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Case Series

Surgery Section

Function-preserving Surgical Management of Benign Peripheral Nerve Sheath Tumours: A Case Series

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ABSTRACT

Peripheral Nerve Sheath Tumours (PNSTs) present a unique surgical challenge, requiring a balance between complete tumour removal and preservation of neurological function. Function-preserving excision techniques offer promising solutions, but their implementation demands careful evaluation and surgical expertise. A case series analysis was conducted on seven patients with PNSTs who underwent function-preserving surgical excision at a tertiary care centre between December 2022 and August 2024. Preoperative diagnostic methods, including high-resolution contrast-enhanced Magnetic Resonance Imaging (MRI) and Fine-Needle Aspiration Cytology (FNAC), were critical for differentiating schwannomas from neurofibromas and guiding surgical planning. Intracapsular enucleation was performed for schwannomas, while interfascicular dissection was used for neurofibromas. Patient demographics, tumour characteristics, surgical approach, and postoperative outcomes were assessed through clinical examination and neurophysiological studies. The series included five schwannomas and two neurofibromas, with a mean tumour size of 2.38 cm (range: 1.5-5.0 cm). Tumours were located in the upper extremity (n=3), the lower extremity (n=2), the neck (n=1), and the spinal region (n=1). Complete tumour resection was achieved in all cases. Transient postoperative deficits resolved within one month, and all patients returned to normal activities with no permanent neurological deficits at the six-month follow-up. Function-preserving surgical techniques demonstrate excellent outcomes in PNST management, achieving tumour control while maintaining neurological function. Careful patient selection, precise surgical technique, and appropriate preoperative planning are crucial for successful outcomes.

Keywords: Biopsy, Fine-needle, Magnetic resonance imaging, Microsurgery, Neurilemmoma, Neurofibroma, Neurosurgical procedures, Treatment outcome

INTRODUCTION

The PNSTs arise from the supporting cells of peripheral nerves and represent 10-12% of all soft-tissue tumours [1]. Categorised into benign variants (e.g., schwannomas and neurofibromas) and Malignant PNST (MPNSTs), these neoplasms significantly impact patients via pain, neurological dysfunction, and potential malignant transformation [2,3].

Traditional management emphasised complete surgical excision, often requiring sacrifice of the affected nerve or its fascicles [4]. Recent advancements in microsurgical techniques, high-resolution imaging, and intraoperative neurophysiological monitoring have transformed the surgical management of these lesions [5,6]. Continuous intraoperative neurophysiological monitoring, including direct nerve stimulation and somatosensory evoked potentials, allows real-time functional assessment during dissection, significantly reducing the risk of iatrogenic nerve injury [7].

Function-preserving surgical techniques- intracapsular enucleation for schwannomas and interfascicular dissection for neurofibromas- have emerged as viable alternatives to conventional nerve-sacrificing resection. These approaches prioritise maximal safe resection while preserving neurological function [8,9].

CASE SERIES

A case series was conducted on patients who underwent function-preserving surgical excision of PNSTs at tertiary care centre from December 2022 to August 2024. Study participants were selected based on the following criteria: age over 18 years, clinically and radiologically confirmed PNSTs, tumours amenable to function-preserving surgical techniques, and a minimum follow-up period of six months. Patients were excluded if they had MPNST, prior surgery at the tumour site, or syndromic conditions predisposing to multiple PNSTs. However, one patient with Neurofibromatosis type 1 (NF1)- presenting with multiple cutaneous neurofibromas and a single symptomatic ulnar nerve schwannoma- was included. Despite her syndromic diagnosis, the schwannoma was managed via interfascicular dissection- a technique comparable to non-syndromic cases- due to its focal nature and debilitating pain. Postoperatively, she achieved complete pain relief without functional deficits, which aligned with the study's goal of preserving neurological function.

All patients underwent comprehensive preoperative evaluation, including detailed neurological examination, high-resolution MRI with contrast, nerve conduction studies, and FNAC. MRI characteristics were analysed to differentiate between schwannomas and neurofibromas and significantly influenced surgical planning decisions, as described by Shirodkar K et al., [10]. Schwannomas typically demonstrate well-circumscribed borders with eccentric location relative to the parent nerve, target sign on T2-weighted imaging, split fat sign, and uniform contrast enhancement [11]. These imaging features guided the decision to proceed with intracapsular enucleation, as the clear plane between the tumour and displaced nerve fascicles was predictive of successful preservation of nerve function. Neurofibromas show central location within the nerve, less defined margins, and variable enhancement patterns [10], prompting the selection of interfascicular dissection techniques. In cases where MRI indicated significant fascicular involvement or tumour extension, we planned for more extensive microsurgical dissection and prepared patients for potential postoperative neurological deficits.

Operations were performed under general or regional anaesthesia using standard surgical techniques. Two distinct surgical approaches were employed based on tumour type. For schwannomas,

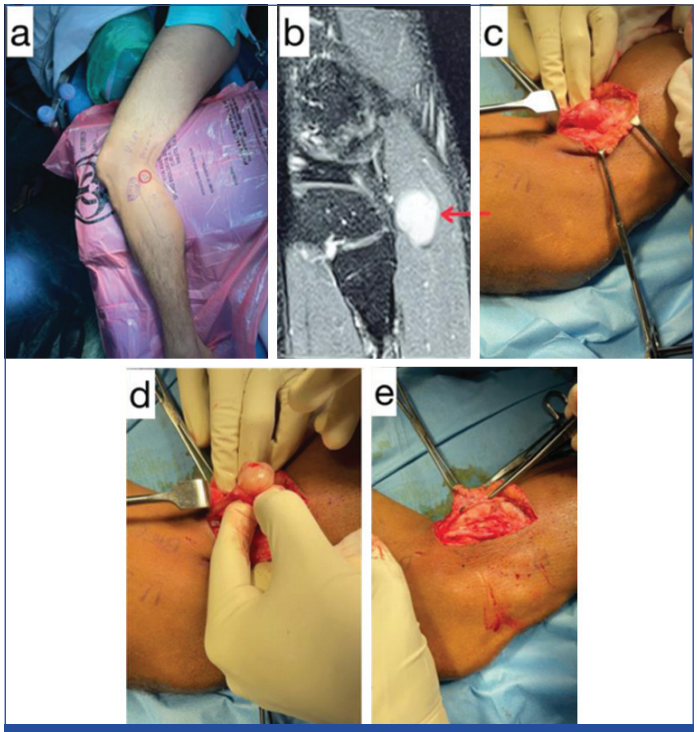
intracapsular enucleation was performed, which involved a longitudinal incision of the tumour capsule, careful separation of the tumour from displaced nerve fascicles, preservation of the capsule containing functional nerve fibres, complete removal of the tumour tissue, and reap proximation of the capsule, as described by Roh JL [12].

In cases of larger PNSTs (>3 cm), we consistently employed standard intracapsular enucleation techniques rather than partial internal decompression approaches. These larger lesions presented unique surgical challenges, including limited surgical exposure, increased vascularity, higher risk of fascicular injury during dissection, and greater tension on the parent nerve during manipulation. To address these challenges, we utilised extended surgical incisions for optimal exposure, performed meticulous haemostasis along with microsurgical dissection, and implemented careful tension-free manipulation techniques. For neurofibromas, an interfascicular dissection approach was utilised, which included meticulous separation of tumour from infiltrated nerve fascicles, preservation of functional fascicles, careful dissection along natural tissue planes, and maximal safe resection while maintaining nerve continuity [9].

Postoperative follow-up was conducted at two weeks, one month, three months, and six months. At each visit, patients underwent detailed neurological examination, assessment of motor strength and sensory function, evaluation of functional recovery, and documentation of any complications. Data collected included patient demographics, tumour characteristics (size, location, type), surgical approach and postoperative outcomes.

Case 1 [Table/Fig-1]

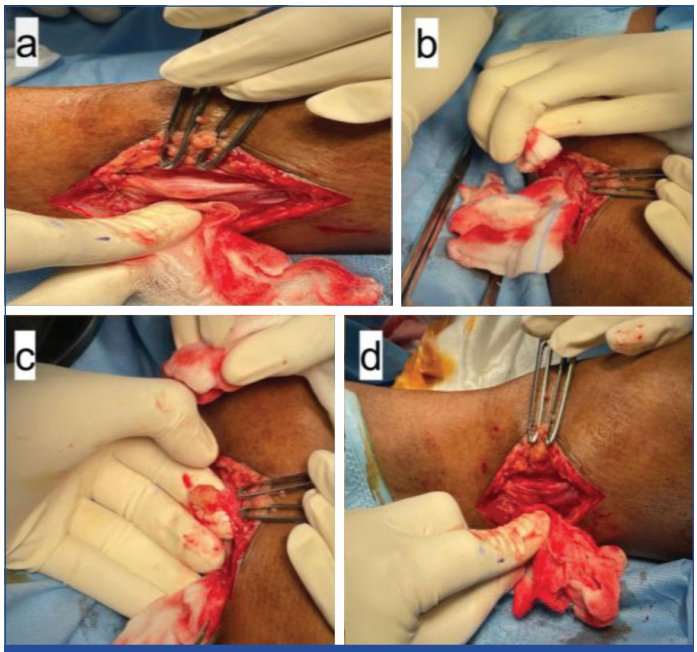
A 41-year-old male with no known comorbidities presented with a 2-month history of an asymptomatic, 2×1 cm fusiform swelling below the left knee joint. The mass was mobile transversely but fixed longitudinally, with a positive Tinel's sign radiating along the common fibular nerve distribution. MRI revealed a well-defined 1.6×1.6×2 cm fusiform lesion displaying T1-hypointense, T2/Proton Density Fat-Saturated (PDFS) hyperintense signals with diffusion restriction and homogeneous enhancement, clearly demonstrating the common fibular nerve entering and exiting the mass, which were features pathognomonic of schwannoma. Preoperative nerve conduction studies were unremarkable. Surgical excision via an S-shaped incision allowed careful microsurgical dissection, achieving complete tumour removal while preserving intact nerve fascicles. Histopathological examination confirmed schwannoma with classic Antoni A and B areas and Verocay bodies. Postoperatively, the patient demonstrated excellent functional outcomes, including preserved motor strength (5/5) in ankle dorsiflexion and eversion, intact sensation over the anterolateral leg and dorsum of the foot, and resolution of Tinel's sign, highlighting the success of balancing complete tumour excision with critical nerve preservation.



[Table/Fig-1]: Clinical and radiological findings in common fibular nerve schwannoma (case 1): a) Preoperative view showing fusiform swelling (red circle) below the left knee joint; b) MRI showing well-defined fusiform lesion (red arrow) of common fibular nerve schwannoma; c) Initial surgical exposure of the well-encapsulated fibular nerve schwannoma; d) Microsurgical dissection preserving nerve fascicles during tumour removal; e) Final stage showing complete tumour excision with preserved nerve integrity.

Case 2 [Table/Fig-2]

A 28-year-old male with no known comorbidities presented with a 2-week history of a 1.5×1 cm swelling in the middle third of the left leg, accompanied by intermittent paraesthesia along the anterolateral aspect of the left lower leg. There was no associated pain or weakness. Clinical examination revealed a firm, rubbery mass with a positive Tinel's sign. Ultrasonography identified a fusiform hypoechoic mass (1.5×0.9 cm) in the subcutaneous plane along the superficial fibular nerve. MRI demonstrated a well-circumscribed lesion in the subcutaneous plane but could not definitively localise the nerve of origin due to its small size and anatomical complexity. Surgical exploration under regional anaesthesia was performed through a vertical incision. Intraoperative findings confirmed the lesion arose from the cutaneous branches of the superficial fibular nerve. Meticulous dissection achieved complete tumour removal while preserving nerve continuity. Histopathology confirmed a schwannoma, revealing a well-encapsulated 1×1×0.6 cm mass with spindle cells, nuclear palisading, and Verocay bodies. Postoperatively, the patient experienced immediate relief from paraesthesia. At the one-week follow-up, the patient demonstrated complete symptom resolution, intact motor and sensory function in the superficial fibular nerve distribution, and a negative Tinel's sign.

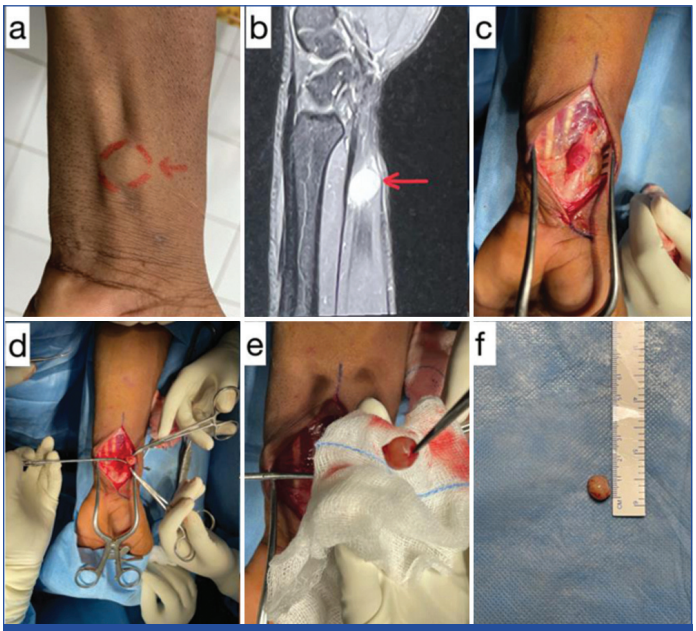


[Table/Fig-2]: Cutaneous superficial fibular nerve schwannoma surgical excision (case 2): a) Intraoperative exposure of nerve tumour; b) Microsurgical dissection of tumour from nerve fascicles; c) Progressive excision preserving nerve integrity; d) Final phase of tumour removal showing preserved nerve structure.

Case 3 [Table/Fig-3]

A 39-year-old male with a 13-year history of smoking and alcohol use (discontinued three years prior) presented with a 6-month history of progressive left wrist swelling (1.5×1.5 cm), causing pain, restricted hand movements, finger paraesthesia, grip weakness, and radiating pain from the shoulder to the fingertips. Examination revealed a firm,

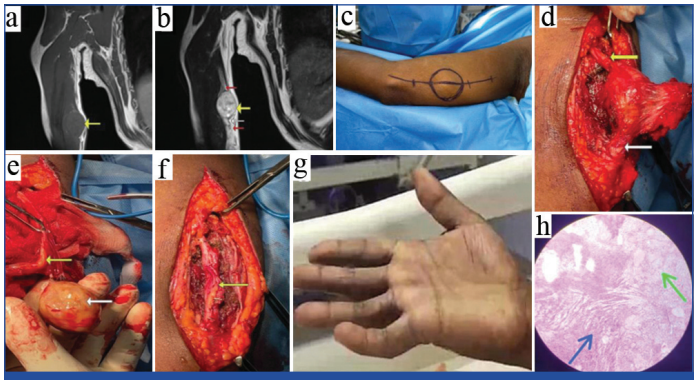
non-pulsatile, mildly tender mass in the flexor compartment between the flexor digitorum superficialis and flexor pollicis longus muscle bellies. Positive Tinel's sign, Phalen's test, a 20-degree reduction in wrist range of motion, and decreased sensation in the median nerve distribution were noted. MRI demonstrated a well-defined, oblong 1.1×1×1.7 cm encapsulated lesion with T1-isointense and T2-hyperintense signals, moderate diffusion restriction, and homogeneous enhancement. FNAC suggested a benign spindle cell lesion of neural origin, despite normal nerve conduction studies. Function-preserving intracapsular excision was performed under regional anaesthesia through a longitudinal incision. Microsurgical dissection achieved complete tumour removal while preserving the median nerve. Histopathology confirmed schwannoma, showing typical Antoni A and B areas with Verocay bodies. Postoperatively, the patient experienced immediate symptomatic improvement with progressive functional recovery. Prophylactic oral anti-inflammatory drugs were administered, and a structured hand physiotherapy program was implemented. The patient demonstrated excellent compliance with the rehabilitation protocol. By four weeks postoperatively, he reported complete resolution of symptoms, restored hand function, normal grip strength, and intact motor and sensory function in the median nerve distribution.



[Table/Fig-3]: Median nerve schwannoma management (case 3): a) Preoperative marking showing swelling location; b) MRI demonstrating the lesion (red arrow) within the subcutaneous plane; c) Initial surgical exposure of the tumour; d) Wider exposure showing intracapsular enucleation of the tumour; e) Tumour enucleation with preservation of nerve fascicles; f) Excised specimen measuring approximately 1 cm.

Case 4 [Table/Fig-4]

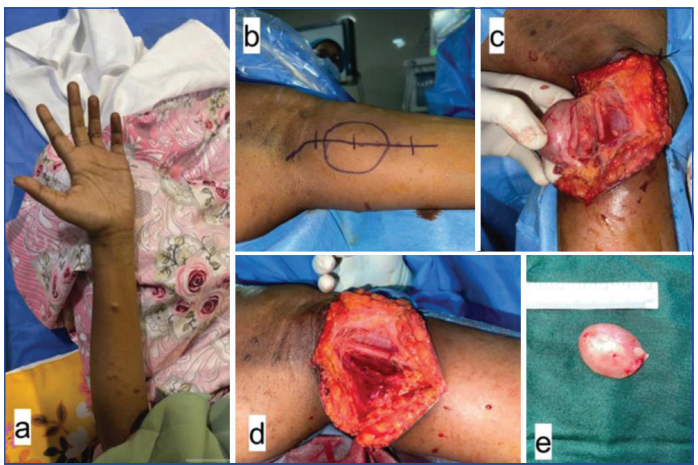
A 52-year-old male heavy-vehicle driver with no comorbidities presented with a 12-year history of a gradually enlarging swelling on the medial aspect of the lower third of his right arm, accompanied by a 3-year history of pain, pressure-induced tingling, and numbness in the little finger and ulnar half of the ring finger. Physical examination revealed a 5×4×3 cm firm, tender, smooth, oval-shaped swelling over the medial aspect of the lower third of the right arm. The lesion was mobile transversely but fixed longitudinally, with a positive Tinel's sign radiating to the ulnar distribution and slight weakness (4/5) in ulnar-innervated intrinsic hand muscles. Ultrasonography showed a fusiform hypoechoic lesion (4.8×2.7×3.5 cm) with cystic areas and marked internal vascularity. MRI demonstrated a well-defined, heterogeneous, enhancing T2-hyperintense lesion (44×34×38 mm) arising from the ulnar nerve without invasion of surrounding structures. FNAC indicated a spindle cell lesion with focal mild nuclear atypia of neural origin. Nerve conduction studies were normal. Following a diagnosis of schwannoma based on clinical, radiological, and cytological evaluation, the patient underwent successful intracapsular enucleation with preservation of ulnar nerve continuity. Postoperatively, he developed a mild ulnar claw deformity, managed with oral Non-steroidal Anti-Inflammatory Drugs (NSAIDs) and a structured rehabilitation protocol involving protected range-of-motion exercises, intrinsic muscle strengthening, and neuromuscular re-education techniques targeting ulnar-innervated hand muscles. The deformity resolved completely by postoperative day 14, attributed to temporary neuropraxia from intraoperative nerve manipulation and postoperative oedema. Histopathological examination confirmed schwannoma with typical Antoni A and B areas and Verocay bodies, without malignant features. By postoperative day 30, the patient demonstrated full recovery of power and function, normal two-point discrimination, and a successful return to work without residual neurological deficits.



[Table/Fig-4]: Ulnar nerve schwannoma (case 4): a-b) MRI showing well-defined nerve tumour (yellow arrows) with nerve continuity (red arrows); c) Preoperative skin marking; d) Intraoperative exposure showing tumour attached to nerve (Note proximal (yellow arrow) and distal (white arrow) nerve continuity within tumour capsule); e) Tumour specimen (white arrow) after microsurgical dissection from parent nerve (yellow arrow); f) Post-dissection view showing preserved nerve integrity; g) Mild ulnar claw deformity on postoperative day 1; h) Histopathological examination (Haematoxylin and Eosin {H&E}, ×100) showing hypercellular Antoni A areas (blue arrow) with Verocay bodies and hypocellular Antoni B areas (green arrow) characteristic of schwannoma.

Case 5 [Table/Fig-5]

A 23-year-old female with known NF1 presented with a 1.5-year history of a 4×4 cm mobile, tender swelling in the left proximal arm, exhibiting restricted longitudinal mobility. The swelling was accompanied by severe pain over the past two weeks, significantly limiting arm function. Neurological examination revealed altered sensation, reduced two-point discrimination, and slight weakness (4/5) in ulnar-innervated muscles, with a positive Tinel's sign. A core-needle biopsy performed two years prior had suggested neurofibroma with degenerative atypia (ancient changes). MRI confirmed a well-defined, T2-hyperintense mass along the ulnar nerve, consistent with neurofibroma. Preoperative nerve conduction

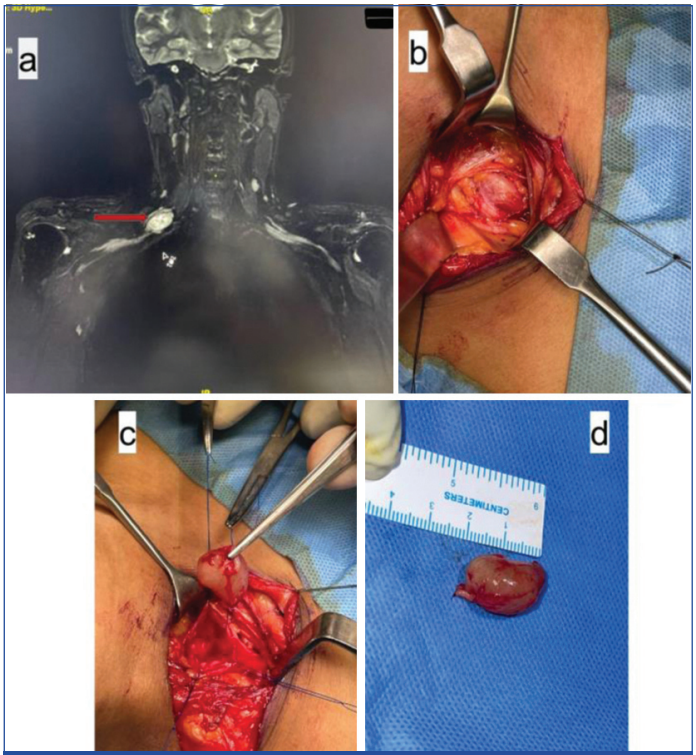


[Table/Fig-5]: Ulnar nerve neurofibroma in NF1 patient (case 5): a) Preoperative appearance showing patient's left arm with mild ulnar claw; b) Surgical site marking with planned incision; c) Intraoperative exposure revealing neurofibroma arising from the ulnar nerve; d) Surgical field after interfascicular dissection showing preserved nerve continuity; e) Excised tumour specimen measuring approximately 4 cm.

studies demonstrated a mild conduction delay in the left ulnar nerve. Due to worsening pain refractory to medications (Ultracet and gabapentin), the patient underwent function-preserving interfascicular dissection. Careful microscopic dissection achieved complete tumour removal while maintaining nerve continuity. Histopathology confirmed neurofibroma with degenerative changes, which explained the recent onset of severe pain and ruled out malignant transformation. Postoperatively, the patient experienced significant pain relief, with intact sensation and normal strength in the ulnar distribution during the one-week follow-up. By one month, she demonstrated complete wound healing, no residual pain or paraesthesia, normal nerve conduction studies, a negative Tinel's sign, full range of motion, and return to normal daily activities.

Case 6 [Table/Fig-6]

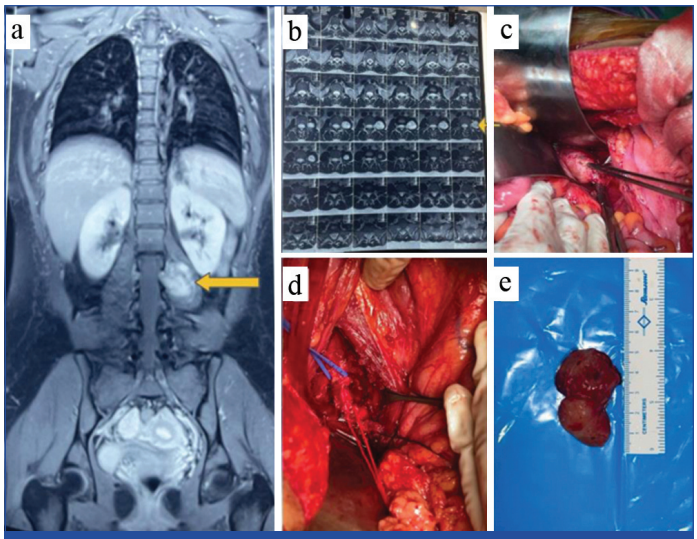
A 58-year-old female with no known comorbidities presented with a one-month history of right neck swelling and pain radiating to the right arm. Examination revealed a 2×1 cm swelling in the right supraclavicular region (level VA). Neurological assessment showed slight weakness (4/5) in C8-innervated muscles, mild hypoesthesia in the C8 dermatome, and a positive Tinel's sign over the swelling. MRI identified a 2.4×1.4×1.4 cm ovoid lesion arising from the right C8 nerve root, suggestive of a schwannoma. Nerve conduction studies indicated bilateral median nerve entrapment at the wrist, with prolonged distal motor latencies and reduced sensory nerve action potentials. Under general anaesthesia, intracapsular excision was performed through a linear skin crease incision. Subplatysmal flap elevation and careful microsurgical dissection allowed tumour removal while preserving nerve function. Histopathology confirmed plexiform schwannoma, demonstrating spindled cells arranged in classic Antoni A and B patterns. Postoperatively, immediate neurological examination showed preserved motor and sensory function. By the second week, hand strength improved slightly (4+/5), and paraesthesia diminished. At one month, the patient reported complete symptom resolution, with normal motor strength (5/5) in all C8-innervated muscles, intact sensation in the C8 dermatome, symmetrical reflexes, full pain-free range of motion, a negative Tinel's sign, and normal follow-up nerve conduction studies.



[Table/Fig-6]: Cervical nerve root schwannoma (case 6): a) MRI showing well-defined ovoid lesion arising from right C8 nerve root (red arrow); b) Intraoperative exposure revealing schwannoma at the cervical nerve root; c) Microsurgical dissection preserving nerve fibres during tumour excision; d) Excised tumour specimen measuring approximately 2 cm.

Case 7 [Table/Fig-7]

A 23-year-old female with known hypothyroidism (on medication) was referred for evaluation of a paravertebral mass incidentally detected during a CT chest scan performed for respiratory symptoms, later confirmed as neurofibroma. The patient reported radiating back pain extending to her lower extremities. Neurological examination revealed mild weakness (4/5) in the L2-L3 myotomes, slight hypoesthesia in the corresponding dermatomes, and preserved deep tendon reflexes. CT thorax demonstrated a hypodense left paravertebral lesion in the upper abdomen extending to the spinal canal. Subsequent whole-spine MRI confirmed a well-defined, lobulated mass (5×3.5×2 cm) in the left paravertebral region at the L2-L3 levels, extending from the neural foramen and consistent with a spinal nerve sheath tumour. Preoperative electromyography and nerve conduction studies revealed mild denervation changes in L2-L3 innervated muscles and slightly reduced compound muscle action potentials. The patient underwent midline laparotomy with medial visceral rotation to access the tumour, followed by successful interfascicular dissection with nerve preservation. Histopathology confirmed neurofibroma. Postoperatively, the patient demonstrated intact motor and sensory function with significant pain reduction. At the second-week follow-up, improved strength (4+/5) in the affected myotomes and diminished paraesthesia were noted. The one-month evaluation revealed complete symptom resolution, with restored normal strength (5/5) in all lower extremity muscle groups, intact sensation in all lumbosacral dermatomes, symmetrical deep tendon reflexes, and return to unrestricted normal activities.



[Table/Fig-7]: Retroperitoneal neurofibroma (case 7): a) Coronal MRI showing well-defined paravertebral mass at L2-L3 level extending through left neural foramen (yellow arrow); b) Axial CT scan series demonstrating the spinal canal extension of the neurofibroma (at L3 level -yellow arrow); c) Intraoperative exposure of the tumour via laparotomy with medial visceral rotation approach; d) Surgical field during interfascicular dissection preserving neural elements; e) Excised neurofibroma specimen measuring approximately 5 cm.

The case series comprised five patients with schwannomas and two with neurofibromas, exhibiting a mean tumour size of 2.38 cm (range: 0.9-5.0 cm). Surgical intervention achieved complete tumour resection in all cases, with intracapsular enucleation employed for schwannomas (n=5) and interfascicular dissection for neurofibromas (n=2) [Table/Fig-8-10].

DISCUSSION

This case series demonstrates the efficacy of function-preserving surgical techniques in managing PNSTs while maintaining neurological function. Three key findings emerge from our experience: 1) the importance of selecting proper surgical technique; 2) the role of preserving the tumour capsule in functional outcomes; and 3) the pattern of early neurological recovery.

Our results support the differentiated approach to surgical management based on tumour type. For schwannomas, intracapsular enucleation

Case no.	Age/sex	Presenting features[1]	Location	Tumour type (FNAC[2]/biopsy)	Size (cm)	Preoperative NCS[2]
1	41/M	Swelling (2 m), No deficit	Left popliteal fossa	Schwannoma	1.6×1.6×2.0	Normal NCS
2	28/M	Swelling (2 w), paraesthesia	Middle 1/3rd of left leg (lateral)	Schwannoma	1.5×1.2×0.9	Normal NCS
3	39/M	Pain, swelling and progressive weakness (6 m)	Left wrist	Schwannoma	1.1×1×1.7	Normal NCS
4	52/M	Gradual swelling (12 y)	Right arm	Schwannoma	4.4×3.4×3.8	Normal NCS
5	23/F	Pain, weakness (1.5 y)	Left proximal arm	Neurofibroma	4×4×2	Normal NCS
6	58/F	Neck swelling (1 m)	Right supraclavicular region	Plexiform schwannoma	2.4×1.4×1.4	Bilateral median nerve entrapment at wrists
7	23/F	Incidental on CT, back pain	Left paravertebral region at L2-L3 level	Neurofibroma	5×3.5×2	EMG/NCS-mild denervation changes in L2-L3 muscles

[Table/Fig-8]: Patient demographics and clinical profile of Peripheral Nerve Sheath Tumours (PNST) (n=7).
[1]Duration in parentheses: m=months, w=weeks, y=years
[2]NCS: Nerve conduction study; FNAC: Fine needle aspiration cytology; EMG: Electromyography

Case no.	Surgical technique	Immediate post-op[3]	Two-week follow-up	One-month follow-up	Three-month follow-up	Six-month status
1	Intracapsular excision	No deficit	Full MS	Complete recovery	Sustained recovery	Full function, No deficits
2	Intracapsular excision	No deficit	Full MS[4] Complete symptom resolution	Complete recovery	Sustained recovery	Full function, No deficits
3	Intracapsular excision	No deficit	Full MS[4] Complete symptom resolution	Complete recovery	Sustained recovery	Full function, No deficits
4	Intracapsular excision	Mild claw	No claw	Complete recovery	Sustained recovery	Full function, No deficits
5	Interfascicular dissection	No deficit	Full MS[4] Complete symptom resolution	Complete recovery	Sustained recovery	Full function, No deficits
6	Intracapsular excision	No deficit	Full MS[4]	Complete recovery	Sustained recovery	Full function, No deficits
7	Interfascicular dissection	No deficit	Full MS[4] Complete symptom resolution	Complete recovery	Sustained recovery	Full function, No deficits

[Table/Fig-9]: Surgical approach and outcomes of Peripheral Nerve Sheath Tumours (PNST).
[3]Postoperative neurological deficits (postoperative day 1); [4]MS: Motor strength; ROM: Range of motion; Follow-up outcomes based on clinical examination and patient reported outcomes; Tumour Characteristics and Histopathology

Characteristic	Schwannoma	Neurofibroma
Mean size (cm)	1.97	3.42
Location		
- Upper limb	2	1
- Lower limb	2	0
- Neck	1	0
- Spinal	0	1
Complete resection	5/5	2/2
Transient postoperative deficit	1/5 (Motor deficit)	0/2

[Table/Fig-10]: Summary of clinical and pathological findings.

proved highly effective, allowing complete tumour removal while preserving nerve function. This aligns with the excellent functional outcomes reported by Guha D et al., in a 2018 series of 201 tumours treated over 17 years (complete enucleation in 133 schwannomas with low permanent deficit rates) [13]. In neurofibroma cases, careful interfascicular dissection- preserving uninvolved fascicles- yielded similarly favourable results, consistent with the 2019 report by Stone JJ et al., which described over 90% preservation of neurological function using this technique [9]. The success of these methods contrasts with historical en bloc resections, which caused permanent deficits in 100% of cases in a 2023 head/neck PNST cohort [14].

A critical finding was the importance of preserving the tumour capsule, which houses crucial functional nerve fibres. This observation extends recent work by Akazawa T et al., who demonstrated that microsurgical intercapsular resection using two Freer dissectors significantly reduces postoperative deficits and recurrence rates in schwannoma surgeries [15]. Their study of 20 cases achieved 100% tumour removal without severing nerve fibres by incising the epineurium at funiculus-free sites. The technique leverages the tumour's encapsulated nature for 'onion-peeling' dissection to preserve functional fascicles, resulting in no permanent deficits and rapid symptom resolution within 2-4 weeks. Our experience suggests that careful capsule handling benefits both schwannoma and neurofibroma cases, providing a natural barrier against complications and supporting nerve regeneration, even in neurofibromas where fascicular infiltration traditionally complicates preservation. Recent guidelines from the European Network for Rare Cancers (EURACAN) reinforce this approach, advocating for nerve-sparing techniques to reduce recurrence and support regeneration [16].

Our cohort demonstrated early neurological improvement, with most patients regaining baseline strength and sensation within 2-4 weeks, as exemplified by the rapid functional recovery observed in the ulnar nerve schwannoma case. This aligns with the findings of Kampel L et al., who reported superior functional outcomes and faster recovery times following intracapsular resection of head and neck PNSTs compared to traditional en bloc resection [14].

Traditional surgical approaches for PNSTs have often prioritised complete tumour excision at the expense of functional preservation, frequently resulting in permanent neurological deficits. Kim DH et al., 30-year series of 397 tumours showed postoperative motor or sensory deficits in over one-third of cases following traditional resections [17]. Our function-preserving approach addresses these limitations by maintaining the structural integrity of uninvolved fascicles and minimising manipulation of functional nerve components, resulting in no permanent deficits in our cohort. Furthermore, Montano N et al., reported that conventional techniques often necessitate nerve grafting due to segmental nerve

resection, a complication completely avoided in our series through meticulous dissection and preservation of neural elements [18].

Our successful management of tumours larger than 3 cm, particularly the 4.4 cm ulnar nerve schwannoma, challenges traditional size-based surgical limitations. Similarly, Date R et al., demonstrated that tumour size alone should not be considered a contraindication to intracapsular enucleation, as favourable neurological outcomes were achieved even in schwannomas exceeding 3 cm in diameter [19]. Similarly, Akazawa T et al., achieved similar results in their series with tumours ≥3 cm using precise microsurgical techniques [15]. Shirodkar K et al., emphasised the importance of thorough preoperative planning with advanced imaging for larger tumours, which we incorporated into our protocol [10]. We also followed principles outlined by Stone JJ et al., who recommended extended exposure and meticulous haemostasis to facilitate safe enucleation of larger lesions [9].

The diverse anatomical distribution in our series, from extremities to spinal regions, demonstrates the versatility of function-preserving techniques. The successful management of the spinal region neurofibroma (case 7) particularly highlights the adaptability of these techniques to anatomically challenging locations, supporting findings by Hajiabadi MM et al., and more recent work by Bachkira E et al., regarding the feasibility of preservation techniques in complex anatomical regions [20,21].

Ijichi K et al., advocated for routine use of intraoperative neurophysiological monitoring for optimal functional outcomes [22]. Our series demonstrates that meticulous surgical technique and thorough anatomical knowledge can yield excellent results even without such technological adjuncts, potentially broadening the applicability of function-preserving approaches to resource-limited settings.

When comparing our outcomes with larger, multicentre studies, our results appear encouraging but warrant cautious interpretation. Guha D et al., analysed 201 PNSTs over 17 years and reported that 14% of patients without preoperative motor deficits experienced postoperative motor worsening [13]. Their cohort included patients with NF and anatomically complex tumours, likely contributing to increased surgical difficulty and higher complication rates. Additionally, their extended follow-up underscores the importance of long-term monitoring for delayed neurological decline or recurrence. Similarly, Uerschels et al., emphasised that Gross-Total Resection (GTR), when feasible, significantly reduces the risk of recurrence and postoperative deficits, particularly in schwannomas as compared to neurofibromas [2]. This is attributed to the more discrete encapsulation of schwannomas, which facilitates safer dissection.

This study has several important limitations that must be acknowledged. Our small sample size (n=7) significantly limits statistical power and generalisability of findings. Selection bias may have influenced outcomes, as cases deemed technically amenable to function-preserving approaches were preferentially included. The relatively short follow-up period (six months) precludes assessment of long-term outcomes and potential late recurrences. Additionally, our subjective assessment of neurological recovery lacked standardised, validated outcome measures for comprehensive functional evaluation. The single-centre nature of our series and absence of a control group further limit comparative efficacy analysis. These methodological constraints necessitate cautious interpretation of our results.

Future research directions should include larger multicentre trials with extended follow-up periods, standardised outcome measures including validated quality-of-life instruments, and comprehensive comparative analyses against conventional surgical techniques. Prospective studies incorporating intraoperative neurophysiological monitoring could help delineate which subgroups of patients might specifically benefit from this adjunctive technology. Additionally, investigation into molecular and genetic factors influencing tumour behavior and response to surgical intervention could further refine patient selection criteria for function-preserving approaches.

CONCLUSION(S)

Function-preserving surgical techniques demonstrate excellent outcomes in PNST management when proper patient selection and surgical principles are followed. Our experience highlights three key factors for success: careful preoperative planning with high-quality imaging, meticulous microsurgical technique with preservation of the tumour capsule, and appropriate patient selection. The consistent achievement of complete tumour resection while maintaining neurological function supports the adoption of these function preserving excision techniques as a standard approach for benign PNSTs.

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