Hyperselective Peripheral Neurotomy for Spasticity: A Prospective Observational Study

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Abstract

Objective The aim of the study was to evaluate the effectiveness of hyperselective peripheral neurotomy in reducing spasticity and pain in patients with upper motor neuron disorders unresponsive to pharmacologic and reversible interventions.

Materials and Methods A prospective observational study was conducted at a tertiary care center involving 21 adult patients with spasticity due to conditions such as stroke, traumatic brain injury, or spinal cord injury. Eligible participants had Modified Ashworth Scale (MAS) scores of 3 to 4 and were resistant to medical treatments like baclofen. Hyperselective neurotomy was performed under general anesthesia, targeting specific nerve branches for controlled reduction of muscle spasticity. Primary outcomes included MAS scores for spasticity reduction, motor power via Medical Research Council (MRC) grading, and pain assessment through visual analog scale (VAS) scores. Patients were assessed preoperatively and at 1, 3, and 6 months postsurgery.

Results All patients (100%) experienced a significant reduction in spasticity, with MAS scores reduced to ≤ 2 in all cases and ≤ 1 in 18 patients ($p < 0.001$) at 6 months. Pain relief was achieved in 62% of patients, with a postoperative VAS score of 0, and residual pain scores of 1 to 2 in the remaining patients. Minimal motor power improvement was observed in six patients, while the majority (71%) showed no change in strength. Complications included transient neuropathic pain in 29% of patients and one case of recurrent stroke.

Keywords
- neurotomy
- peripheral nerve surgery
- spasticity
- stroke
- traumatic brain injury
- rehabilitation

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Conclusion Hyperselective peripheral neurotomy proved effective in reducing spasticity and pain for patients with refractory upper motor neuron disorders. With minimal impact on motor function and sustained relief, it presents a promising option for focal spasticity management. Further studies are recommended to confirm long-term benefits and optimize patient selection criteria.

Introduction

Spasticity is a major complication of upper motor neuron disorders, including stroke, traumatic brain injury, spinal cord injury, and cerebral palsy.[1] This condition often causes severe impairments in quality of life, resulting in pain and joint deformities that can become progressively disabling. Initial management of spasticity typically involves medications such as baclofen; however, for cases that are advanced or unresponsive to drugs, various interventional treatments are available.

Interventions for spasticity fall into two main categories: reversible and permanent procedures. Reversible treatments include Botulinum toxin injections and intrathecal baclofen pumps, while permanent options encompass techniques such as hyperselective peripheral neurotomy, selective dorsal root lesioning, dorsal root entry zone lesioning, and C7 neurectomy.[2,3] Hyperselective peripheral neurotomy, a particularly effective intervention, involves carefully severing 60 to 70% of terminal nerve branches to reduce muscle tone imbalance between flexor and extensor muscles. This technique not only alleviates spasticity but also aids in the partial restoration of motor functions. It has demonstrated safety, efficacy, and long-lasting benefits in managing spasticity, significantly enhancing patient mobility and quality of life.[4,5]

This article presents our clinical experience with hyperselective peripheral neurotomy for various indications, demonstrating its applications in both upper and lower limbs.

Methods

This prospective observational study was conducted at a tertiary medical center to evaluate the efficacy of hyperselective peripheral neurotomy in patients with spasticity resulting from upper motor neuron disorders. The study was approved by the institutional ethics committee, and informed consent was obtained from all participants.

Participants and Inclusion Criteria

Eligible participants included patients between the ages of 18 and 80 years with spasticity caused by conditions such as stroke, traumatic brain injury, or spinal cord injury. Participants were included if they had persistent spasticity (grade 3–4 on modified Ashworth scoring) unresponsive to medical treatments (e.g., baclofen). Exclusion criteria included patients with active infections at the intervention site, bleeding disorders, or those who had previously undergone neurotomy in the affected area.

Procedure

Hyperselective peripheral neurotomy was performed under general anesthesia without muscle relaxants. During the procedure, the terminal branches of the nerves responsible for the spastic muscles were identified and carefully traced to their distal-most branches. Approximately 70% of these terminal nerve branches were selectively severed to reduce the overactivity of spastic muscles, thereby balancing flexor and extensor muscle tone.

To reduce spasticity at the elbow, the musculocutaneous nerve was targeted at the midarm. The median nerve was addressed to control pronation in the forearm. For managing spasticity in the hand and fingers, the ulnar nerve was accessed posterior to the olecranon process, where selective fascicle resections were performed to target the affected muscles. In cases of spasticity affecting the foot and toes, the tibial nerve was exposed behind the popliteal fossa. Neuromonitoring was employed throughout to distinguish motor from sensory fascicles, ensuring precise intervention.[6] Additionally, tendon releases were performed in patients with fixed joint contractures to optimize functional outcomes.

Postoperatively, all patients underwent rehabilitation using various muscle-stretching and range-of-movement exercises. Oral baclofen was continued in the same dose or reduced according to the patient's need.

Sample Size

Since the inclusion criteria focused on patients with spasticity resistant to oral baclofen and physiotherapy, further response to these treatments was unlikely. However, assuming an approximate 50% response rate among patients to drug therapy, the required sample size was calculated to be 21 procedures using the Kelsey method.

Data Collection and Outcomes

Patients were assessed preoperatively and postoperatively at 1, 3, and 6 months. The primary outcome was the reduction in spasticity, measured by the Modified Ashworth Scale (MAS). Secondary outcomes included motor scores (measured by the Medical Research Council grading [MRC grades]), and pain scores (measured by a visual analog scale [VAS]). Adverse events, including weakness, infection, nerve damage, and recurrence of spasticity, were also recorded.

Statistical Analysis

Descriptive statistics were used to summarize baseline characteristics and outcomes. Changes in the MAS, pain scores, and motor power scores from baseline to follow-up points were analyzed using paired *t*-tests. Statistical significance was set at $p < 0.05$.

Results

Patient Demographics and Sites of Spasticity

The patient demographics can be seen in ►**Table 1**. A total of 21 patients, comprising 15 males and 6 females, with an age range of 25 to 75 years were included in the study. The most common sites of spasticity were the elbow (9 patients), hand and fingers (7 patients), and foot and toes (5 patients). The results reported were at 6 months of follow-up.

Spasticity Outcomes

Preoperatively, all patients had severe spasticity, with MAS scores ranging from 3 to 4. Postoperatively, all 21 patients (100%) experienced a significant reduction in spasticity, as indicated by the MAS scores decreasing to ≤2. ►**Figs. 1** and **2** show improvement in hand and foot postures, respectively. Specifically, the MAS scores decreased to ≤1 in 18 patients,

Table 1 Patient characteristics

Sl. no.	Age/gender	Diagnosis	Site of surgery for relieving spasticity	Preop spasticity (MAS)	Post-op spasticity (MAS)	Pre-op power (MRC)	Post-op power (MRC)	Pre-op pain (VAS)	Post-op pain (VAS)	Adverse events
1	35/M	Stroke	Elbow	3	1	0	0	3	0	–
2	32/M	Stroke	Hand and fingers	3	2	0	0	2	0	–
3	75/M	Stroke	Hand and fingers	4	0	0	1	2	0	Neuropathic pain for 3 mo
4	63/F	Stroke	Hand and fingers	4	0	0	0	2	0	Had a recurrent stroke 4 d after surgery
5	35/M	Head injury	Foot and toes	4	1	0	0	3	1	–
6	75/M	Stroke	Elbow	4	1	0	0	2	0	–
7	35/M	Head injury	Elbow	3	1	0	0	3	1	–
8	34/M	Stroke	Hand and fingers	3	2	2	2	2	1	Neuropathic pain for 1 mo
9	62/F	Stroke	Elbow	4	1	0	0	3	0	–
10	25/F	Spine injury	Foot and toes	4	1	0	0	8	2	–
11	32/M	Stroke	Foot and toes	4	2	0	0	2	0	–
12	46/M	Head injury	Elbow	4	1	0	1	4	0	–
13	46/M	Stroke	Hand and fingers	4	1	0	1	4	2	Neuropathic pain for 3 mo
14	43/M	Stroke	Elbow	4	1	0	1	3	0	–
15	43/M	Stroke	Hand and fingers	4	0	0	1	2	0	–
16	25/F	Spine injury	Foot and toes	4	1	0	0	8	2	–
17	75/M	Stroke	Elbow	4	0	0	0	2	0	Neuropathic pain for 3 mo
18	35/M	Stroke	Elbow	3	1	0	0	2	0	–
19	34/M	Stroke	Hand	3	1	0	0	2	0	–
20	63/F	Stroke	Elbow	4	1	0	0	2	0	Neuropathic pain for 2 mo
21	25/F	Stroke	Foot and toes	4	0	0	1	5	2	–

Abbreviations: F, female; M, male; MAS, Modified Ashworth Scale; MRC, Medical Research Council; VAS, visual analog scale.

A. B.

Fig. 1 (A) A patient with a severe spastic hand with the thumb and fingers folded inward and the forearm in mid-pronation. He underwent musculocutaneous, median, and ulnar neurotomies. (B) Improvement in the hand.

A. B.

Fig. 2 (A) Preoperative image of a patient with an old D12 spinal fracture with spastic foot deformity. She underwent bilateral tibial neurotomy with Achilles tendon release. (B) Postoperative improvement of the deformity and rehabilitation.

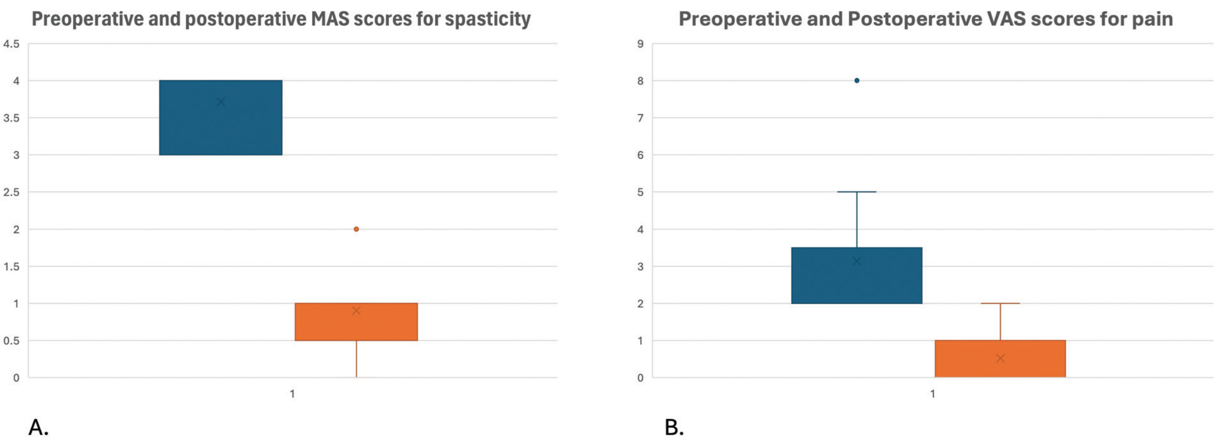

Fig. 3 Box charts for preoperative and postoperative spasticity (MAS scores) and pain (VAS scores). (**A**) Preoperative (*blue rectangle*) and postoperative (*orange rectangle*) MAS scores for spasticity. (**B**) Preoperative (*blue rectangle*) and postoperative (*orange rectangle*) VAS scores for pain. MAS, Modified Ashworth Scale; VAS, visual analog scale.

and reached 2 in the remaining 3 patients. The p-value using the paired t-test came to be less than 0.001. ►**Fig. 3A** shows the box chart for the MAS scores preoperatively and postoperatively.

Motor Power (MRC Score)

Preoperative motor power, as measured by the MRC scale, was uniformly low across all patients. Postoperatively, minimal improvement in power was noted in six patients, with MRC scores increasing to 1 in these individuals. The majority of the patients (71%) showed no change in motor power following the intervention. The p-value was not calculated, as only six patients showed minimal improvement, which was insufficient for meaningful statistical analysis.

Pain (VAS Scores)

Preoperative pain scores, assessed using the VAS, ranged from 2 to 8. Thirteen patients (62%) experienced complete relief from pain with a postoperative VAS score of 0. The remaining 8 patients (38%) experienced a reduction in pain but had residual VAS scores between 1 and 2. The p-value using the paired t-test came to be less than 0.001. ►**Fig. 3B** shows the box chart for the preoperative and postoperative VAS scores.

Additional Procedures

Six patients required eight additional tendon releases. The tendons released were the Achilles tendon ($n=4$), flexor digitorum superficialis ($n=2$), flexor carpi radialis ($n=2$), and flexor carpi ulnaris ($n=2$).

Adverse Events

Adverse events occurred in six patients (29%). The most common complication was transient neuropathic pain, affecting five patients, with symptoms lasting from 1 to 3 months. Additionally, one patient experienced a recurrent middle cerebral artery stroke 4 days postsurgery, which was attributed to a previously undetected carotid plaque.

Discussion

This study demonstrates the effectiveness of hyperselective peripheral neurotomy in reducing spasticity and associated pain in patients with upper motor neuron disorders unresponsive to pharmacologic and reversible interventions. Hyperselective neurotomy successfully reduced spasticity in all patients, as indicated by significant improvements in the MAS scores, and decreased pain in the majority, showcasing the technique's potential for substantial, long-lasting symptom relief. While motor power improvement was modest, the significant gains in spasticity reduction and pain relief highlight neurotomy as a valuable option in comprehensive spasticity management. Neurotomies also have additional applications beyond treating spasticity, including indications such as migraine management.[7,8]

Hyperselective peripheral neurotomy offers several advantages over other interventions, such as intrathecal baclofen pumps, selective dorsal rhizotomy, and dorsal root entry zone (DREZ) lesioning, and C7 neurectomy.[3,9–11] Similar to C7 neurectomy is S1 neurectomy for lower limbs.[3,12] By selectively severing specific nerve fascicles, neurotomy preserves adjacent sensory and motor functions, allowing for targeted reduction of disabling spasticity in a particular muscle or muscle group. This approach enhances functional outcomes and minimizes weakness compared with the broader effects seen in C7 neurectomy, which, while effective and straightforward, reduces spasticity throughout the entire upper limb.

Unlike intrathecal baclofen pumps, hyperselective neurotomy does not involve an implanted device, eliminating device-related risks such as infection, dislodgement, and the need for frequent refills and adjustments. Furthermore, in contrast to selective dorsal rhizotomy and DREZ lesioning, hyperselective neurotomy provides a more localized and less invasive approach. Selective dorsal rhizotomy, typically used for lower limb spasticity in cerebral palsy, lyses sensory nerve roots, carrying risks of permanent sensory deficits and requiring intensive postoperative rehabilitation. DREZ lesioning, often reserved for severe cases, involves ablating

DREZs, posing risks of motor and sensory complications due to its irreversible and extensive nature. Hyperselective neurotomy's precise targeting of specific muscle involvement offers flexibility in treatment planning and a potentially lower complication rate.

However, hyperselective neurotomy has limitations. Its permanent effects mean that there is limited potential for postsurgical adjustment. Furthermore, while the procedure effectively reduces spasticity and pain, it provides limited improvement in motor power, as seen in our study, where only six patients showed minor gains in muscle strength. Additionally, some patients experienced transient neuropathic pain postoperatively—a manageable but noteworthy complication.

The choice between neurotomy, intrathecal baclofen pumps, C7 neurectomy, selective dorsal rhizotomy, and DREZ lesioning should be guided by each patient's specific needs, goals, and risk profile.[10] Hyperselective neurotomy is particularly well suited for patients with localized spasticity that is unresponsive to other treatments, offering a minimally invasive targeted option with proven safety and efficacy. In contrast, for patients with more generalized or fluctuating spasticity, reversible options like intrathecal baclofen pumps may be more appropriate. Extensive surgeries like selective dorsal rhizotomy or DREZ lesioning remain alternatives for those with severe, debilitating spasticity where other treatments have not succeeded, while C7 neurectomy may be considered for broader upper limb spasticity.

Limitations

This study has several limitations. First, the small sample size may limit the generalizability of the findings, and a larger cohort would be needed to confirm these results. Second, the 6-month follow-up period only captures short-term outcomes, leaving questions about the long-term durability of spasticity reduction and pain relief. Third, the lack of a control group, such as patients managed with intrathecal baclofen pumps or selective dorsal rhizotomy, limits our ability to directly compare hyperselective neurotomy with other interventions. Finally, variability in the sites of spasticity treated and the uniformly low preoperative motor function made it challenging to assess site-specific outcomes or improvements in motor power. Longer-term studies with control groups and larger patient samples would help address these limitations.

Conclusion

This study highlights the efficacy of hyperselective peripheral neurotomy in significantly reducing spasticity and pain in patients unresponsive to pharmacologic and reversible treatments. The procedure offers targeted relief with minimal impact on motor function, positioning it as a valuable option for focal spasticity management. While promising, further research with larger patient cohorts and extended follow-up is needed to validate long-term outcomes and compare effectiveness with other spasticity treatments.

Ethical Approval
Institutional review board permission was obtained for this manuscript.

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Conflict of Interest
None declared.

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