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Brief Report

Comparison of the effectiveness of pulsed radiofrequency of the suprascapular nerve and intra-articular corticosteroid injection for hemiplegic shoulder pain management

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Many patients complain of hemiplegic shoulder pain following stroke. Here, the effectiveness of pulsed radiofrequency stimulation of the suprascapular nerve is compared with intra-articular corticosteroid injection for chronic hemiplegic shoulder pain following stroke. This single-center, prospective, randomized controlled study included 20 patients with hemiplegic shoulder pain after stroke, randomly assigned to the pulsed radiofrequency and intra-articular corticosteroid injection treatment groups ($n = 10$ in each). Hemiplegic shoulder pain severity was measured by numeric rating scale and passive shoulder range motion was assessed at baseline and one and two months after each procedure. Compared to the baseline numeric rating scale scores, post-treatment scores decreased significantly in both groups ($p < 0.001$). However, score reduction through time was significantly greater for intra-articular corticosteroid injection for pulsed radiofrequency ($p < 0.001$). Similarly, a significant post-treatment increase was observed in almost all range of motion measurements in both groups (pulsed radiofrequency group: flexion, $p = 0.015$; abduction, $p = 0.014$; external rotation, $p = 0.038$; internal rotation, $p = 0.063$; intra-articular corticosteroid injection group: all range of motion, $p < 0.001$). Moreover, the measurements for all ranges of motion in the intra-articular corticosteroid injection group were significantly higher than those in the pulsed radiofrequency group ($p < 0.001$). Thus, intra-articular corticosteroid injection appears more effective than pulsed radiofrequency for control of hemiplegic shoulder pain, whereas, pulsed radiofrequency of the suprascapular nerve has minimal effect. However, in patients at risk for developing complications following corticosteroid injections, pulsed radiofrequency of the suprascapular nerve may be an option in management of hemiplegic shoulder pain.

Keywords

Pulsed radiofrequency; Corticosteroid; Hemiplegic shoulder pain; Stroke; Peripheral neurons; Neurology

1. Introduction

Following stroke many patients experience different types of pain syndrome [1, 2]. Among these, hemiplegic shoulder pain (HSP) is one of the most frequent [3, 4]. Although their etiology is unclear, adhesive capsulitis, subacromial bursitis, shoulder subluxation and spasticity are known to be associated with the development of HSP [5]. HSP resolves in most cases within six months, but approximately 20% of patients experience debilitating and persistent shoulder pain [6]. Persistent HSP may hinder functional recovery after stroke, decrease quality of life and lead to emotional problems, such as depression and anxiety [5].

Generally, clinicians employ range of motion (ROM) exercises, oral medications and other modalities of therapy to control HSP [7]. However, despite this, HSP persists in many patients. For the treatment of persistent HSP, unresponsive to conventional modes of therapy, intra-articular corticosteroid injection (ICI) into the shoulder joint is widely used, but its palliative effect has only a relatively short duration [8]. Furthermore, corticosteroids may have adverse effects, including allergic reactions, flushing, hyperglycemia, menstrual disturbances and adrenal suppression [9, 10]. Suprascapular nerve block (SSNB) is another option for relieving HSP [11, 12]. The suprascapular nerve (SSN) originates from the ventral rami of the C4, C5 and C6 spinal nerves and emerges from the upper trunk of the brachial plexus. It provides 70% of the sensory innervation of the shoulder joint [13]. Thus, blockage of pain transmission through the SSN provides effective control of HSP. However, the efficacy of SSNB varies with the study population and depends on the therapeutic modality with which it is compared [14]. Moreover, the effect of SSNB may also be limited due to the short duration of action of local anesthetic agents.

Pulsed radiofrequency (PRF) was introduced by Sluijter in 1997 [15]. Many previous studies have reported its safety and effectiveness in alleviating pain. In this procedure, an electrical field is generated around the targeted nerves or tissues, but these structures are not damaged by this stimulation. Conventional radiofrequency provides continuous electrical simulation to the targeted nerves or tissues and ablates these structures due to the high temperatures around the radiofrequency needle tip [16–19]. However, PRF only provides electrical stimulation for brief durations between prolonged resting phases. Therefore, it does not produce heat sufficient to

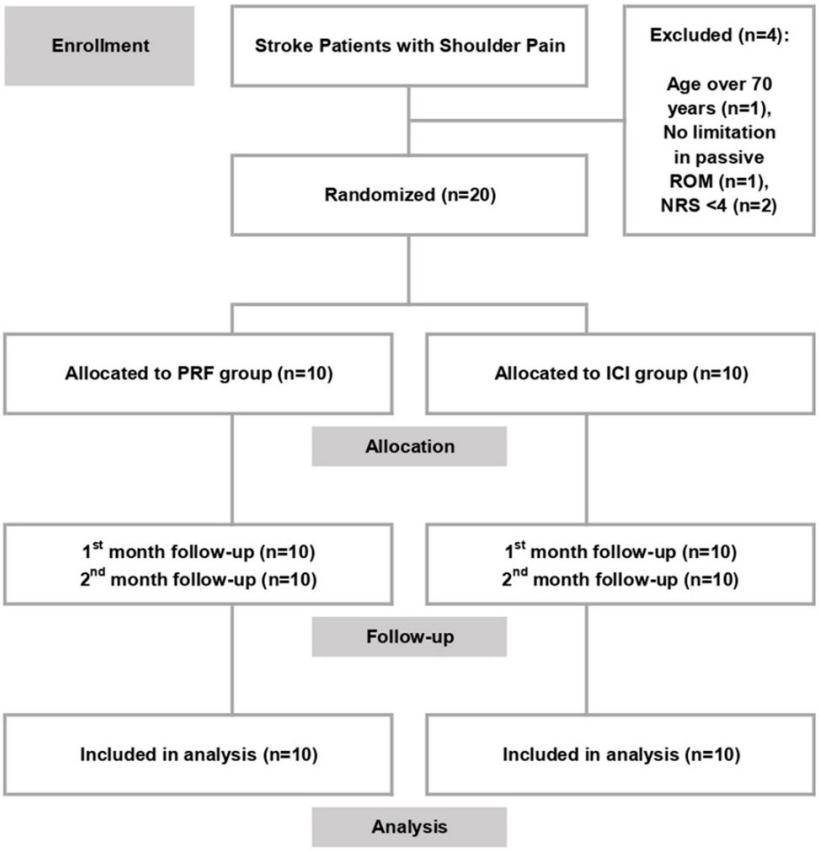

Fig. 1. Study flow diagram for pulsed radiofrequency and intra-articular corticosteroid injection groups. Abbreviations: ROM, range of motion; NRS, numeric rating scale; PRF, pulsed radiofrequency; ICI, intra-articular corticosteroid injection.

damage surrounding structures [20]. The primary mechanism of PRF is modulation of pain signals by the generated electrical field [21]. Several previous studies have reported that PRF can be effective in controlling various types of pain, such as neuralgia, muscle pain and joint pain [9, 22, 23]. Additionally, recent studies have shown that PRF of the SSN may effectively manage shoulder pain [24–27]. However, the effect of PRF stimulation of the SSN in the management of HSP after stroke remains undetermined.

Therefore, this study, investigated whether PRF stimulation of the SSN could effectively reduce shoulder pain and increase the shoulder ROM in patients with HSP following chronic stroke. Furthermore, the effectiveness of PRF and ICI was compared in these patients.

2. Materials and methods

2.1 Subjects

20 consecutive stroke patients were prospectively recruited, including 13 men and 7 women, mean age 58.0 ± 8.7 years (range, 42–69 years). 11 patients were diagnosed with cerebral infarct and 9 with intracerebral hemorrhage. Mean stroke duration was 13.2 ± 2.6 months. All patients were admitted to the Department of Physical Medicine and Rehabilitation at a hospital for post-stroke rehabilitation treatment. Inclusion criteria were: (1) history of stroke, (2) stroke duration at least months, (3) age 21–70 years, (4) presence of hemiplegia caused by stroke, (5) significant shoulder pain with a minimum score of four on the numeric rating scale (NRS, where "0" indicates no pain and "10" indicates the most severe pain) persistent for at least three months, (6) no change in pain severity (NRS score) after four weeks despite taking pain medication (meloxicam, acetaminophen, and tramadol hydrochloride alone or in combination), (7) limitation in passive ROM on physical examination, (8) no history of ICI administration in the shoulder and (9) no severe aphasia or cognitive dysfunction (to ensure accurate measurement of the pain degree).

Written informed consent was obtained from all subjects. The study protocol was approved by the Institutional Review Board of Yeungnam University Hospital (2017-02-011). The sample size was based on the findings of a previous study [24]. The reduction in the NRS score after treatment (PRF of the SSN vs. lidocaine injection) was 1.50 ± 1.12 in that study. Applying a type I error of 0.05 for 80% power and using a two-sided test, a sample size of nine subjects per group was found to be adequate for this study. Allowing for a 10% dropout rate, 10 subjects were recruited for each group.

Subjects were allocated (by random number table) to receive either PRF stimulation of the SSN (PRF group) or ICI

administration in the shoulder joint (ICI group) (Fig. 1). An experienced clinician performed the assigned procedure once for each subject under ultrasound (US) guidance. All patients underwent rehabilitation therapy (Monday to Friday: 2.5 h/day; Saturday: 1 h/day).

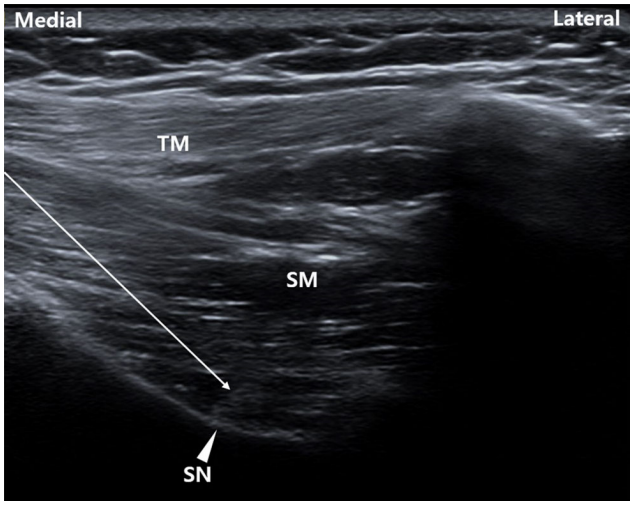

Fig. 2. Ultrasound image of suprascapular nerve with linear ultrasound probe. Abbreviations: TM, trapezius muscle; SM, supraspinatus muscle; SN (arrow head), suprascapular nerve; arrow, pulsed radiofrequency needle pathway.

2.2 Procedures

The procedure was conducted from behind the patient by a physician with the patient in an upright position. A US device (LOGIQ P6, General Electric, Republic of Korea) with an 11-MHz linear probe was used to guide injection administration. During PRF stimulation and ICI administration, the hand on the side of the injection could be placed on the contralateral shoulder. For PRF stimulation, the US probe was placed just above and parallel to the scapular spine. The supraspinatus muscle and scapular notch were visualized on the US images. The SSN was seen as a hyperechoic structure in the scapular notch, 3–4 cm below the transverse scapular ligament. A 22-gauge, 10-cm cannula with a 10-mm active tip (Cosman RF Cannula, CC10522, Cosman Medical, Burlington, MA, USA) was inserted towards the scapular notch using a medial-to-lateral approach (Fig. 2). An electrode was connected to the PRF needle. When the patient reported paresthesia during sensory stimulation (50 Hz, 1 ms pulse width, $\leq$0.5 V) and contraction of the supra- and infraspinatus muscles was observed during motor stimulation (2 Hz, 1 ms pulse width, $\leq$0.5 V), the PRF (Cosman G4 radiofrequency generator, Cosman Medical) was applied at 2 Hz and 30 ms pulse width for 360 s at 45 V. The electrode tip temperature did not exceed 42 °C. For ICI, the US probe was placed over the long axis of the myotendinous junction of the infraspinatus tendon, presenting the posterior glenoid labrum and the posterior part of the humeral head. The needle tip was advanced into the glenohumeral joint and a 10-mL solution containing triamcinolone actinide (20 mg), 1% lidocaine (1 mL) and normal saline (8.5 mL) was injected.

2.3 Outcome measurements

Patients were assessed prior to the study (baseline) and at one and two months after the procedure. The same investigator, blinded to the therapeutic intervention, assessed the clinical outcomes before and during follow-up. The intensity of pain in the affected shoulder was assessed using the NRS. Passive shoulder joint ROM was investigated using a goniometer. Shoulder flexion, abduction and external and internal rotations were assessed with the patients in a supine position. Degree of shoulder flexion and abduction was measured with the elbow in extension and ROM of external and internal rotations evaluated with the elbow at 90° flexion and the arm at 90° abduction. For precise measurement of the ROM, the shoulder joint was positioned with the proximal segment stabilized to exclude articular movement. To measure passive ROM, the examiner moved the patient's arm until the movement was mechanically limited or the patient felt pain.

Change in NRS score was measured as the difference between the pre-treatment score and the score at each time point during post-treatment follow-up. Change in NRS (%) was calculated as "((pre-treatment score - score after treatment)/pre-treatment score) $\times$ 100". Successful treatment was defined as $\geq$50% reduction in the NRS score at the two month follow-up when compared to the pre-treatment NRS score.

2.4 Statistical analysis

Data were analyzed using Statistical Product and Service Solutions software (SPSS, version 22.0, IBM Corporation, Armonk, NY, USA). Intergroup comparison of the demographic data and the rate of successful pain relief employed the Mann–Whitney U-test and Fisher's exact test, respectively. A normality test employed the Kolmogorov–Smirnov test. Repeated measure one-factor analysis was used to evaluate changes in the NRS scores in the PRF and ICI groups. A repeated measure two-factor analysis was used to compare the changes between the groups over time. Multiple comparisons were obtained using the Bonferroni correction. The level of statistical significance was set at $p < 0.05$.

3. Results

All enrolled subjects completed the study and no adverse events were observed in either group. There were no significant differences in the demographic characteristics between the two groups ($p > 0.05$) (Table 1).

The intragroup analysis showed that the NRS scores differed significantly over time in both the groups (PRF group: $p = 0.009$; ICI group: $p < 0.001$). In the PRF group, the NRS scores at baseline and at one and two months post-treatment were 5.9 $\pm$ 0.8, 5.0 $\pm$ 2.2, and 5.2 $\pm$ 2.0, respectively. In the ICI group, the mean NRS score decreased from 6.2 $\pm$ 1.1

Table 1. Patient demographic characteristics and baseline clinical data.

	PRF group (n = 10)	ICI group (n = 10)	*p*-value
Age, years	56.5 ± 9.3	59.4 ± 8.3	0.579
Sex (Male : Female), *n*	6:4	7:3	0.648
Affected hemisphere (Right : Left), *n*	6:4	4:6	0.656
Months from onset	13.1 ± 2.5	13.3 ± 2.9	0.912
Stroke type (infarct : hemorrhage), *n*	7:3	4:6	0.648
Initial NRS	5.9 ± 1.4	6.2 ± 1.1	0.684
Initial passive ROM of shoulder, degree			
Flexion	123.5 ± 29.8	126.0 ± 24.1	0.796
Abduction	121.5 ± 28.3	122.0 ± 26.6	0.971
External rotation	56.0 ± 11.7	61.0 ± 9.9	0.353
Internal rotation	67.0 ± 8.6	69.5 ± 6.0	0.393
MBC	2.3 ± 1.1	2.1 ± 0.9	<0.999
FAC	2.4 ± 0.5	2.4 ± 0.5	0.912
MMSE	27.2 ± 2.7	27.7 ± 2.7	0.684

Values are given as mean ± standard deviation.

Abbreviations: PRF, pulsed radiofrequency; ICI, intra-articular corticosteroid injection; NRS, numeric rating scale; ROM, range of motion; MBC, modified Brunnstrom classification (scores range from 1 to 6; higher scores indicate better hand function); FAC, Functional Ambulation Category (scores range from 0 to 5; higher scores indicate better walking ability); MMSE, Mini-Mental State Examination.

at baseline to 2.8 ± 0.9 at one month and 3.2 ± 1.1 at two months post-treatment. In both groups, the post-treatment scores at one and two months were significantly lower than the pre-treatment scores (PRF group: one month, $p = 0.010$, two months, $p = 0.025$; ICI group: $p < 0.001$ for both one and two months) (Fig. 3). Except for internal rotation, all measurements of the passive shoulder ROM differed significantly over time in the PRF group (flexion ROM, $p = 0.015$; abduction ROM, $p = 0.014$; external rotation ROM, $p = 0.038$; and internal rotation ROM, $p = 0.063$). A significant increase in the passive shoulder ROM was observed in the flexion, abduction, and external rotation at one and two months after PRF stimulation (flexion ROM at one month, $p = 0.022$; flexion ROM at two months, $p = 0.025$; abduction ROM at one month, $p = 0.005$; abduction ROM at two months, $p = 0.025$; external rotation ROM at one month, $p = 0.017$; external rotation ROM at two months, $p = 0.048$; internal rotation ROM at one month, $p = 0.052$; and internal rotation ROM at two months, $p = 0.081$) (Fig. 3). In the ICI group, all ROM measurements increased significantly over time ($p < 0.001$), and a significant increase was noted at one and two months after ICI ($p < 0.001$) (Fig. 4).

In the intergroup analysis, changes in the NRS scores and all ROM measurements differed significantly over time between the two groups ($p < 0.001$). The NRS score was significantly lower and all ROM measurements were significantly higher in the ICI group as compared to the PRF group at one and two months post-treatment ($p < 0.001$) (Figs. 3,4). The individual data of all subjects are presented in **Supplementary 1**.

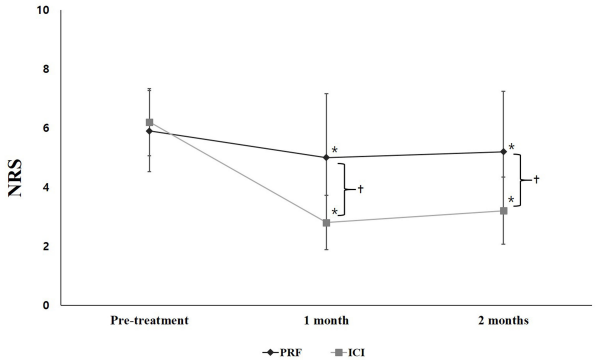

Fig. 3. Changes in the numeric rating scale scores. Compared to the pre-treatment NRS scores, both groups showed a significant decrease in the scores at one and two months after treatment. However, the NRS scores were significantly lower in the ICI group than in the PRF group at one and two months after the procedure. Abbreviations: NRS, numeric rating scale; PRF, pulsed radiofrequency; ICI, intra-articular corticosteroid injection. *$p < 0.05$: Intragroup comparison of NRS values at pre- and post-treatment (repeated measure one-factor analysis). †$p < 0.05$: Intergroup comparison at each time point (repeated measure two-factor analysis).

Pain relief (pain improvement ≥50%) was achieved in two out of ten subjects in the PRF group (20%) and in seven out of ten subjects in the ICI group (70%). There was a trend towards more successful pain relief in the ICI group than in the PRF group ($p = 0.070$).

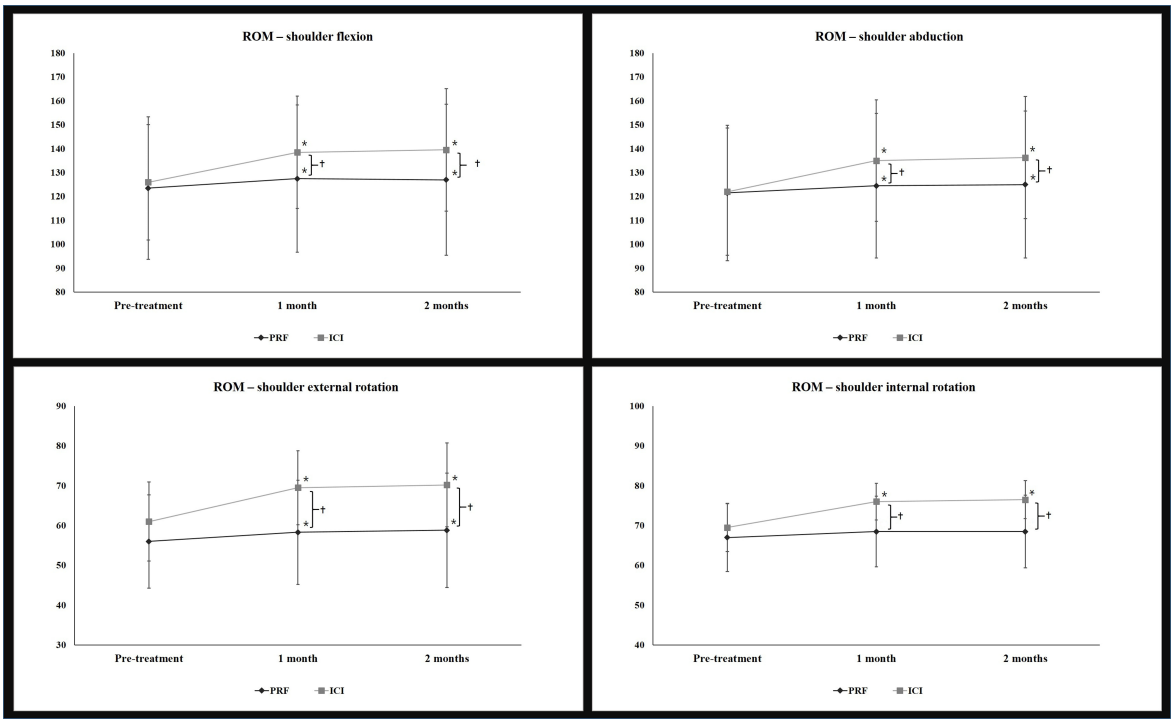

Fig. 4. Changes in the passive shoulder joint range of motion measurements. In the PRF group, a significant increase in the shoulder ROM was observed in flexion, abduction, and external rotation at one and two months after PRF. In the ICI group, a significant increase was found in all ROM measurements at one and two months after ICI administration. In the intergroup comparison, all ROM measurements were significantly higher in the ICI group than in the PRF group. Abbreviations: ROM, range of motion; PRF, pulsed radiofrequency; ICI, intra-articular corticosteroid injection. $*p < 0.05$: Intragroup comparison between the shoulder ROM at pre- and post-treatment (repeated measure one-factor analysis). $\dagger p < 0.05$: Intergroup comparison at each time point (repeated measure two-factor analysis).

4. Discussion

This study investigated the effectiveness of PRF of the SSN in alleviating pain and compared it with ICI treatment in patients with HSP after chronic stroke. The severity of pain measured by NRS was significantly reduced at one and two months after both interventions. However, the NRS scores were significantly lower in the ICI group than in the PRF group at one and two months post-treatment. Furthermore, only two out of ten patients (20%) who underwent PRF had successful pain relief ($\geq$50% pain reduction at two months after treatment). In contrast, ICI showed a trend towards more successful pain relief (70%) than PRF, although the difference was not statistically significant. Moreover, it was found that both interventions improved nearly all the shoulder ROM measurements and the effect was sustained for at least two months. However, similar to the improvement in pain, all ROM measurements were significantly higher in the ICI group as compared to the PRF group.

The mechanism of action of PRF of the SSN has not yet been clearly identified. However, based on previous studies, some mechanisms can be suggested. Cosman *et al.* [28] reported that pain reduction after PRF stimulation was correlated with the long-term depression of synaptic transmission following low-frequency electrical stimulation of neurons by PRF. Therefore, the PRF of the SSN seems to inhibit the transfer of nociceptive stimuli from the shoulder joint. Additionally, Hagiwara [29] reported that when the electromagnetic field produced by PRF stimulates the peripheral nerves, excitatory C-fibers are inhibited and activity of the descending serotonergic and noradrenergic pain inhibitory pathways is enhanced. The effectiveness of ICI in this study is consistent with the findings of several previous studies on HSP [5, 30, 31]. Here, the potent anti-inflammatory effect of corticosteroids seemed to have reduced the shoulder pain and increased the extensibility of the shoulder joint capsule in the ICI group [5]. It is believed that the outcome of ICI was better than that of PRF because the corticosteroid injection was administered at the origin of pain. In contrast, PRF controlled the shoulder pain indirectly by acting on the SSN. Despite the superior effect of the ICI, its potential adverse effects should be considered [9, 10]. Therefore, PRF treatment of the SSN may be a helpful therapeutic modality in the management of HSP, especially in patients contraindicated for or who experience significant side effects with corticosteroid injections. Furthermore, US was used to guide the PRF needle when approaching the SSN. US not only increases the safety and accuracy of the procedure, but also diagnoses shoulder disorders accurately [32, 33].

Several previous studies have demonstrated the efficacy of PRF treatment of the SSN for shoulder pain due to rotator cuff pathology or adhesive capsulitis. However, to the author's knowledge, only one study has evaluated the effectiveness of PRF stimulation of the SSN in HSP after stroke [24–27]. In 2018, Picelli *et al.* [34] retrospectively evaluated the effect of PRF of the SSN in six chronic stroke patients with HSP. They reported that the intensity of shoulder pain evaluated using the visual analog scale was significantly reduced and the shoulder ROM significantly improved with PRF, with a sustained effect for at least four months. The present study is the first prospective randomized controlled study to compare the effectiveness of PRF and ICI in HSP after chronic stroke. However, its limitations should be considered. First, there was no investigation of the long-term effects of the therapy beyond two months. Second, patients were not blinded to the treatment they received. Third, the study did not include a placebo group. Finally, the mechanisms causing HSP, such as soft tissue problems, motor impairment and neural factors, were neither considered nor evaluated.

5. Conclusions

Results indicate that the effectiveness of PRF of the SSN in pain reduction, as evaluated by NRS score, was minimal in patients with HSP after stroke. Although NRS scores were significantly reduced following PRF, only 20% of patients experienced successful pain reduction. In contrast, there was a greater decrease in the severity of pain after ICI, and 70% of patients experienced successful pain reduction. Furthermore, improvement in the shoulder ROM was greater with ICI than with PRF. Therefore, it is suggested that ICI may more effectively control HSP in patients with stroke than PRF of the SSN. However, in patients at a risk of complications with corticosteroids, PRF of the SSN may be a reasonable clinical option.

Abbreviations

HSP, hemiplegic shoulder pain; ROM, range of motion; SSNB, suprascapular nerve block; SSN, suprascapular nerve; PRF, pulsed radiofrequency; ICI, intra-articular corticosteroid injection; NRS, numeric rating scale; US, ultrasound.

Author contributions

THK and MCC conceived and designed the experiments; THK and MCC performed the experiments; THK and MCC analyzed the data; THK and MCC contributed reagents and materials; THK and MCC wrote the paper.

Ethics approval and consent to participate

Informed consent was obtained from all the participants. The Institutional Review Board of Yeungnam University Hospital approved this study (code 2017-02-011).

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Conflict of interest

The authors declare no conflict of interest.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/j.jin2003073.

References

[1] Choi G, Chang MC. Effects of high-frequency repetitive transcranial magnetic stimulation on reducing hemiplegic shoulder pain in patients with chronic stoke: a randomized controlled trial. International Journal of Neuroscience. 2018; 128: 110–116.

[2] Choi-Kwon S, Choi SH, Suh M, Choi S, Cho KH, Nah HW, *et al.* Musculoskeletal and central pain at 1 year post-stroke: associated factors and impact on quality of life. Acta Neurologica Scandinavica. 2017; 135: 419–425.

[3] Lindgren I, Jönsson A, Norrving B, Lindgren A. Shoulder pain after stroke: a prospective population-based study. Stroke. 2007; 38: 343–348.

[4] Ratnasabapathy Y, Broad J, Baskett J, Pledger M, Marshall J, Bonita R. Shoulder pain in people with a stroke: a population-based study. Clinical Rehabilitation. 2003; 17: 304–311.

[5] Chang MC. The effects of ultrasound-guided corticosteroid injection for the treatment of hemiplegic shoulder pain on depression and anxiety in patients with chronic stroke. International Journal of Neuroscience. 2017; 127: 958–964.

[6] Anwer S, Alghadir A. Incidence, Prevalence, and risk factors of hemiplegic shoulder pain: a systematic review. International Journal of Environmental Research and Public Health. 2020; 17: 4962.

[7] Viana R, Pereira S, Mehta S, Miller T, Teasell R. Evidence for therapeutic interventions for hemiplegic shoulder pain during the chronic stage of stroke: a review. Topics in Stroke Rehabilitation. 2012; 19: 514–522.

[8] Buchbinder R, Green S, Youd JM. Corticosteroid injections for shoulder pain. Cochrane Database of Systematic Reviews. 2003; 2003: CD004016.

[9] Lim JW, Cho Y, Lee DG, Chang MC. Comparison of intraarticular pulsed radiofrequency and intraarticular corticosteroid injection for management of cervical facet joint pain. Pain Physician. 2017; 20: E961–E967.

[10] Manchikanti L. Role of neuraxial steroids in interventional pain management. Pain Physician. 2002; 5: 182–199.

[11] Adey-Wakeling Z, Crotty M, Shanahan EM. Suprascapular nerve block for shoulder pain in the first year after stroke: a randomized controlled trial. Stroke. 2013; 44: 3136–3141.

[12] Picelli A, Bonazza S, Lobba D, Parolini M, Martini A, Chemello E, *et al.* Suprascapular nerve block for the treatment of hemiplegic shoulder pain in patients with long-term chronic stroke: a pilot study. Neurological Sciences. 2017; 38: 1697–1701.

[13] Vorster W, Lange CPE, Briët RJP, Labuschagne BCJ, du Toit DF, Muller CJF, *et al.* The sensory branch distribution of the suprascapular nerve: an anatomic study. Journal of Shoulder and Elbow Surgery. 2008; 17: 500–502.

[14] Chang K, Hung C, Wu W, Han D, Yang R, Lin C. Comparison of the effectiveness of suprascapular nerve block with physical

therapy, placebo, and intra-articular injection in management of chronic shoulder pain: a meta-analysis of randomized controlled trials. Archives of Physical Medicine and Rehabilitation. 2016; 97: 1366–1380.
[15] Sluijter M. Pain in Europe, Barcelona. In 2nd Annual Congress of the European Federation of IASP Chapters 326. 1997.
[16] Podhajsky RJ, Sekiguchi Y, Kikuchi S, Myers RR. The histologic effects of pulsed and continuous radiofrequency lesions at 42 degrees C to rat dorsal root ganglion and sciatic nerve. Spine. 2005; 30: 1008–1013.
[17] Vallejo R, Benyamin RM, Kramer J, Stanton G, Joseph NJ. Pulsed radiofrequency denervation for the treatment of sacroiliac joint syndrome. Pain Medicine. 2006; 7: 429–434.
[18] West M, Wu H. Pulsed radiofrequency ablation for residual and phantom limb pain: a case series. Pain Practice. 2010; 10: 485–491.
[19] Vatansever D, Tekin I, Tuglu I, Erbuyun K, Ok G. A comparison of the neuroablative effects of conventional and pulsed radiofrequency techniques. Clinical Journal of Pain. 2009; 24: 717–724.
[20] Sluijter ME, Cosman ER, Rittmann WB, Van Kleef M. The effects of pulsed radiofrequency fields applied to the dorsal root ganglion: A preliminary report. Pain Clinic. 1998; 11: 109–117.
[21] Van Zundert J, de Louw AJA, Joosten EAJ, Kessels AGH, Honig W, Dederen PJWC, *et al.* Pulsed and continuous radiofrequency current adjacent to the cervical dorsal root ganglion of the rat induces late cellular activity in the dorsal horn. Anesthesiology. 2005; 102: 125–131.
[22] Cho IT, Cho YW, Kwak SG, Chang MC. Comparison between ultrasound-guided interfascial pulsed radiofrequency and ultrasound-guided interfascial block with local anesthetic in myofascial pain syndrome of trapezius muscle. Medicine. 2017; 96: e6019.
[23] Lee DG, Chang MC. The effect of caudal epidural pulsed radiofrequency stimulation in patients with refractory chronic idiopathic axonal polyneuropathy. Pain Physician. 2018; 21: E57–E62.
[24] Gofeld M, Restrepo-Garces CE, Theodore BR, Faclier G. Pulsed radiofrequency of suprascapular nerve for chronic shoulder pain: a randomized double-blind active placebo-controlled study. Pain Practice. 2013; 13: 96–103.
[25] Jang JS, Choi HJ, Kang SH, Yang JS, Lee JJ, Hwang SM. Effect of pulsed radiofrequency neuromodulation on clinical improvements in the patients of chronic intractable shoulder pain. Journal of Korean Neurosurgical Society. 2013; 54: 507–510.
[26] Liu A, Zhang W, Sun M, Ma C, Yan S. Evidence-based status of pulsed radiofrequency treatment for patients with shoulder pain: a systematic review of randomized controlled trials. Pain Practice. 2016; 16: 518–525.
[27] Wu Y, Ho C, Chen Y, Li T, Lee K, Chen L. Ultrasound-guided pulsed radiofrequency stimulation of the suprascapular nerve for adhesive capsulitis: a prospective, randomized, controlled trial. Anesthesia & Analgesia. 2014; 119: 686–692.
[28] Cosman ER Jr, Cosman ER Sr. Electric and thermal field effects in tissue around radiofrequency electrodes. Pain Medicine. 2005; 6: 405–424.
[29] Hagiwara S, Iwasaka H, Takeshima N, Noguchi T. Mechanisms of analgesic action of pulsed radiofrequency on adjuvant-induced pain in the rat: roles of descending adrenergic and serotonergic systems. European Journal of Pain. 2009; 13: 249–252.
[30] Dekker JH, Wagenaar RC, Lankhorst GJ, de Jong BA. The painful hemiplegic shoulder: effects of intra-articular triamcinolone acetonide. American Journal of Physical Medicine & Rehabilitation. 1997; 76: 43–48.
[31] Lim J, Koh J, Paik N. Intramuscular botulinum toxin-a reduces hemiplegic shoulder pain: a randomized, double-blind, comparative study versus intraarticular triamcinolone acetonide. Stroke. 2008; 39: 126–131.
[32] Hsu P, Chang K, Wu W, Wang J, Özçakar L. Effects of ultrasound-guided peritendinous and intrabursal corticosteroid injections on shoulder tendon elasticity: a post hoc analysis of a randomized controlled trial. Archives of Physical Medicine and Rehabilitation. 2021; 102: 905–913.
[33] Wu WT, Chen LR, Chang HC, Chang KV, Özçakar L. quantitative ultrasonographic analysis of changes of the suprascapular nerve in the aging population with shoulder pain. Frontiers in Bioengineering and Biotechnology. 2021; 9: 640747.
[34] Picelli A, Lobba D, Vendramin P, Castellano G, Chemello E, Schweiger V, *et al.* A retrospective case series of ultrasound-guided suprascapular nerve pulsed radiofrequency treatment for hemiplegic shoulder pain in patients with chronic stroke. Journal of Pain Research. 2018; 11: 1115–1120.