



Pulsed Radiofrequency Neuromodulation for Post-Stroke Shoulder Pain in Patients with Hemorrhagic Stroke

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Objective : Post-stroke shoulder pain (PSSP) is a common complication that limits the range of motion (ROM) of the shoulder, the patient's rehabilitation and in turn, affects the patients' quality of life (QoL). Several treatment modalities such as sling, positioning, strapping, functional electrical stimulation, and nerve block have been suggested in literatures, however none of the treatments had long-term effects for PSSP. In this study, the authors evaluated clinical efficacy of pulsed radiofrequency (PRF) neuromodulation on the suprascapular nerve for PSSP, and suggested it as a potential treatment with long-term effect.

Methods : This retrospective case series was conducted at a single center, a private practice institution. From 2013 to 2021, 13 patients with PSSP underwent PRF neuromodulation of the suprascapular nerve. The primary outcome measure was the Visual analog scale (VAS) score. The secondary outcome measurements included the shoulder ROM, Disability assessment scale (DAS), modified Ashworth scale, modified Rankin scale (mRS), and EuroQoL-5 dimension-3L questionnaire (EQ-5D-3L) scores. These parameters were evaluated before PRF modulation, immediately after PRF modulation, and every 3 months until the final follow-up visit.

Results : Six men and seven women were enrolled, and all patients were followed-up for a minimum of 12 months. The mean VAS score was 7.07 points before PRF neuromodulation and 2.38 points immediately post-procedure. Shoulder ROM for abduction and flexion, DAS for pain, mRS, and EQ-5D-3L demonstrated marked improvement. No complications were reported.

Conclusion : PRF neuromodulation of the suprascapular nerve is an effective modality in patients with PSSP, and has long-term effect of pain relief, improvement of QoL.

Key Words : Stroke · Shoulder pain · Chronic pain · Pain management · Neuromodulation · Pulsed radiofrequency.

INTRODUCTION

Post-stroke shoulder pain (PSSP) is a common complication found in stroke patients and is a major cause of disability after stroke¹⁾. PSSP causes severe pain and hinders post stroke patients' rehabilitation and quality of life (QoL)²⁾. Therefore, ef-

fective control of PSSP is important when considering the prognosis in stroke patients. However, the treatment of PSSP is limited, even though treatment modalities have improved. Several treatment modalities, such as slings, positioning, strapping, functional electrical stimulation (FES), and nerve blocks have been suggested in the literature; however, evidence

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of evaluating their effectiveness in preventing or managing PSSP is still lacking⁵).

Pulsed radiofrequency (PRF) is a novel therapeutic modality with potential applications in pain management. Several studies have reported favorable outcomes of PRF neuromodulation for chronic shoulder pain⁷. However, few studies have reported the clinical efficacy of PRF neuromodulation for PSSP patients. Our study aimed to evaluate the clinical efficacy of PRF neuromodulation on the suprascapular nerve in patients with PSSP after hemorrhagic stroke, with a minimum follow-up period of 12 months.

MATERIALS AND METHODS

The Institutional Review Board (IRB) of Chuncheon Sacred Heart Hospital approved this study (IRB No. 2021-06-006), and written informed consent was obtained from all patients. All experiments in this study were performed following the tenants of the Declaration of Helsinki.

Patient selection criteria

From March 2013 to March 2021, 2825 patients were diagnosed with a hemorrhagic stroke at our institute. Among them, 693 patients were diagnosed with PSSP based on the criteria shown in Table 1²⁹.

Patients were recruited for the study and PRF neuromodulation based on the selection criteria outlined in Fig. 1. All selected patients had a history of hemorrhagic stroke with motor weakness of grade II-IV, VAS of ≥ 6 points, shoulder range of motion (ROM) limitation, and alert consciousness without

aphasia, and age under 70 years. Prior to PRF neuromodulation, all patients underwent conservative treatment, including medication (e.g., nonsteroidal anti-inflammatory drugs) and physical therapy. A nerve block, using 1.0% lidocaine and dexamethasone, was performed twice at a 2-week interval. A positive response to the nerve block indicated an improvement in the shoulder ROM or reduction of pain by more than 50%. Among those eligible for suprascapular nerve block, PRF neuromodulation was performed for patients whose symptoms worsened again within 2 weeks. Thirteen patients with hemorrhagic stroke with PSSP underwent PRF neuromodulation on the suprascapular nerve.

PRF procedure

Patients received either ultrasonography-guided or fluoroscopy-guided PRF stimulation. The procedure was conducted arbitrarily according to the condition of the equipment at that time. Among the 13 patients, eight received ultrasonography-

Table 1. Diagnostic criteria for post-stroke shoulder pain

Diagnostic criteria
Unilateral cerebral insult due to stroke, hemorrhage
At least 6 months after stroke
Absence of shoulder pain prior to the stroke
Absence of peripheral neuropathies in the upper extremity prior to the stroke
Demonstrated by at least one of the following :
Joint pain : pain is sharp and stabbing
Muscle pain : a pulling sensation located in the muscle being stretched
Altered sensitivity : pain that is localized to the shoulder and is sharp, diffuse, aching
Shoulder-hand syndrome : pain syndrome encompasses the entire upper limb

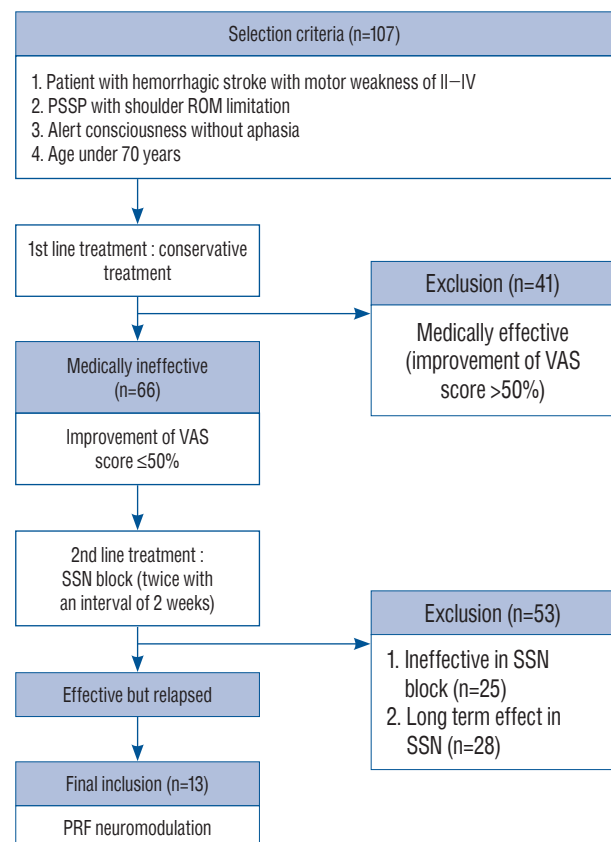


Fig. 1. treatment paradigm of PSSP and the patient inclusion process. PSSP : post-stroke shoulder pain, ROM : range of motion, VAS : Visual analogue scale, SSN : suprascapular nerve, PRF : pulsed radiofrequency.

guided PRF and five were treated with fluoroscopy-guided PRF. To locate the spine of the scapula, a line was drawn from the acromion tip to the medial border of the scapula. The center of the line was identified, and a perpendicular line parallel to the vertebral column was drawn through it. The entry point was marked 2 cm cranial and 2 cm medial to the spine of the scapula. The superior border of the scapula was aseptically draped.

For ultrasonography-guided PRF the suprascapular notch, situated just medial to the base of the coracoid process and representing the superior border of the scapula, was identified using ultrasonography (Fig. 2A). The needle was inserted following the out-of-plane technique. In the case of fluoroscopy-guided PRF, fluoroscopy was angled caudal and oblique by approximately 10° to 20°, and the position of the needle tip was adjusted by comparing it with the suprascapular notch (Fig. 2B).

PRF neuromodulation was performed using a Cosman G4 radiofrequency generator (Cosman Inc., Burlington, MA, USA) in the neurointervention room. A radiofrequency cannula (disposable 22-gauge) with an active tip (5-mm) was used. After inserting the radiofrequency cannula, the stylet was removed, and the RF electrode (Diros OWL RF cannula; Diros Technology, Inc., Markham, Canada) was inserted. Once the cannula tip was positioned on the suprascapular notch, sensory stimulation at 50 Hz was conducted. Temporary paresthesia in the shoulder joint was observed at stimulation below 0.3 volts (V). Motor stimulation was performed at 2 Hz. Abduction and external rotation (supraspinatus and infraspinatus muscles) appeared at a stimulation below 0.4 V. After a positive stimulation, PRF neuromodulation was conducted for 240 pulses at 45 V, keeping the needle temperature below 42°C. After PRF stimulation, the local anesthetic (4 mL of 1% lidocaine) was administered through the cannula to alleviate procedure-related pain. Patients were discharged if no complications such as pneumothorax and bleeding, occurred.

Outcome evaluation

Primary outcome

The same physician assessed the pain before PRF neuromodulation, immediately after PRF neuromodulation, and every 3 months after until the last follow-up visit. The primary outcome measurement was the Visual analog scale (VAS) score (0, no pain; 10, worst possible pain imaginable).

Secondary outcome

Secondary outcome measurements included shoulder ROM, Disability assessment scale (DAS), modified Ashworth

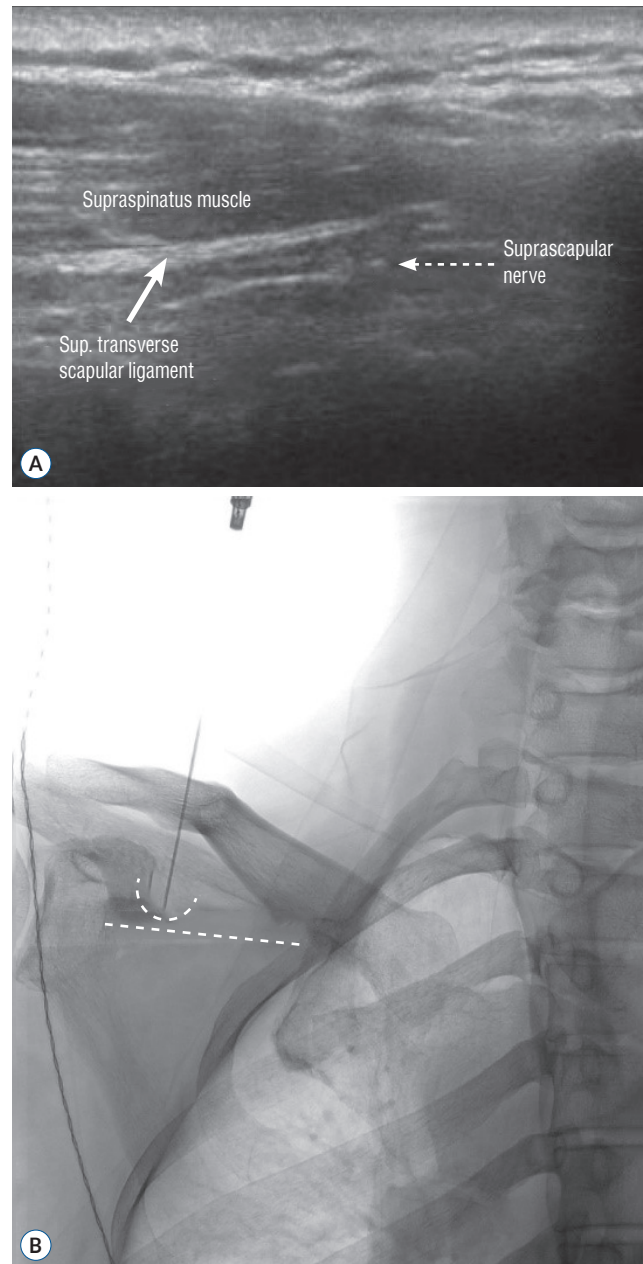


Fig. 2. A : Ultrasonography image of the suprascapular nerve. The superior transverse scapular ligament (white arrow) bridges the suprascapular notch, converting it into a suprascapular foramen. The suprascapular nerves (white dashed arrow) traverse through the suprascapular foramen. B : Fluoroscopy image of pulsed radiofrequency neuromodulation showing landmarks for the suprascapular nerve, which is located in the suprascapular notch (white semicircle) at the scapular spine (white straight line).

scale (mAS), modified Rankin scale (mRS), and EuroQol-5 dimension-3L questionnaire (EQ-5D-3L) scores. The same physician assessed shoulder flexion, extension, and abduction ROM. DAS evaluated functional disability in areas such as patient hygiene, dressing, limb position, and pain⁶. The mAS measured shoulder adductor muscle tone. This 5-point score grades resistance to rapid passive stretch from 0 (no muscle tone increase) to 4 (rigid joint)²³. The mRS quantified the degree of disability or dependence in the daily activities of individuals with neurological disabilities by seven grades²⁶. QoL was evaluated using the EQ-5D-3L from 0 (worst health state) to 100 (best health state)⁹.

Statistical analysis

Data were analyzed using R-4.1.0 (R Foundation for Statistical Computing, Vienna, Austria) for Windows (32/64 bit). Changes in VAS, mAS, mRS, DAS, EQ-5D-3L scores, and ROM were assessed using the Wilcoxon signed-rank test. The level of significance was set at $p < 0.05$.

RESULTS

Six men (mean age, 52 years) and seven women (mean age, 61 years) were enrolled for PRF neuromodulation. The mean age of the entire group was 56 years (range, 37–85), and the mean follow-up period was 54 months. The mean duration of symptoms was 13.69 months. During the follow-up period, the pre-PRF VAS score decreased by more than 50% in comparison to the VAS score at 1 year after PRF in 10 out of 13 patients. Although some patients reported recurrent pain, the overall VAS score showed a decline. Baseline shoulder magnetic resonance imaging and shoulder radiography were conducted for all patients. Among them, five patients had rotator cuff tears, and three patients had adhesive capsulitis. Patient demographics are summarized in Table 2.

The mean VAS score was 7.08 points before PRF neuromodulation, and significantly decreased to 2.38 points immediately after the procedure (median value 7 to 3). Improvement was observed in the following parameters compared to baseline : VAS (median value, 7 to 3 immediately after PRF, $p=0.001$; 7 to 1 at 1 year after PRF, $p=0.002$); mRS (median value, 2 to 1 at 1 year after PRF, $p=0.0047$); DAS for pain (median value, 2 to 1 immediately after PRF, $p=0.002$; 2 to 1 at 1 year after PRF,

$p=0.004$); EQ-5D-3L (median value, 8 to 6 immediately after PRF, $p=0.002$; 8 to 6 at 1 at 1 year after PRF, $p=0.003$); shoulder ROM for abduction (mean value, 136.92 to 155.38 immediately after PRF, $p=0.0352$); and flexion (mean value, 137.69 to 156.92 immediately after PRF, $p=0.02$; 137.69 to 155.38 at 1 year after PRF, $p=0.02$). The changes in the values of significant statistical differences before and after procedure were plotted over time (Fig. 3). Tables 3-5 provide a summary of comparisons for outcome data and treatment effects at all follow-up time points.

No complications, such as pain, bleeding, pneumothorax, or nerve injury, occurred in any of the patients.

Case illustration

A 40-year-old patient presented to the emergency center in 2013 with left-sided motor weakness. Computed tomography revealed spontaneous intracerebral hemorrhage in the right thalamus ($2.3 \times 2.6 \text{ cm}^3$) (Fig. 4A). Clinical symptoms improved with conservative treatment, and at discharge, the patient's left upper extremity muscle strength was assessed as Medical Research Council grade 3. In the baseline shoulder imaging study, a focal tear in the supraspinatus tendon was confirmed (Fig. 4B). The patient reported intractable shoulder

Table 2. Characteristics of patients who underwent PRF neuromodulation for PSSP

Characteristic	Value
Sex, M/F	7/6
Age (years)	56.1±8.7 (37-85)
Symptom duration before PRF (months)	13.7±19.1 (2-67)
Follow-up time (months)	54.0±28.3 (12-85)
Location of hemorrhagic stroke	
ICH	10 (76.9)
Putamen	5 (38.4)
Thalamus	2 (15.4)
Subcortical (frontal, temporal lobe)	3 (23.1)
SAH	3 (23.1)
Shoulder image finding	
Rotator cuff tear	5 (38.4)
Tendinosis	3 (23.1)
Adhesive capsulitis	3 (23.1)
Subluxation	2 (15.4)

Values are presented as mean±standard deviation (range) or number (%). PRF : pulsed radiofrequency, PSSP : post-stroke shoulder pain, M : male, F : female, ICH : intracerebral hemorrhage, SAH : subarachnoid hemorrhage

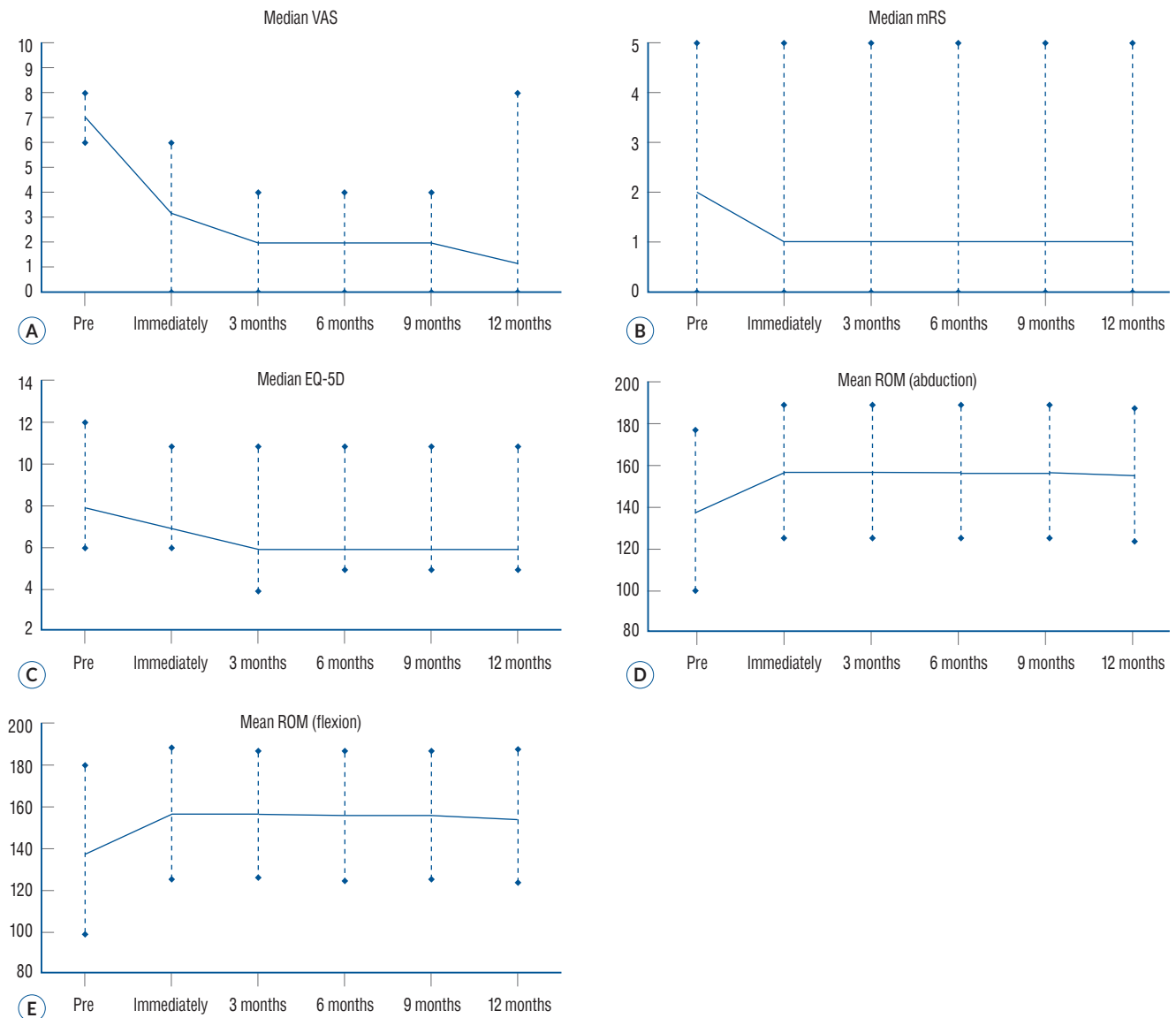


Fig. 3. A : Median VAS score of patients during the follow-up period. B : Median mRS score of patients during the follow-up period. C : Median EQ-5D score of patients during the follow-up period. D : Mean passive shoulder abduction ROM of patients during the follow-up period. E : Mean passive shoulder flexion ROM of patients during the follow-up period. VAS : Visual analogue scale, mRS : modified Rankin scale, EQ-5D : EuroQol-5 dimension, ROM : range of motion.

pain, limited ROM, and numbness. PRF was performed 9 months after intracranial hemorrhage with a diagnosis of PSSP. Pre-block shoulder flexion ROM was confirmed to be 140° (Fig. 4C). Post-PRF shoulder flexion ROM was 180° at 1 month after the procedure (Fig. 4D and Supplementary Videos 1 and 2). The VAS score improved from 8 points at baseline to 4 points at 1 year after PRF. Additionally, the EQ-5D-3L and mAS scores also showed improvement 1 year after PRF.

DISCUSSION

PSSP is commonly used to describe a set of complex problems with unknown causes. Various factors have been suggested to explain the pathophysiological mechanisms of PSSP, including chronic regional pain syndrome type I (CRPS-I), altered sensitivity, rotator cuff tears, subluxation, and adhesive capsulitis²⁷. Biomechanical factors significantly contribute and may occur in conjunction with changes in tone or neuro-

Table 3. Outcomes of pre, immediately after, and 1 year after PRF

Outcome	Pre-PRF (T0*)		Post-PRF (T1*)		1 year (T2*)	
	Mean±SD	Median (min-max)	Mean±SD	Median (min-max)	Mean±SD	Median (min-max)
VAS (0-10)	7.08±0.86	7 (6-8)	2.38±1.80	3 (0-6)	2.08±2.39	1 (0-8)
mAS	1.08±1.22	1 (0-4)	0.85±1.09	1 (0-4)	0.69±1.12	0 (0-4)
mRS	2.31±1.70	2 (0-5)	2.08±1.70	1 (0-5)	1.54±1.70	1 (0-5)
DAS-H	1.38±1.04	1 (0-3)	1.15±0.89	1 (0-3)	1.08±0.86	1 (0-3)
DAS-D	1.69±1.03	2 (0-4)	1.46±0.96	1 (0-3)	1.38±0.86	1 (0-3)
DAS-L	1.38±1.12	1 (0-3)	1.31±1.03	1 (0-3)	1.31±1.03	1 (0-3)
DAS-P	1.85±0.37	2 (1-2)	0.85±0.55	1 (0-2)	0.85±0.68	1 (0-2)
EQ-5D	8.31±2.25	8 (6-12)	7.15±2.03	6 (5-11)	6.92±1.80	6 (5-11)

*T0, before PRF; T1, immediately after PRF; T2, 1 year after PRF. PRF : pulsed radiofrequency, SD : standard deviation, VAS : Visual analogue scale, mAS : modified Ashworth scale, mRS : modified Rankin scale, DAS : Disability assessment scale, H : hygiene, D : dressing, L : limb position, P : pain, EQ-5D : EuroQol-5 dimension

Table 4. Range of motion of pre, immediately after, and 1 year after PRF

ROM	Pre-PRF (T0)	Post-PRF (T1)	1 year (T2)
ROM-extension (degree)	40.38±10.89	46.15±7.68	46.15±7.68
ROM-abduction (degree)	136.92±39.19	155.38±31.98	151.53±32.56
ROM-flexion (degree)	137.69±39.19	156.92±31.98	155.38±32.56

Values are presented as mean±standard deviation. PRF : pulsed radiofrequency, ROM : range of motion

Table 5. Comparisons of treatment effects on all outcome measures

Outcome	Wilcoxon signed-rank test	
	T0 vs. T1	T0 vs. T2
VAS (0-10)	0.0015*	0.0023*
mAS	NS ($p=0.148$)	NS ($p=0.089$)
mRS	NS ($p=0.1489$)	0.0048*
DAS-H	NS ($p=0.1489$)	NS ($p=0.1736$)
DAS-D	NS ($p=0.1489$)	NS ($p=0.1736$)
DAS-L	NS ($p=1.000$)	NS ($p=1.000$)
DAS-P	0.002*	0.004*
EQ-5D	0.0028*	0.0031*
ROM-extension (degree)	NS ($p=0.054$)	NS ($p=0.054$)
ROM-abduction (degree)	0.0352*	NS ($p=0.1056$)
ROM-flexion (degree)	0.0222*	0.0241*

*Statistically significant ($p<0.05$). T0 : pre-pulsed radiofrequency, T1 : post-pulsed radiofrequency, T2 : 1 year, pulsed radiofrequency pulsed radiofrequency, VAS : Visual analogue scale, mAS : modified Ashworth scale, NS : not significant, mRS : modified Rankin scale, DAS : Disability assessment scale, H : hygiene, D : dressing, L : limb position, P : pain, EQ-5D : EuroQol-5 dimension, ROM : range of motion

pathic mechanisms. Ryerson and Levit²¹⁾ concluded that glenohumeral subluxation, CRPS-I, and orthopedic conditions (such as spasticity) might be responsible for PSSP. PSSP is one of the major complications and is observed in approximately 5–80% of stroke patients²⁴⁾. The loss of muscle strength due to

hemiplegia can adversely affect the shoulder complex through three mechanisms : abnormal movement patterns, secondary changes to the surrounding soft tissue, and glenohumeral joint subluxation⁵⁾. Recent studies have suggested that not only a musculoskeletal factor but also a neuropathic pain sim-

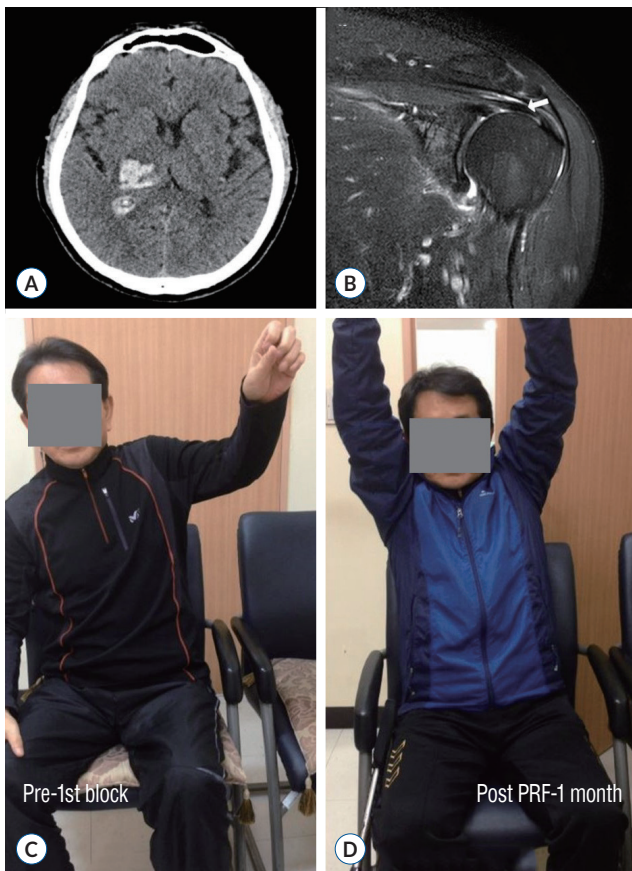


Fig. 4. A : Computed tomography shows intracranial hemorrhage (2.3×2.6 cm) in the right thalamus. B : Left shoulder magnetic resonance imaging shows supraspinatus tendon tear (white arrow). Severe tendinosis of the supraspinatus, subscapularis tendon and adhesive capsulitis were also confirmed. C : The pre-block shoulder flexion range of motion (ROM) was 140°. D : The shoulder ROM was improved to 180° at 1 month after pulsed radiofrequency neuromodulation.

ilar to central sensitization contribute to the disease¹⁶. Central sensitization modified the pain signal pathway leading to neuroplasticity¹⁵. Central post-stroke pain is also reported as one of the primary causes of PSSP¹¹.

Several techniques for the treatment of PSSP, including sling, positioning, strapping, FES, and nerve block are available; however, research evaluating their efficacy is limited^{5,10,14,17,20}. Studies on the effects of conservative treatment on PSSP lack quantitative results. According to another study, a low rate of spontaneous pain resolution for PSSP (14% at 12 months) was observed¹. Procedures such as suprascapular block, FES, and botulinum toxin administration have been reported to improve pain by 50–80%; however, the long-term effects have not been confirmed^{3,17,20}.

The procedure targeting the suprascapular nerve has been reported to reduce pain and improve the ROM in patients with shoulder pain, including those with rotator cuff lesions and frozen shoulder. The suprascapular nerve innervates the supraspinatus and infraspinatus muscles, providing 70% of the sensory signal of the shoulder joint²⁵. Numerous targeted therapeutic procedures focus on the suprascapular nerve. Among these modalities, PRF neuromodulation has been shown to have long-term effects on various pain disorders⁷. PRF neuromodulation for the suprascapular nerve offers pain control without tissue destruction and subsequent sequelae in chronic shoulder pain¹³. Our study investigated the effect of PRF neuromodulation on the suprascapular nerve in patients with PSSP.

One of the crucial mechanisms of PSSP is the central and peripheral sensitization, where the transmission of pain signals in the peripheral and central nervous systems becomes overactive due to persistent shoulder pain²². Peripheral sensitization involves an increased sensitivity to afferent nerve signal⁸. Pain induces the secretion of endogenous substances like serotonin, bradykinin, and potassium ions. These chemical mediators stimulate receptors on nociceptive terminals, affecting the depolarization threshold and modulating the excitability of nociceptor terminals¹⁸. Central sensitization is characterized by the overactivation of neurons in nociceptive pathways. The sustained pain signal eventually induces neuronal plasticity in the central nervous system, resulting in pain even from minimal sensory input¹⁵. PSSP is often considered a peripherally limited pain leading to a lack of response to conservative treatment. PRF stimulation is less effective in patients with central and peripheral sensitization. Efficient patient selection is paramount for successful PRF stimulation in PSSP. As presented in Fig. 1, PRF neuromodulation was performed on patients who tested positive for the suprascapular nerve block in our study. This screening block excludes central and peripheral sensitization from the patient population, thereby maximizing the effects of PRF stimulation.

Several other studies investigating PRF neuromodulation for PSSP, despite having different follow-up periods after the procedure (ranging from 16 weeks to 3 months), have consistently confirmed the sustained effect of PRF neuromodulation during the follow-up period^{3,19,28}. Compared to previous studies, our study is important in that the follow-up time was at least 1 year which confirmed that PRF neuromodulation ef-

fects continued for 1 year.

As mentioned above, the loss of muscle strength contributes to shoulder joint instability, resulting in damage to surrounding connective tissues such as rotator cuff tears, tendinosis, and subluxation⁵). This, in turn, leads to shoulder stiffness, limiting the rehabilitation of the upper extremity. In our study, PRF neuromodulation immediately alleviated pain and improved the limitation in ROM after the procedure. This early relief facilitates prompt rehabilitation, a crucial factor for functional recovery. In our study, 69% of patients with PSSP exhibited a decrease in the mRS score one year after PRF neuromodulation. The mRS score at 1 year after PRF neuromodulation showed a 33% reduction compared to the baseline mRS (mean mRS, 2.31 vs. 1.54 points). In a previous prospective observational cohort study, it was reported that 34% of patients surviving hemorrhagic stroke experienced a 32% decrease in the mRS score between hospital discharge and the follow-up examination after 12 months (mean mRS score, 2 vs. 1.36 points)¹²). Notably, in our study, patients who underwent PRF neuromodulation demonstrated a greater improvement in disability compared to those with hemorrhagic stroke. The enhanced functional impairment through rehabilitation and pain relief appeared to have a significant impact of the QoL⁴). We attribute the favorable outcomes in the mRS in our study to the facilitated rehabilitation after PRF neuromodulation for PSSP.

This study had several limitations. First, it was retrospective and not a randomized controlled study. Second, the sample size was small (n=13). In our center, the neurosurgery department only managed patients with hemorrhage, not infarction. Therefore, only patients with hemorrhage were included in this study. Third, although the improvements in outcomes were maintained for 5 years post-procedure in most patients, statistical analysis on data beyond 1 year was not possible. Despite collecting data on outcome for more than 1 year, the data after 1 year were not consistently obtained. We followed up with patients regularly up to 3, 6, 9, and 12 months after PRF. After the last 12 months of outpatient treatment, the patient was asked to come to the hospital freely. Fourth, inclusion criteria were quite strict. In this study, patients who underwent PRF neuromodulation included a small proportion of patients diagnosed with PSSP. While performing PRF neuromodulation, it is necessary to confirm whether the target nerve has been correctly selected through conversation with the patient.

This maximizes the effect of the procedure and reduces the possibility of damage to the surrounding tissues. Therefore, patients with poor communication capabilities due to old age, aphasia, and deterioration of consciousness were excluded. Randomized controlled studies with a larger sample size and longer follow-up period are required to support the clinical efficacy and long-term effect of PRF neuromodulation for PSSP in patients with hemorrhagic stroke.

CONCLUSION

PSSP is one of the major obstacles to the rehabilitation of patients with a hemorrhagic stroke. PRF neuromodulation targeting the suprascapular nerve not only achieves immediate and persistent pain relief, but with proper patient selection, also facilitates rehabilitation, enhances functional conditions and improves QoL. Moreover, it proves to be more efficient and safer than other treatments. The authors suggest that PRF neuromodulation targeting the suprascapular nerve could serve as an efficient modality for treating PSSP in patients with hemorrhagic stroke.

AUTHORS' DECLARATION

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Informed consent

Informed consent was obtained from all individual participants included in this study.

Author contributions

Conceptualization : HJC, DN; Data curation : JY, DN; Formal analysis : HJC, MSP; Funding acquisition : HJC, JPJ; Methodology : HJC, YJC; Project administration : YJC; Visualization : MSP, JY, JPJ; Writing - original draft : HJC, DN; Writing - review & editing : HJC, MSP

Data sharing

None

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• Supplementary materials

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