Splint efficacy in chronic post-stroke spasticity: a pilot study

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Abstract

Introduction. Hand spasticity after stroke is a serious issue and may lead to hygiene problems, range of motion limitations, or contractures. Hand splints are often used to reduce spasticity and prevent movement limitations; however, there is little research available on the efficacy of splints in spasticity. The study aimed to investigate the efficacy of a reflex inhibitory splint (RIS) for upper extremity spasticity in stroke patients by using clinical and electrophysiological studies.
Methods. Stroke patients with elbow and hand spasticity were allocated into 2 groups. The splint group ($n = 16$) wore RIS. The control group ($n = 13$) did not wear any upper extremity splint. Both groups received the same rehabilitation program during this period. They were evaluated for motion in the upper extremity with the Brunnstrom scale and Fugl-Meyer upper extremity scale. Electrophysiological measurements showing motor neuron excitability such as the ratio between the maximum amplitude of H-reflex and the maximum amplitude of M-response (H_{max}/M_{max} ratio), H-reflex latency, and F-wave persistence and latency were also studied. All clinical and electrophysiological measurements were performed in both groups on days 0 and 15.
Results. At the end of the treatment, elbow and finger flexion tonus decreased and active wrist extension angle increased in the splint treatment group compared with both baseline and the control group. Compared with the pre-treatment status, a correlation was detected between the H_{max}/M_{max} ratio and the wrist flexion tonus in the splint group.
Conclusions. RIS may be useful for the management of post-stroke upper-limb spasticity.
Key words: reflex inhibitory splint, spasticity, Ashworth scale, H-reflex

Introduction

Spasticity accounts for functional impairment in 17–41% of patients with stroke [1]. It is characterized by an increased velocity-dependent resistance to passive stretch. In hemiplegia, spasticity is severe in patients with more motor weakness who developed hemihypoesthesia and with a history of stroke [2–4]. The aim of spasticity treatment programs is to reduce or normalize the muscle tone to prevent secondary complications. If spasticity is not treated, shortening, fibrosis, calcification, and contracture develop in the muscles [5]. Treatment options include stretching, splinting, strengthening the agonist muscle, oral medications, or local injections (phenol or botulinum toxin) [6]. As the muscles remain in a long position because of splinting or stretching, motor neuron excitability may decrease and the biomechanical properties of the muscle fascicles may change [7]. Decreased spasticity may lead to increased motor function, decreased pain, and improved patient and caregiver quality of life [5, 8].

Hand spasticity can be a major complication that increases disability after stroke. It may cause muscle shortening and contractures, pain from muscle spasms, oedema, poor hygiene, loss of function, and depression [9]. Hand-wrist splints are commonly used to prevent these complications. Splints provide a biomechanical effect by stretching the muscle and connective tissue. It also reduces the reflex stretch of the muscles and reduces spasticity with neurophysiological effects [10]. Although the reflex inhibitory splint (RIS) is one of these splints, the few studies in the literature have provided contradicting results on the efficiency of RIS for spasticity. These heterogeneous studies are small in number, with a short follow-up (2–8 weeks) [11, 12]. In a review, Steultjens et al. [13] concluded that splint usage reduced spasticity. However, Lannin and Ada [14] reported that splint usage at night neither reduced spasticity nor prevented contractures. The aim of this study was to investigate the effectiveness of a RIS for upper extremity spasticity in stroke patients with clinical and electrophysiological studies.

Subjects and methods

Adult spastic hemiplegic patients with upper extremity involvement and who had a stroke for the first time were evaluated for inclusion in the study. Inclusion criteria were age > 18 years, stroke duration > 1 month, spasticity in wrist or finger flexors with Ashworth scale score ≥ 2, and being treatment-naive for spasticity (botulinum toxin injection, previous splinting, or anti-spasticity medications). Excluded were patients whose H-reflex could not be demonstrated by electrophysiological studies, as well as those with polyneuropathy or radiculopathy of the upper extremity, upper motor neuron lesion to the non-hemiplegic upper extremity, complex regional pain syndrome or upper extremity contractures, or severe cognitive problems. Patients were alternatively allocated to the splint or control group one by one.

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Demographic and clinical characteristics of the patients, findings on neurologic examination of upper extremities, and range of motion of the affected upper extremities were recorded. Clinical and instrumental outcome measures were obtained at baseline and on the 15th day. The patients were evaluated with the Ashworth spasticity scale, Brunnstrom scale, Fugl-Meyer upper extremity motor function scale, and electrophysiological studies. Electrophysiological studies included H-reflex and F-wave studies in both upper extremities.

The electrophysiological assessment occurred when the patient was lying in a supine position in a warm, quiet room and performed by using Medtronic Keypoint 4-channel electromyography. Bilateral median and ulnar motor and sensory conduction studies and unilateral tibial and peroneal motor and sural sensory conduction studies were carried out to rule out polyneuropathy.

H-reflex and F-wave response were measured to evaluate motor neuron excitability. The H-reflex of the patients was recorded from the flexor carpi radialis (FCR) muscle. Active surface electrodes were placed over the FCR muscle belly. A stimulator was placed at the antecubital fossa to stimulate the median nerve. The maximum amplitude of H-reflex, H-reflex latency, and compound muscle action potential of the FCR were recorded [10]. The H_{max}/M_{max} ratio was calculated for both sides. The F-wave responses were measured from the abductor pollicis brevis muscle. Persistence of the F-wave response was calculated by using 20 consecutive stimulations and included in the statistics as percentages. Minimum values of F-wave latency (ms) were recorded.

The study and control groups received a standard conventional rehabilitation program (range of motion exercises, stretching exercises, posture exercises, and neurophysiological exercises – Brunnstrom approach) 2 hours a day, 5 days a week, for 2 weeks. The splint group wore the RIS 8 hours a day, except while sleeping, for 15 days. The control group did not wear any upper extremity splint. The patients treated with a RIS were asked about pain or discomfort to determine tolerability, evaluated with visual analogue scale.

The RIS devices were made of thermoplastic material. They were placed on the palmar surface of the hand and auto-adhesive straps were located on the hand, wrist, and forearm dorsal face. The patient's joint positioning was as follows: wrist in 15° extension, metacarpal joints proximal, distal interphalangeal joints in neutral position, and the fingers in abduction position (Figure 1).

Figure 1. Reflex inhibitory splint

Statistical analysis

Statistical analyses were performed with the MedCalc program, version 11.5.0. Descriptive statistics were shown as mean ± standard deviation for continuous variables, and nominal variables were presented as the number of cases and percentages. Inter- and intra-group comparisons were performed by using Student's *t*-test, chi-square test, Mann-Whitney *U* test, and Wilcoxon test where appropriate. Spearman's method was applied to calculate the correlation rho. The value of $p < 0.05$ was accepted as significant for the results.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ankara Physical Medicine and Rehabilitation Training and Research Hospital ethical committee (approval number: 09-3852).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Overall, 39 patients were involved in the study, but 4 were removed for not being treatment-naive. The remaining 35 patients were allocated either to the splint ($n = 18$) or to the control group ($n = 17$). After electromyographic evaluation, 6 participants were excluded from the study for having additional neurologic deficits ($n = 4$) or for not having a demonstrable H-reflex ($n = 2$). The remaining 29 patients (16 in the splint group and 13 in the control group) continued the study.

The demographic and clinical data of the study population are shown in Table 1. Both groups were similar in age, gender distribution, side of hemiplegia, and duration and aetiology of stroke. At baseline, there was no statistically significant difference in the scores for upper extremity Brunnstrom scale, hand Brunnstrom scale, elbow, wrist, or finger flexor Ashworth scale, Fugl-Meyer upper extremity motor function scale, H-reflex amplitude, H-reflex latency, M amplitude, H_{max}/M_{max} ratio, F-wave latency, or F-wave persistence (%) between the groups ($p > 0.05$).

In the splint treatment group, the 15th day elbow and finger flexion tonus were decreased (Table 2). There was no significant difference in spasticity in the control group (Table 3). H-reflex amplitude, H_{max}/M_{max} ratio, H-reflex latency, F-wave

Table 1. The demographic and clinical data of the patients

Parameters	Splint group	Control group	p
n	16	13	–
Age (years)	54.2 ± 8.7	61.4 ± 11.5	0.3[a]
Gender (*n*; male/female)	9/7	7/6	0.8[b]
Aetiology (*n*; haemorrhagic/ thromboembolic)	6/10	4/9	0.6[b]
Lateralization (*n*; right/left)	9/7	3/10	0.1[b]
Dominant hand (*n*; right/left)	14/2	12/1	0.8[b]
Duration of stroke (months)	18.2 ± 26.9	12.3 ± 11.4	0.4[a]

[a] *t*-test, [b] chi-square test

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Table 2. Upper extremity tonus, clinical and electrophysiological evaluation in splint group

Parameters	Day 0[a]	Day 15[a]	p[b]
Elbow flexion tonus*	1.8 ± 0.7	1.1 ± 0.6	0.004
Elbow extension tonus*	0.7 ± 0.9	0.5 ± 0.9	> 0.05
Wrist flexion tonus*	1.3 ± 0.5	1 ± 0.5	> 0.05
Wrist extension tonus*	0.1 ± 0.3	0.1 ± 0.2	> 0.05
Finger flexion tonus*	1.6 ± 0.9	1.1 ± 0.9	0.01
Fugl-Meyer scale**	10 ± 9.5	13.3 ± 11.7	> 0.05
H_{max}/M_{max}	0.8 ± 1.3	0.4 ± 0.2	0.9
H-reflex latency (ms)	16.8 ± 1.5	16.5 ± 1.3	0.6

[a] mean ± standard deviation, [b] Wilcoxon test, * Ashworth scale,
** Fugl-Meyer upper extremity motor function scale

Table 3. Upper extremity tonus in control group

Parameters	Day 0[a]	Day 15[a]	p[b]
Elbow flexion tonus*	1.7 ± 1.0	2.0 ± 1.0	> 0.05
Elbow extension tonus*	0.4 ± 0.7	0.4 ± 0.7	> 0.05
Wrist flexion tonus*	1.2 ± 0.6	1.4 ± 0.9	> 0.05
Wrist extension tonus*	0.1 ± 0.4	0.1 ± 0.3	> 0.05
Finger flexion tonus*	2.2 ± 1.0	2.2 ± 1.1	> 0.05

[a] mean ± standard deviation, [b] Wilcoxon test, * Ashworth scale

Table 4. Magnitude of differences in comparisons of clinical data of both groups between baseline and day 15

Parameters	Splint[a]	Control[a]	p[b]
Fugl-Meyer upper extremity motor function scale	1.8 ± 3.8	0.2 ± 0.6	0.4
Wrist flexion (PROM degree)	4.6 ± 22.1	1.1 ± 14.7	0.1
Wrist flexion (AROM degree)	1.2 ± 6.2	0.7 ± 2.8	0.9
Wrist extension (PROM degree)	1.2 ± 12.7	0.9 ± 8.2	0.1
Wrist extension (AROM degree)	6.9 ± 16.2	−0.4 ± 1.4	0.04

PROM – passive range of motion, AROM – active range of motion
[a] mean ± standard deviation, [b] Mann-Whitney *U* test

latency, and F-wave persistence of the groups were similar between baseline and the 15th day. The active wrist extension was significantly higher in the splint treatment group on the 15th day (Table 4). In the splint treatment group, on the 15th day, wrist flexion tonus decreased in 5/16 patients and none had increased tonus, whereas in the control group it increased in 6/13 patients and none had improvement.

All of the patients in the splint group were able to tolerate RIS. The mean visual analogue scale score of patients wearing splints equalled 2.74 ± 1.8. No participant complained of pain associated with splinting.

Discussion

This study investigated the impact of RIS on upper extremity spasticity in hemiplegic patients with clinical and electrophysiological assessments. In addition to the conventional rehabilitation program provided to both groups, the patients in the splint group were also administered a RIS. Relative to the pre-treatment status, the splint group exhibited

a reduction in the tonus of the elbow and finger flexors and a difference in active wrist extension angle after treatment. No significant difference was detected in the electrophysiological parameters.

Spasticity and contracture are actually intertwined conditions. Two mechanisms have been proposed to explain the effect of contracture on spasticity development. In the first mechanism, if a muscle is shortened, the joint angle changes, so the muscle fibres are stretched more than normally and the reflex response increases. The other mechanism involves more tension reflexes than the muscle in the short state. Thus, a spasticity-contracture-spasticity cycle develops. One of the methods used to prevent this mechanism is splints [15].

RIS is suggested to reduce spasticity by stretching the wrist dorsiflexors and finger extensors [16]. Some authors believe that dorsal splints are more effective in reducing spasticity because palmar splints are thought to increase spasticity by stimulating the flexor muscles. However, there is no evidence to support this idea. Even when a dorsal splint is used, tapes will still be in the palmar region [10]. Although with RIS, changing clothing was a little more difficult than with the other hand splints in our study, the patient compliance with the splint was good.

Pizzi et al. [11] followed spastic hemiplegic patients who wore a RIS for 3 months. They found increased wrist range of motion, reduced tonus of elbow flexion, and reduced FCR H_{max}/M_{max} ratio. In this study, the splint group exhibited a reduction in the tonus of the wrist and finger flexors, an increase in upper extremity Functional Independence Measure values, and differences in active wrist extension angle after treatment. Similar to our results, Basaran et al. [10] reported that H-reflex latency and H_{max}/M_{max} ratio were not statistically significantly different after 5 weeks of splint usage in hemiplegic patients.

In the evaluation of spasticity, there are clinical methods, as well as biomechanical and electrophysiological methods. Recently, elastography and myotonometry methods have been used. Although H-reflex is the most commonly applied method, there is no correlation with spasticity in most studies [17, 18]. We used electrophysiological measurements for objective and sensitive assessment. In the literature, there are many studies on H-reflex in lower extremities, but studies in the upper extremities are limited. Phadke et al. [19] found that FCR H-reflex could be a reliable and sensitive indicator in hemiplegia for both paretic and non-paretic hands. In our study, we detected a statistically significantly higher H_{max}/M_{max} ratio on the spastic side compared with the non-hemiplegic side. The difference persisted after the treatment period. Although mechanical and electrophysiological measurements are attractive and parametrical, they are generally not correlated with clinical changes (as in our study). Even though these clinical scales are inadequate, they still remain the most used assessment methods.

In the splint group, we detected a significantly higher increase in the active wrist extension angle on day 15. This was attributed to the extension in the muscle due to positioning or a reduction in the flexor spasticity. The absence of an increase in the other joints range of motion could result from the short follow-up time. Relative to the pre-treatment status, the splint group exhibited a reduction in the tonus of the wrist, elbow, and finger flexors. A statistically significant improvement was observed in the splint group in the elbow flexion tonus, wrist flexion tonus, and finger flexion tonus.

Two studies implied a reduction in elbow flexion tonus [11, 20]. Like us, Pizzi et al. [11] hypothesized that biceps brachii hyperactivity was inhibited by wrist flexors group II

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afferents from the stretched FCR or/and other wrist flexors. Regarding the wrist flexion tonus, 5 of the 16 patients in the splint group showed a reduction, whereas 6 of the 13 patients in the control group had an increased tonus; however, the difference was not statistically significant. This may be due to the short follow-up. In the study by Pizzi et al. [11], one patient could not tolerate the RIS, whereas all participants in our study tolerated the splint.

Limitations

Our study limitations are the short post-treatment assessment period, non-randomized design, and the small number of patients. In addition, we did not evaluate the sensation or hemi-neglect in the participants. We assessed the patients after 2 weeks of treatment. In the literature, similar studies present treatment and follow-up periods of 2–12 weeks [11, 21].

Conclusions

RIS appears to be effective in reducing spasticity. Longer follow-up studies are needed to evaluate the long-term effect.

Disclosure statement
No author has any financial interest or received any financial benefit from this research.

Conflict of interest
The authors state no conflict of interest.

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