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# Microsurgical encapsulated resection of brachial plexus schwannoma with intraoperative neuromonitoring to preserve neurological function: 36 cases report and literature review

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## Abstract

**Objective** To investigate the effect of protecting neural function of microsurgical encapsulated resection of brachial plexus schwannoma with intraoperative neuromonitoring.

**Methods** 36 patients with 36 brachial plexus schwannoma were retrospectively analyzed, who underwent surgical treatment in our department from June 2016 to December 2023. The age, gender, tumor size and location, preoperative symptoms, ultrasound and magnetic resonance imaging(MRI) findings, and postoperative functions of the patients were analyzed.

**Results** The common symptoms of brachial plexus schwannoma were palpable masses(36/36), local tenderness(30/36), sensory changes(10/36), and positive Tinel's sign(30/36). 11 tumors were located in the nerve roots, 10 in the trunks, 10 in the divisions and cords, and 4 in the branches, 1 intraspinal and extraspinal invasion extending from c5-c6 intervertebral foramen. Complete microsurgical encapsulated resection with intraoperative neuromonitoring was performed in all 36 patients. 6 patients developed neurogenic pain in the early postoperative period. 3 patients experienced transient postoperative motor dysfunction, which were alleviated after 6 months. According to an follow-up for at least 3 months, there were no recurrence happened in this study.

**Conclusions** The surgical technique of microsurgical encapsulated resection of brachial plexus schwannoma with intraoperative neuromonitoring is safe and may preserve neurological function.

**Keywords** Brachial plexus schwannoma, Intraoperative neuromonitoring, Encapsulated resection

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## Introduction

The anatomical structure of brachial plexus(BP) is complex, and it is a challenge for neurosurgeons to deal with BP tumors for a lack of surgical experiences. Previous reports showed that the incidence of postoperative functional impairment might reach up to 50% [1]. Intraoperative neuromonitoring could help to reduce injury to normal nerve fibers. Through the technique of microsurgical encapsulated resection, tumor can be removed while causing minimal damage to adjacent structures and preserving BP nerve function [2]. In this study, the clinical data of patients with BP schwannoma were analyzed and the preservation of neurological function following brachial plexus schwannoma microsurgical encapsulated resection was assessed.

## Materials and methods

From June 2016 to December 2023, there were 53 patients with BP tumors admitted to our department, including 36 schwannoma, 12 neurofibroma, 3 hemangioma, 1 hamartoma, and 1 metastatic tumor. The 36 patients with pathologically confirmed schwannoma were retrospectively analyzed. The data were collected, including age, gender, clinical manifestations, the nerve which the tumor originated from, tumor characteristics, surgical method and complications. Every patient had an MRI and high resolution B-ultrasound to evaluate the location, size, and other characteristics of the tumor. All patients were followed-up in outpatient department for more than 3 months (average 3.5 years, 3 months to 6.5 years).

## Surgical procedure and intraoperative neuromonitoring

The patient was positioned in a supine position with a roll beneath the ipsilateral shoulder and the head turned 30 degrees toward the opposite side. Under general anesthesia, the skin incision parallel to the clavicle along the transverse line of the neck was made according to the location of the tumor (Fig. 1A). The incision was lifted along the subplatysmal layer and dissected along the low posterior line of the sternocleidomastoid muscle. After the omohyoid muscle was stretched, the phrenic nerve could be exposed in front of the anterior scalene muscle, and the BP and the tumor were further exposed. It was not necessary to expose the tumor completely, usually only a portion of the tumor needed to be exposed, with a 2–3 cm width of operating space. The capsule of tumor was incised 1–2 cm longitudinally at the place with thinnest and least nerve fiber bundle under the microscope (Fig. 1C), after confirmed by intraoperative neuromonitoring. Subsequent procedure was carried out in this space. The capsule was sharply dissected along with directions of the affected nerve and retracted with sutures (Fig. 1D). The tumor was removed by sharply resecting from the capsule on either side of the neural bundle (Fig. 1E). To avoid damaging the nearby fascicles, coagulation of the surrounding nerve capsule was avoided during tumor resection, and the minor bleeding would stop spontaneously. The bleeding vessels in the capsule after tumor resection should be coagulated with low-power bipolar under the higher magnification to avoid nerve damage (Fig. 1F). After tumor resection, the operating region was rinsed with saline solution. The patient was discharged the next day.( BP schwannoma operation process.mp4).

Neuromonitoring was performed with a four-channel nerve integrity monitor (NIM-3, Medtronic, USA) in all of these patients. The electrodes were placed in the muscles of forearm, upper arm and hand, including deltoid, brachioradialis, biceps brachii, triceps brachii or thenar (Fig. 1B). In general anesthesia, short-acting muscle relaxants were used only once for intubation. During the operation, a unipolar stimulating probe was used to stimulate the tumor or the nerves before removing the tumor, and enucleation was started only after the monitored muscles showed no response to stimulation up to a level of 1.0 mA. If there are nerve bundles covering the tumor, the nerve bundles should be separated or the tumor be turned over.

One of these patients suffered a tumor with intraspinal and extraspinal invasion, extending from c5-c6 intervertebral foramen (Fig. 2). This patient received an operation on the spinal canal tumor at first for preserve the spinal cord, then the rest BP tumor resection was done one month later. All of the rest 35 patients only received BP tumors resection as described above.

## Results

36 patients with BP schwannoma were included in this study, including 14 males and 22 females, aged from 26 to 70 years (49.8 ± 12.5 years). The symptom period before diagnosis lasted for 1 week to 3 years (8.4 ± 8.9 months). 10 patients underwent preoperative percutaneous biopsy or open biopsy before visiting neurosurgery, 5 of them suffered neurogenic pain after biopsy. 19 tumors were on the right side and 17 on the left (Table 1). The main complaints were palpable masses ($n = 34$), local pain ($n = 32$), and sensory abnormalities ($n = 10$). 6 patients had typically mild neurological deficits (motor: 2, sensory: 4). 30 patients had positive Tinel's sign(Table 2).

B-ultrasound examination was performed in all patients, which showed an oval hypoechoic mass with an echogenic ring around the tumor, that could be distinguished from normal lymph nodes with central portal blood flow. The mouse tail sign of a schwannoma could be seen at the junction of one or both ends of the tumor's long axis with the nerve (Fig. 3A).

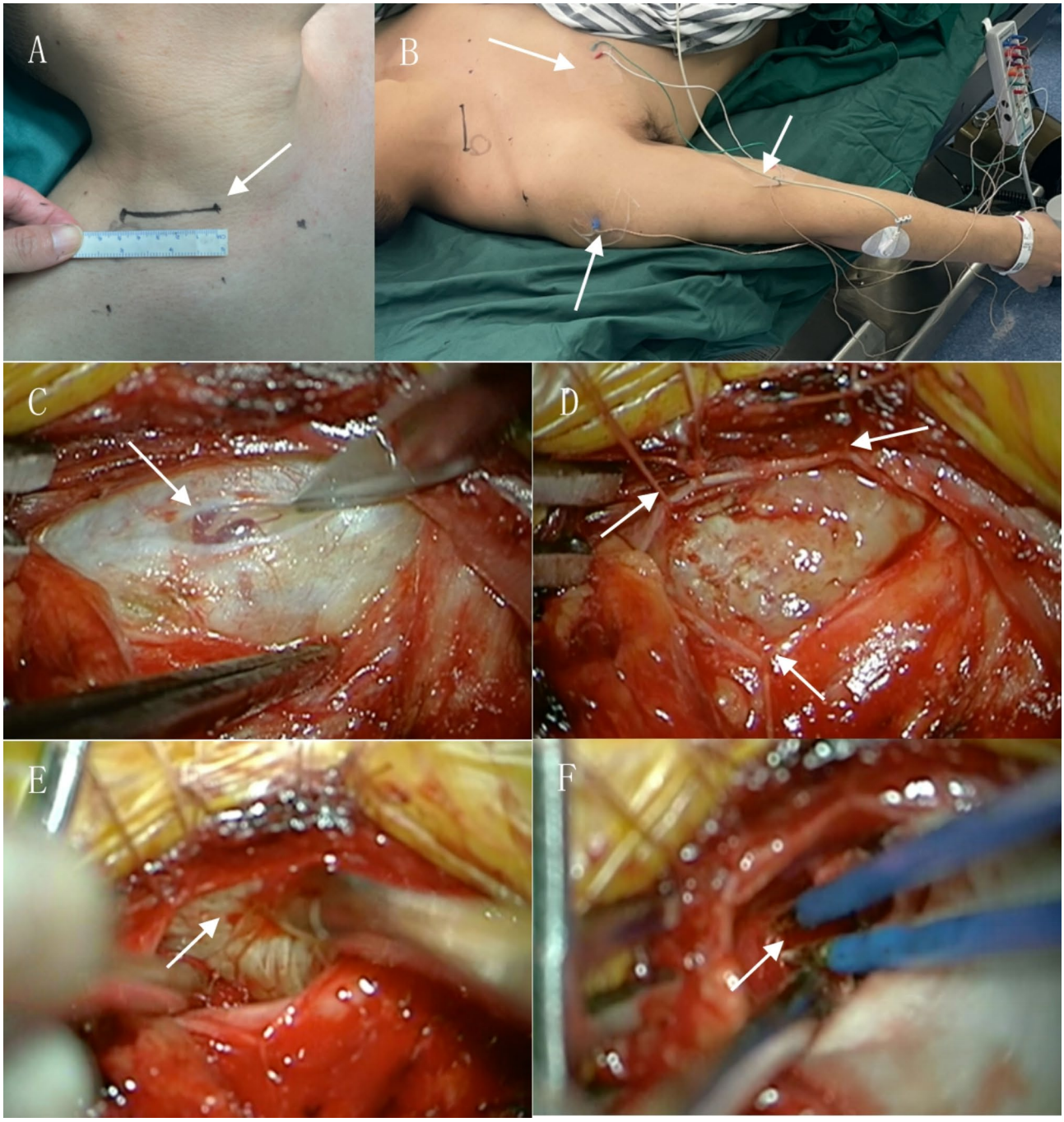


**Fig. 1** **A**: Skin incision. **B**: The electrodes. **C**: The capsule of tumor incised 1–2 cm longitudinally. **D**: The capsule was retracted with sutures. **E**: The tumor was encapsulated resected. **F**: The bleeding vessels in the capsule was coagulated with bipolar

All patients underwent enhanced MRI examination to evaluate the size, morphology, and location of the BP tumor. The tumor had sharp edges, with a generally consistent long axis with the nerve, and deviated from the nerve (eccentricity), and the entering and exiting nerves were involved by the tumor (Fig. 3B). The longest size ranged from 17 mm to 60 mm (27.2 ± 9.5 mm). The patient with intraspinal and extraspinal tumors, extending from c5-c6 intervertebral foramen (Fig. 2A), had an extraspinal tumor reaching 60 mm*30 mm in size (Fig. 2B). 11 tumors were located in the nerve roots, 10 in the trunks, 10 in the divisions and cords, and 4 in the branches (Table 3). 8 tumors were less than 20 mm in size, 16 tumors were 20–30 mm, 12 tumors were more than 30 mm(Table 4 ).

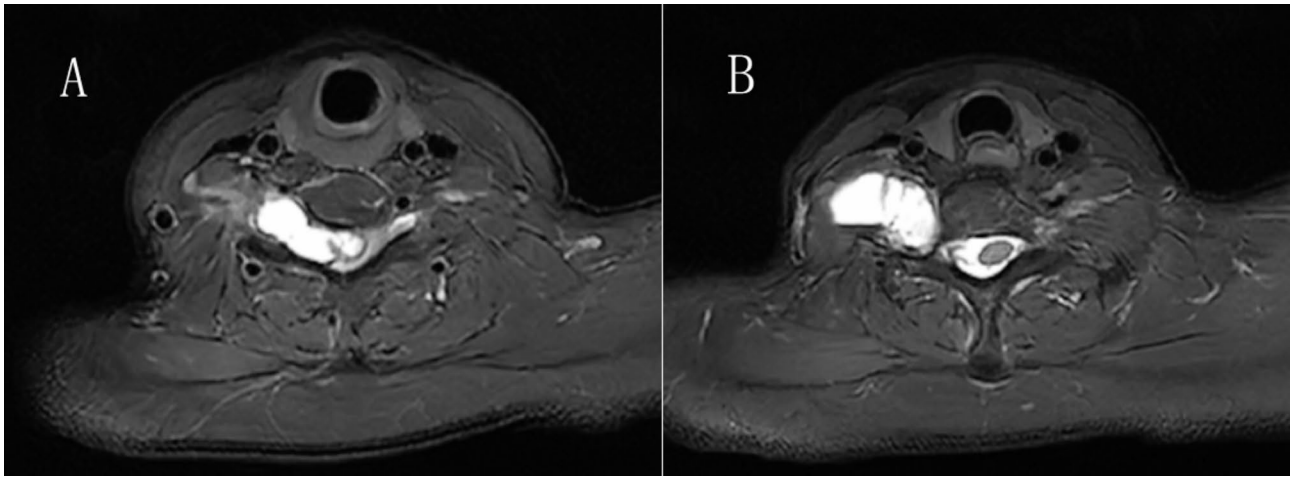


**Fig. 2** **A**: Intraspinal and extraspinal invasion, extending from c5-c6 intervertebral foramen. **B**: Extraspinal tumor: 60 mm*30 mm

**Table 1** Patient characteristics

| Characteristics | Value |
|---|---|
| Age | 26–70 (49.8 ± 12.5)y |
| Male | 14 |
| Female | 22 |
| Right | 19 |
| Left | 17 |
| Biopsy | 10 |
| Course of tumor | 1w-3y (8.4 ± 8.9)months |
| Tumor size | 17–60 mm (27.2 ± 9.5)mm |

**Table 2** Clinical symptom and complication

| Clinical symptom | Cases | Percentage (100%) |
|---|---|---|
| Palpable mass | 34 | 94.4 |
| numbness | 32 | 88.9 |
| tenderness | 10 | 27.8 |
| Motor deficit | 2 | 5.5 |
| Sensitive deficit | 4 | 11.1 |
| No symptom | 2 | 5.5 |
| Tinel's sign | 30 | 83.3 |
| Post operation | | |
| neurogenic pain | 6 | 16.7 |
| transient motor dysfunction | 3 | 8.3 |

Complete encapsulated resection was performed in all 36 patients. 6 patients developed neurogenic pain in the early postoperative period, sometimes severe but relieved within a few weeks. Among the 6 patents, 3 tumors were located in the roots, 3 in the divisions and cords. And 5 of them, the tumor was more than 30 mm in size, only 1 tumor was less than 20 mm. 3 patients experienced transient postoperative motor dysfunction, which were alleviated after 6 months. In all of these 3 patients, the tumors were more than 30 mm in size, and located in the roots or intraspinal and extraspinal (Tables 3 and 4). According to a follow-up for at least 3 months, no recurrence happened in this study. There were no infection, hematoma, lymphatic leakage or subclavian artery injury happened in this series of cases.

## Discussion

The most common type of the BP tumor is benign schwannoma, then neurofibroma and malignant tumor [3]. Jia [4] reported 143 BP tumors including 83% tumors of schwannomas and 8% tumors of neurofibromas. Ramin [5] summarized and analyzed 687 patients with primary BP tumors (693 cases), and found that 421 tumors of schwannoma, 126 tumors of neurofibroma. In our study, schwannomas(36/53) was also the most common type. Most of reports on BP tumors were small series [6]. There were only 3 reports involved more than 100 patients in the available literature: Das [1] reported 144 patients, Desai [7] reported 115 patients, and Jia [4] reported 143 patients.

Most patients with BP tumors experienced painless mass, sensory changes, pains, motor dysfunctions [3]. Our results indicated three common symptoms: palpable masses(34/36), local tenderness(30/36), and sensory changes(10/36). Ramin [5] analyzed 687 patients (693 tumors) with BP tumors, which were characterized by swelling (447), pain (320), sensory disorders (327), and motor disorders (129). Tinel's sign is a distinguishable characteristic from other cervical masses. In this study, 30 patients showed positive Tinel's sign. Desai [7] and Jia [4] also provided description on similar symptoms of BP tumors.

It is necessary to fully evaluate the spatial location of the BP tumor before surgery. Ultrasound can clearly display the morphology of the BP and the specific location of tumor [8]. For patients with malignant tumors complicated by BP damage, ultrasound could be the first choice for diagnosis [9]. MRI can clearly display the location, shape, size, and adjacent relationship with surrounding tissues of the tumor, and can restructure the BP by

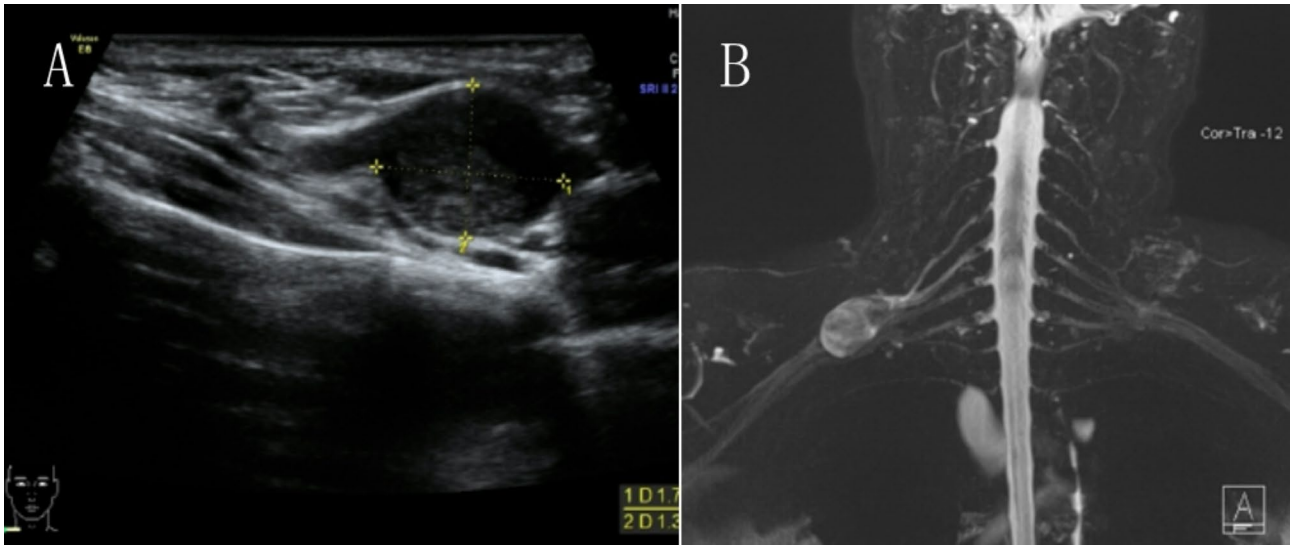


**Fig. 3** **A**: ultrasonic imaging: elliptical hypoechoic lesion with clear boundaries and a capsule. The mouse tail sign at the junction the tumor's long axis with the nerve. **B**: MRI(3D-STIR-SPACE): The tumor and BP nerves clearly visualized

**Table 3** Tumor location on MRI and post operation complication

| Tumor origin | cases | Post operation pain | transient motor dysfunction |
|---|---|---|---|
| Roots | 11 | 3 | 2 |
| Trunks | 10 | 0 | 0 |
| Cords or Divisions | 10 | 3 | 0 |
| Branches | 4 | 0 | 0 |
| Intra-and Extraspinal | 1 | 0 | 1 |

**Table 4** Tumor size and post operation complication

| Tumor size | cases | Post operation pain | transient motor dysfunction |
|---|---|---|---|
| < 2 cm | 8 | 1 | 0 |
| 2–3 cm | 16 | 0 | 0 |
| > 3 cm | 12 | 5 | 3 |

multi-plane and multi-angle observation [10]. Filler [11] considered that Magnetic Resonance Neurography would be the first choice for peripheral neuropathy. Contrast-enhanced 3D-STIR-SPACE sequence is an advanced fat-suppressed T2WI imaging with high resolution and strong background signal suppression, which makes the low-protein liquid in the nerve fasciculus show high signal, so that the nerve structure could be clearly displayed (Figs. 2 and 3B). The accurate and clear display of nerve tissue could better reflect the source of tumor and its relationship with surrounding tissues [12]. In our study, Contrast-enhanced 3D-STIR-SPACE sequence was performed in all patients, which provided distinct visualization and accurate assessment of anatomy.

Preoperative puncture biopsy of BP schwannoma was still controversial [15]. It was possible to damage the nerves and surrounding tissues, leading to bleeding, thus further causing pressure on the nerves, and resulting in neurologic deficits [14, 17]. Preoperative imaging examinations such as ultrasound and MRI can clearly display the morphology, location, size, and adjacent relationship with surrounding tissues of the tumor, and can distinguish other malignant tumors [8, 10]. The bleeding and adhesion of the surrounding tissues will also affect the surgical approach [17]. In our study, 10 cases underwent puncture biopsies under ultrasound guidance or open biopsies before neurosurgical consultation, but 5 of them suffered neurogenic pain after biopsy.

Schwannoma grew slowly as an eccentric mass [17]. Daniel [19] analyzed 227 peripheral nerve tumors and found that BP tumors were often more inert. Schwannoma could often be wrapped and separated from adjacent nerves [21]. During the operation, it was necessary to cut the tumor capsule longitudinally at the place with the least and thinnest nerve fiber bundles under the microscope, and remove the tumor inside the capsule, which can reduce the damage of nerve. Low-dose electrical stimulation should be given to the tissue with unidentified function, and the Compound muscle action potential (CAMP) and motor Nerve conduction velocity (MNCV) of the corresponding muscles could be measured to determine whether it was a functional nerve or not [13, 18]. The blood vessels around the tumor should be coagulated by low-power bipolar to avoid nerve damages. Intracapsular tumor resection was a more conservative and safe technique for nerve-preserving, and was effective in the treatment of BP schwannoma [2].

Serious postoperative neurological deficits of BP tumor was reported in previous literature [5, 16, 17]. With the improvements of surgical techniques by increasing use of intraoperative neuromonitoring and microscope, the postoperative neurological deficits had been minimized a lot [4, 16]. Desai [7] reported that only 5 patients had persistent sensorimotor disorder in 115 cases. Our study has similar results: pain and sensory abnormalities would occurred in early postoperative period. However, 3 cases had initial transient motor weakness due to nerve apraxia, but all alleviated in 6 months. Siqueira [15] and Go [20] also reported similar symptoms of transient paralysis after complete resection of benign tumors.

Through the analysis of this series of cases, we found that in the 6 patients with postoperative pain, 3 tumors were located in the roots, 3 in the divisions and cords. And 5 of them, the tumor was more than 30 mm in size. In the 3 patients with transient postoperative motor dysfunction, the tumors were more than 30 mm in size, and located in the roots or intraspinal and extraspinal. The occurrence of postoperative neuropathic pain and movement disorder was related to the size and location of the tumor. The larger the tumor, the closer to the spinal cord, the higher the incidence of postoperative neurological deficits. Of course, it still needs to be verified by large sample data.

## Conclusions

Because of the complex anatomical structure of BP schwannoma and the high incidence of postoperative functional defects, it is necessary to carefully evaluate the interaction between the surrounding tissues and the tumor before operation. It is suggested to use intraoperative neuromonitoring to protect the integrity of the nerve during the operation. The tumor capsule should be incised longitudinally at the place with the least and thinnest nerve fiber bundles, and tumor be resected under the microscope. The bleeding vessels in the capsule should be coagulated with low-power bipolar under the higher magnification to avoid nerve damage after tumor resection. The occurrence of postoperative neuropathic pain and movement disorder may also related to the size and location of the tumor. The larger the tumor, the closer to the spinal cord, the higher the incidence of postoperative neurological deficits. This study has the limitations of a small number of enrolled cases and in a single institution, and the surgical experience or a professional electrophysiologist could affect the results. Nonetheless, the surgical technique of microsurgical encapsulated resection of BP schwannoma is safe and may preserve neurological function.

### Abbreviations

BP Brachial plexus
CAMP Compound muscle action potential
MNCV Nerve conduction velocity
MRI magnetic resonance imaging

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12893-025-02842-8.

Supplementary Material 1

Supplementary Material 2

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None.

### Author contributions

Jingsen Chen responsible for the operation and follow-up of patients, was a major contributor in writing the manuscript. Shenglong Cao, Xiao Dong participated in the operation of patients, collected and analyzed the clinical data. Hanghuang Jin responsible for editing the surgery video and image processing. Haiying Hu write the original draft and review. All authors reviewed the manuscript.

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### Data availability

Data is provided within supplementary information files: patients data.xlsx.

## Declarations

### Ethics approval and consent to participate

This retrospective review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the Helsinki Declaration. The Ethical review and approval were approved by The Ethics Committee for Human Research at the Second Affiliated Hospital of Zhejiang University School of Medicine, ID: I20231262. All patients admitted to our hospital had sign a consent form, including the clinical data may be used for medical education or clinical research.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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