонализированный алгоритм реабилитации при невропатии лицевого нерва на основе интеграции клинических шкал, иммуновоспалительных биомаркеров и электронейромиографических показателей. Материалы и методы: сравнительный массив данных, включающий 103 пациента, получавших рТМС с частотой 1 Гц, рТМС с частотой 10 Гц либо традиционную терапию, был систематизирован и преобразован в клинически применимые критерии принятия решений.

Результаты: протокол рТМС с частотой 10 Гц продемонстрировал наиболее устойчивое преимущество по клиническим, иммунологическим и ЭНМГ-показателям: улучшение по шкале House–Bracktmann составило 86,5%, прирост показателя Sunnybrook — приблизительно 100%, восстановление по шкале Yanagihara было более выраженным, уровень IL-6 снизился на 33–35%, СРО примерно на 30%, а амплитуда М-ответа увеличилась на 53%. Протокол 1 Гц также превосходил традиционную терапию и представлялся более целесообразным в случаях преобладания избыточной активности, гипертонуса или риска синкинезий. Заключение: персонализированный алгоритм позволяет снизить эмпирический характер выбора терапии, обосновать более рациональное применение рТМС и повысить адресность нейрореабилитационных мероприятий.

Ключевые слова: персонализированная реабилитация, алгоритм рТМС, невропатия лицевого нерва, IL-6, CRP, ЭНМГ, нейрореабилитация, паралич Белла.

ЮЗ НЕРВИ НЕВРОПАТИЯСИДА ИНДИВИДУАЛЛАШТИРИЛГАН rTMS АЛГОРИТМИНИ ИШЛАБ ЧИҚИШ: КЛИНИК ШКАЛАЛАР, ИММУН МАРКЕРЛАР ВА ЭНМГ ИНТЕГРАЦИЯСИ

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✓ ***Резюме***

Тадқиқот мақсади: юз нерви невропатиясида клиник шкалалар, иммун-яллиғланиш биомаркерлари ва электронейромиографик кўрсаткичларни интеграция қилиш асосида индивидуаллаштирилган реабилитация алгоритмини ишлаб чиқиш ва кенгайтиришдан иборат. Материал ва усуллар: 1 Гц rTMS, 10 Гц rTMS ёки анъанавий терапия олган 103 нафар беморга оид қиёсий маълумотлар таҳлил қилиниб, клиник амалиётда қўллаш мумкин бўлган қарор қабул қилиш мезонлари шакллантирилди. Натижалар: 10 Гц rTMS протоколи клиник, иммунологик ва ЭНМГ кўрсаткичлар бўйича энг барқарор устунликни намоён қилди: House–Brackmann шкаласи бўйича яхшиланиш 86,5% ни, Sunnybrook кўрсаткичининг ўсиши тахминан 100% ни ташкил этди, Yanagihara шкаласи бўйича тикланиш янада яққол бўлди, IL-6 даражаси 33–35% га, CRP тахминан 30% га пасайди, M-жавоб амплитудаси эса 53% га ошди. 1 Гц протоколи ҳам анъанавий терапияга нисбатан устун натижа берди ва айниқса ортиқча фаоллик, гипертонус ёки синкинезия хавфи устун бўлган ҳолатларда мақсадга мувофиқроқ деб баҳоланди. Хулоса: индивидуаллаштирилган алгоритм даволаш усулини эмпирик танлашни камайтиради, rTMS протоколини оқилона асослашга ёрдам беради ва нейрореабилитация тадбирларининг мақсадлилигини оширади.

Калит сўзлар: индивидуаллаштирилган реабилитация, rTMS алгоритми, юз нерви невропатияси, IL-6, CRP, ЭНМГ, нейрореабилитация, Белл фалажи.

Relevance

Facial nerve neuropathy is a clinically heterogeneous disorder that includes Bell's palsy and other peripheral lesions of the seventh cranial nerve. Patients with apparently similar visible facial weakness may differ substantially in the underlying pathophysiology: some present with an inflammation-dominant phenotype, others with more pronounced axonal impairment, and some with a greater risk of maladaptive reinnervation, synkinesis or persistent hypertonus. For this reason, using a single rehabilitation strategy for all patients is rarely optimal [1,2]. Repetitive transcranial magnetic stimulation (rTMS) has emerged as a promising non-invasive neuromodulatory intervention capable of influencing cortical excitability, neuroplastic reorganization and functional recovery. In general physiological terms, higher frequencies are associated with facilitation of cortical excitability, whereas lower frequencies may modulate excessive activity and improve motor control. Contemporary literature supports the therapeutic promise of rTMS in facial palsy; however, there is still insufficient standardization regarding which patient profile should preferentially receive 10 Hz stimulation, which should receive 1 Hz stimulation and which may be managed with conventional monitoring alone [3,4]. The dissertation dataset underlying this article provides an opportunity to convert comparative therapeutic results into a practical, decision-oriented model. Instead of treating rTMS as a fixed package, the present work frames it as a flexible rehabilitation platform guided by three domains: (1) the clinical severity and dynamics of facial dysfunction, (2) the immune-inflammatory profile, and (3) ENMG indicators of conduction and reinnervation.

The aim of the article is therefore to expand the original concept into a more detailed personalized algorithm that can be used in clinical neurorehabilitation.

Materials and methods

The proposed algorithm was derived from a comparative clinical dataset of 103 patients with facial nerve neuropathy. Patients were distributed into three treatment arms: conventional therapy plus 1 Hz rTMS (n=35), conventional therapy plus 10 Hz rTMS (n=37), and conventional therapy alone (n=31). The original therapeutic analysis included repeated assessment of clinical scales, immune markers and ENMG indices before and after treatment.

The algorithm-building framework intentionally grouped the variables into three domains. The clinical domain included the House–Brackmann Facial Grading System (HBGS) for global severity, the Sunnybrook Facial Grading System for integrated functional assessment and the Yanagihara score for finer gradation of facial movement deficits. The immune domain included IL-6 and C-reactive protein (CRP) as markers of inflammatory activity and IL-10 as an indicator of compensatory anti-inflammatory regulation. The ENMG domain included distal latency, M-response amplitude and additional motor unit potential indices, which together characterize impulse conduction, axonal integrity and ongoing reinnervation.

For the present synthesis, the comparative findings were translated into decision points rather than reanalyzed as a new inferential study. Priority rules were formed by identifying patterns in which one protocol demonstrated consistent advantage across domains. The practical logic was as follows: if the patient demonstrates more severe motor deficit and has biological and ENMG indicators of active impairment but still retains recovery potential, high-frequency 10 Hz stimulation is prioritized. If recovery is already underway but there is concern for excessive activity, co-contraction or synkinesis, the 1 Hz option becomes more relevant. Mild stable cases with favorable ENMG and limited inflammatory burden may remain under conventional monitoring.

Table 1.

Core elements of the personalized assessment framework

Domain	Variables used	Clinical meaning
Clinical	HBGS, Sunnybrook, Yanagihara	Severity, functional recovery, fine movement deficit
Immune-inflammatory	IL-6, IL-10, CRP	Inflammatory activity and compensatory regulation
ENMG	Distal latency, M-response amplitude, motor unit potential indices	Conduction delay, axonal function, reinnervation potential
Therapeutic output	10 Hz rTMS / 1 Hz rTMS / conventional monitoring	Personalized rehabilitation branch

Result and discussions

The comparative dataset showed a coherent superiority pattern for the 10 Hz protocol. In the clinical domain, House–Brackmann improvement reached 86.5%, Sunnybrook gain was approximately 100%, and Yanagihara recovery was about twofold better than the control trajectory. In the immune domain, IL-6 decreased by 33–35% and CRP by about 30%, while IL-10 increased more favorably than in the other groups. In the ENMG domain, M-response amplitude increased by 53%, and distal latency shortened more distinctly than in both the 1 Hz and conventional therapy arms.

The 1 Hz protocol also performed better than conventional therapy. It was associated with House–Brackmann improvement of 74.3%, Sunnybrook gain of about 70%, IL-6 reduction of approximately 25–30% and M-response amplitude increase of 42%. These data suggest that the 1 Hz branch should not be interpreted as inferior in all contexts; rather, it seems to occupy a different therapeutic niche, especially when the clinician’s concern shifts from accelerating strength recovery to refining motor control and minimizing maladaptive activity patterns.

Conventional treatment alone showed smaller shifts across nearly all domains. House–Brackmann improvement was approximately 45.2%, Sunnybrook gain 40–50%, IL-6 reduction around 8%, CRP reduction around 8% and M-response amplitude increase around 20%. Although conventional therapy clearly retains a role—especially in milder or already improving cases—its effects were less pronounced when compared with rTMS-assisted rehabilitation.

Table 2.

Comparative efficacy profile synthesized from the dissertation dataset

Outcome / domain	Conventional therapy	1 Hz rTMS	10 Hz rTMS
House–Brackmann improvement	45.2%	74.3%	86.5%
Sunnybrook gain	40–50%	≈70%	≈100%
Yanagihara recovery	about 31%	about 60%	about 95% / about twofold better than control
IL-6 reduction	≈8%	25–30%	33–35%
CRP reduction	≈8%	≈22%	≈29–30%
M-response amplitude increase	≈20%	42%	53%
Practical implication	Monitoring / mild cases	Control modulation branch	Acceleration branch

Figure 1 demonstrates the changes in immune-inflammatory markers after treatment in three therapeutic groups: 1 Hz rTMS, 10 Hz rTMS, and conventional therapy. The most pronounced positive dynamics were observed in the 10 Hz rTMS group, where IL-6 and CRP levels decreased markedly, while IL-10 increased. This indicates a reduction in pro-inflammatory activity and activation of anti-inflammatory regulation.

In the 1 Hz rTMS group, favorable changes were also observed, but they were less pronounced than in the 10 Hz group. Conventional therapy showed the weakest immune-inflammatory response, with only minimal reduction of IL-6 and CRP. These findings suggest that high-frequency 10 Hz rTMS may have not only a neuromodulatory effect, but also an additional anti-inflammatory influence in patients with facial nerve neuropathy.

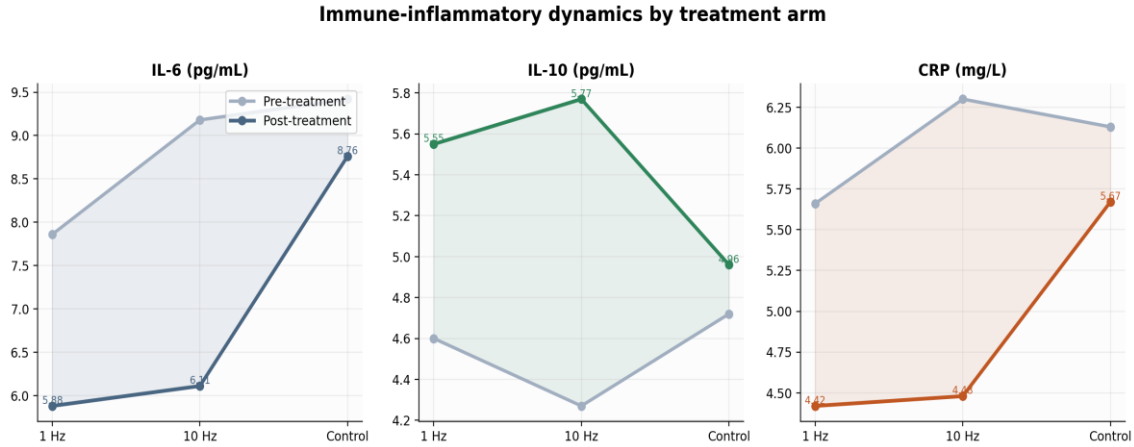

Figure 1. Immune-inflammatory dynamics by treatment arm

Figure 2 shows the dynamics of two key electroneuromyographic recovery markers: distal latency and M-response amplitude. Distal latency decreased after treatment in all groups, which reflects improvement in nerve impulse conduction. The greatest reduction was observed in the 10 Hz rTMS group, indicating a more pronounced restoration of facial nerve conductivity.

M-response amplitude increased after treatment in all groups, demonstrating improved motor unit activation and better neuromuscular transmission. The most marked increase was again observed in the 10 Hz rTMS group, followed by the 1 Hz rTMS group, while the conventional therapy group showed the weakest improvement.

Overall, the figure confirms that rTMS-assisted rehabilitation, especially the 10 Hz protocol, produced stronger ENMG recovery than conventional therapy alone. This supports the use of high-

frequency rTMS as an effective neuromodulatory approach for accelerating functional recovery in facial nerve neuropathy.

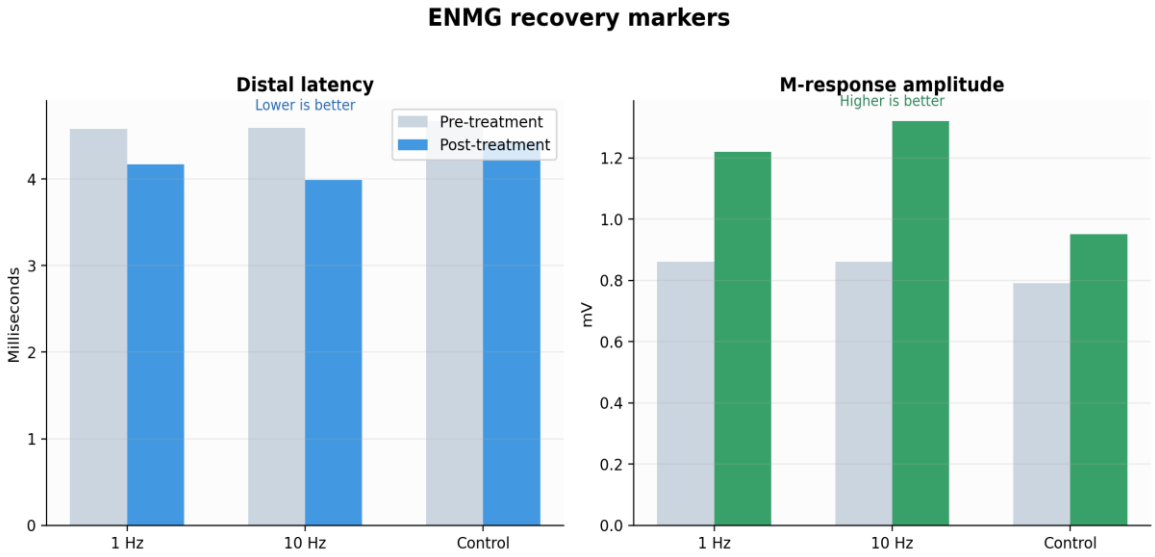

Figure 2. ENMG recovery markers by treatment arm

Discussion: The principal contribution of this article is conceptual rather than merely descriptive. It reframes rTMS selection from a protocol-centered model to a phenotype-oriented model. In the proposed framework, 10 Hz stimulation is not simply “the best” treatment in universal terms; instead, it is the most appropriate branch for patients whose profile suggests a combination of significant motor deficit, active inflammatory-conduction impairment and preserved capacity for neuromodulation-assisted acceleration. This phenotype is represented by low Sunnybrook and Yanagihara scores, elevated IL-6 or CRP, reduced M-response amplitude and prolonged distal latency.

The 1 Hz protocol occupies a more selective but clinically meaningful role. The comparative dataset showed that it still produced strong clinical and biological effects, clearly outperforming conventional therapy. Yet its most logical use may be in patients who are not primarily limited by lack of recovery, but rather by the risk of excessive activity, hypertonus, co-contraction or early synkinesis. In other words, if 10 Hz is the acceleration branch, 1 Hz may be considered the modulation-and-control branch.

Conventional therapy alone remains acceptable for milder presentations, especially when the patient shows stable spontaneous improvement and objective testing is favorable. However, the present synthesis argues against passive persistence with the same strategy in all circumstances. Because immune markers and ENMG findings can change during follow-up, the algorithm should be dynamic. A patient initially observed in the conventional branch may later require 10 Hz stimulation if inflammatory or conduction abnormalities remain active; conversely, a patient first treated with 10 Hz may later transition to a 1 Hz branch if synkinetic patterns emerge.

From a practical standpoint, the integration of these domains can reduce empiricism in daily clinical work. It encourages the clinician to move beyond visual grading alone and to use biomarker-informed and ENMG-informed reasoning. This is particularly valuable in a condition where the visible phenotype may lag behind or underrepresent the biological state of nerve recovery. The approach also aligns with broader neurorehabilitation trends toward personalization and multimodal monitoring.

Several limitations should be acknowledged. The algorithm is based on synthesis of one dissertation dataset rather than on a separate prospective validation cohort. Some effect estimates are approximate because the decision framework prioritizes clinical usability over excessive statistical granularity. Therefore, the current algorithm should be interpreted as a structured translational model requiring future validation in prospective, multicenter and ideally randomized settings.

Conclusion

1. A personalized algorithm based on clinical scales, immune markers and ENMG can make rTMS selection in facial nerve neuropathy more rational and transparent.

2. The 10 Hz protocol is best suited for patients requiring rapid motor recovery and demonstrating an inflammatory-conduction impairment phenotype.

3. The 1 Hz protocol may be especially useful when hypertonus, co-contraction or synkinesis risk becomes clinically dominant.

4. Conventional therapy alone remains a reasonable option for mild, stable cases, but dynamic reassessment is essential because patients may shift between branches over time.

5. The proposed model should be regarded as a clinically grounded translational framework and as a basis for future prospective validation.

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