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Original Article

Analysis of the efficacy and postoperative complications of thoracoscopic resection through the transthoracic posterior approach of thoracic paravertebral dumbbell-shaped schwannoma

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Abstract: This study aim to compare the clinical efficacy and postoperative complications total incidence rates of the thoracoscopic resection through the trans-thoracic posterior approach thoracic paravertebral dumbbell-shaped schwannoma with the traditional posterior median approach, in order to provide a reference for clinical treatment. This study was a retrospective cohort study. A total of 265 patients with thoracic paravertebral dumbbell-shaped schwannoma in our hospital from January 2020 to December 2024 were retrospectively included as the research subjects. According to the actual surgical method received, patients were divided into the experimental group (n=130) and the control group (n=135). The patients in the experimental group received thoracoscopic resection through the transthoracic posterior approach, while the patients in the control group received traditional posterior median approach. All patients were followed up for 12 months, 24 months, and 36 months after surgery. The baseline data, primary outcome indicator (total incidence rate of postoperative complications), and secondary outcome indicators (surgical basic conditions, degree of surgical resection, pathological results, and changes in patient efficacy indicators throughout the follow-up period, and total recurrence rate of thoracic paravertebral dumbbell-shaped schwannoma) were compared and analyzed between the experimental group and the control group. The total incidence rate of complications in the experimental group was lower than that in the control group (P<0.05). The average operation time, postoperative ambulation time, average incision length, and average blood loss of the patients in the experimental group were all lower than those in the control group (P<0.05). The degree of surgical tumor resection was higher than that in the control group (P<0.05). There was no statistically significant difference in the postoperative pathological results between the two groups (P>0.05). At different follow-up times, the Japanese Orthopaedic Association (JOA) score and the 36-Item Short Form Health Survey (SF-36) score of the experimental group were higher than those of the control group (P<0.05), while the visual analogue scale (VAS) score was lower than that of the control group (P<0.05). There was no statistically significant difference in the American Spinal Injury Association (ASIA) grade and McCormick spinal function grade between the two groups (P>0.05). The JOA score, SF-36 score, and ASIA grading of all patients in both groups gradually increased with the increase of follow-up time (P<0.05), while the VAS and McCormick grade gradually decreased with the increase of follow-up time (P<0.05). During the 36 month follow-up time, the total recurrence rates of thoracic paravertebral dumbbell-shaped schwannoma were 0 in both groups. Compared with traditional posterior midline approach surgeries, the thoracoscopic resection through the transthoracic posterior approach had better efficacy and a lower total incidence rate of postoperative complications.

Keywords: Thoracic paravertebral schwannoma, posterior approach, thoracoscopy, efficacy analysis, postoperative complications

Introduction

Dumbbell-shaped schwannomas are a common type of tumor in the paravertebral region of the thoracic spine, accounting for 10%-15% of all neurogenic tumors [1]. It usually originates from the nerve root and is formed by nerve sheath cells, growing along the nerve root, passing through the intervertebral foramen, and simultaneously extending into the spinal

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canal and the thoracic cavity, thus forming a characteristic dumbbell-shaped morphology [2, 3]. This tumor grows slowly, but as the tumor enlarges, it will compress on surrounding nerve tissues, the spinal cord, and organs within the thoracic cavity [4], thereby causing various clinical symptoms such as back pain, numbness in the limbs, and weakened muscle strength in the limbs [5].

At present, clinical treatment is mainly surgical treatment. The traditional treatment method is mainly to remove the thoracic paravertebral dumbbell-shaped schwannoma through the posterior midline approach [6, 7]. Although this method can remove most of the tumor, traditional surgeries are time-consuming, require extensive soft tissue dissection during the operation, and have large surgical trauma [8]. Current studies have shown that patients with thoracic paravertebral dumbbell-shaped schwannomas might be affected by factors such as large tumor volume, long surgical duration, excessive intraoperative bleeding, dural tear, cerebrospinal fluid leakage, and abnormal clinical test indicators [9, 10]. After surgery, they were prone to complications such as pleural effusion, incision infection, back pain, and central nervous system infection, which affected the postoperative rehabilitation process, quality of life, and recovery of neurological function of the patients [11]. In recent years, with the development of minimally invasive surgical techniques, new technologies have been applied in the treatment of thoracic paravertebral tumors [12]. The thoracoscopic resection through the transthoracic posterior approach is a surgical method that has gradually gained popularity in recent years [13]. However, the specific efficacy and safety of this surgical method still need to be further verified.

Based on this, this study used the thoracoscopic resection through the transthoracic posterior approach to remove the parathoracic dumbbell schwannoma. The basic surgical conditions, degree of surgical resection, pathological results, changes in efficacy indicators, postoperative recurrence, and total incidence of complications were compared with the traditional posterior median approach surgery. In order to provide more effective and safe surgical treatment options for patients with thoracic paravertebral dumbbell-shaped schwannoma.

Materials and methods

Sample size calculation

Based on previous literature reports [6, 7, 13], the complication rates of the traditional posterior median approach (P0) and thoracoscopic resection through the transthoracic posterior approach (P1) were approximately 25% and 10% respectively. Under the conditions of α= 0.05 (two-sided) and test power (1-β) =0.80, using the PASS software, it was calculated that each group needed at least 100 patients. Considering a 20% dropout rate, this study required at least 125 patients to be included.

Study population

This study was a retrospective cohort study. A total of 265 patients with thoracic paravertebral dumbbell-shaped tumors in our hospital from January 2020 to December 2024 were included as the research subjects. The surgical approach for the patient was determined by the surgical team based on the preoperative imaging assessment (including tumor size, location, and relationship with important blood vessels and nerves), age, physical condition score, and personal wishes. According to the actual surgical methods received, the patients were divided into two groups: the experimental group (n=130) received thoracoscopic resection through the transthoracic posterior approach, and the control group (n=135) received traditional posterior median approach (**Figure 1**). To assess and control the potential selection bias caused by non-random grouping, this study conducted a comparative analysis of the baseline data of the two groups of patients. The results were shown in **Table 1**. There were no statistically significant differences between the two groups in key prognostic factors, such as age, gender, maximum tumor diameter, Eden classification, and tumor-involved segments (all P>0.05). This indicated that the baseline characteristics of the two groups of patients were well comparable, thereby significantly reducing the impact of potential selection bias on the results of this study. All patients were followed up for a period of 36 months after the surgery. The follow-up visits were conducted at 12, 24 and 36 months postoperation. The conduct of this study complied with the World Medical Association's

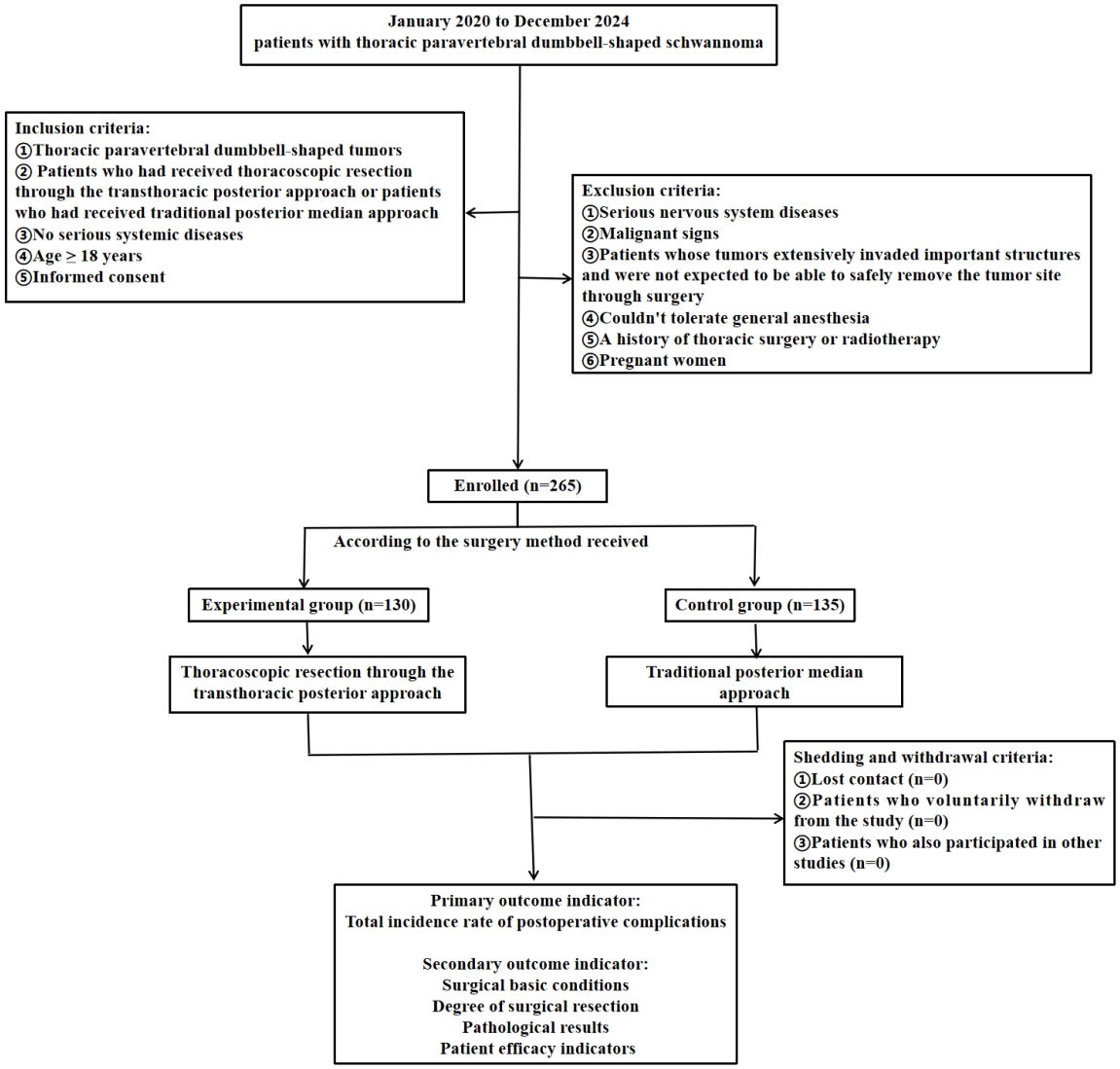

Figure 1. Research design flowchart.

Declaration of Helsinki and relevant laws and regulations of China, and has been approved by the Science and Technology Ethics Committee of Linyi People's Hospital [Approval No.: 202509-H-001].

Diagnostic criteria of paravertebral dumbbell-shaped tumors

The diagnosis of thoracic paravertebral dumbbell-shaped tumors required the following criteria [14]: (1) Clinical manifestations included radicular pain, progressive spinal cord compression symptoms, and possible thoracic-related symptoms; (2) Imaging features characteristic of included dumbbell-shaped masses both inside and outside the spinal canal, with an enlarged intervertebral foramen (MRI was the gold standard, showing the tumor connecting the inside and outside of the spinal canal through the intervertebral foramen); (3) Pathology diagnosis was a neurogenic tumor (such as schwannoma). The final diagnosis should be comprehensively determined based on clinical symptoms, imaging features, and pathological results. Among them, the typical dumbbell-shaped morphology shown by MRI and the involvement of the intervertebral foramen are the key bases for diagnosis.

Diagnostic criteria for postoperative complications

Postoperative complications refer to unexpected adverse conditions or diseases that occur

Table 1. Comparison of baseline data between the experimental group and the control group

Indicator	Experimental group (n=130)	Control group (n=135)	t/χ^2	*P*
Age (years)	54.27±13.15	52.27±14.12	1.192	0.234
Disease course (monthy)	9.31±1.24	9.15±1.32	1.017	0.310
Gender [*n* (%)]			0.769	0.381
Male	55 (42.3)	50 (37.0)		
Female	75 (57.7)	85 (63.0)		
BMI (kg/m^2)	24.87±2.12	25.34±2.07	-1.830	0.068
Weight (Kg)	67.24±9.52	69.17±10.32	-1.581	0.115
Height (m)	1.68±0.12	1.70±0.09	-1.539	0.125
Maximum diameter of the tumor (mm)	56.26±12.32	54.17±9.02	1.580	0.115
Affected segments by the tumor [*n* (%)]			2.081	0.353
T1-T6	44 (33.8)	39 (28.9)		
T6-T12	54 (41.5)	68 (50.4)		
T12-L1	32 (24.6)	28 (20.7)		
Eden classification [*n* (%)]			2.675	0.444
I	11 (8.5)	6 (4.4)		
II	54 (41.5)	68 (50.4)		
III	38 (29.2)	34 (25.2)		
IV	27 (20.8)	27 (20.0)		
History of diabetes [*n* (%)]			1.917	0.166
Yes	54 (41.5)	67 (49.6)		
No	76 (58.5)	68 (50.4)		
History of hypertension [*n* (%)]			1.844	0.174
Yes	81 (62.3)	73 (54.1)		
No	49 (37.7)	62 (45.9)		
History of coronary heart disease [*n* (%)]			1.662	0.197
Yes	70 (53.8)	62 (45.9)		
No	60 (46.2)	73 (55.6)		
Smoking history [*n* (%)]			1.531	0.216
Yes	49 (37.7)	61 (45.2)		
No	81 (63.3)	74 (54.8)		
Alcohol consumption history [*n* (%)]			1.354	0.245
Yes	33 (15.4)	43 (31.9)		
No	97 (74.6)	92 (68.1)		
Preoperative medication situation [*n* (%)]			1.905	0.386
Compound neomycin sulfate	54 (41.5)	45 (33.3)		
Celecoxib capsules	43 (33.1)	51 (37.8)		
Mecobalamin tablets	33 (25.4)	39 (28.9)		

during the surgical procedure or within a certain period after the surgery [15]. The severe postoperative complications of thoracic paravertebral dumbbell-shaped schwannoma mainly included central nervous system infection, intermuscular venous thrombosis, pulmonary infection, pleural effusion, and anemia; mild postoperative complications included pleural effusion, pulmonary infection, back pain, low back pain, lower limb pain, limb numbness, fasciitis, fever, hyponatremia, and hypokalemia [16]. The diagnostic basis for various postoperative complications were as follows:

(1) Pleural effusion: Within 12 mouth after the surgery, refer to the consensus on thoracic

diagnosis and treatment [17], and make a comprehensive assessment based on postoperative imaging (X-ray/CT) showing signs of effusion and clinical manifestations (such as shortness of breath and chest pain).

(2) Pulmonary infection: Within 1 month after the surgery, according to the diagnostic guidelines for hospital-acquired pneumonia [18], at least two of the following conditions must be met: new onset respiratory symptoms, imaging findings of infiltrates, abnormal inflammatory indicators, and pathogenic evidence.

(3) Back pain/lower back pain/lower limb pain: After the surgery, for several months, according to the International Association for the Study of Pain (IASP) [19], it was defined as new or exacerbated pain that occurs after surgery, lasting for at least 3 months, and excluding other clear causes (such as infection, recurrence, etc.).

(4) Limb numbness: Within 48 hours to several months after the surgery, it manifested as postoperative sensory abnormalities, which were confirmed by neuroelectrophysiological examinations as nerve function damage, and non-surgical-related neuropathy was ruled out [20].

(5) Fasciitis: Within several days to several weeks after the surgery (such as 1-3 days after the surgery, or even delayed until 10-14 days), according to the the clinical guidelines for orthopedics [21], the symptoms include local pain, muscle tension or a sense of cord-like sensation. Imaging studies support the presence of increased fascial thickness or edema, and the exclusion of similar diseases such as infection or hematoma.

(6) Fever: After 24 to 48 hours post-operation, according to the American College of Surgery (ACS) and the Surgical Infection Society (SIS) [22], it was defined as having a body temperature persisting above 38.3°C for 24-48 hours after the surgery, or having a temperature exceeding 38.0°C multiple times within 24 hours.

(7) Central nervous system infection: Within 3 to 7 days after the surgery, according to the consensus of neurosurgical infection experts [23], the following clinical manifestations are required: fever, changes in consciousness, and signs of meningeal irritation. These should be combined with the results of cerebrospinal fluid or imaging examinations.

(8) Anemia: Throughout the entire follow-up period, it was defined as hemoglobin <130 g/L in men or <120 g/L in women, assessed from the immediate postoperative period throughout follow-up [24].

(9) Intermuscular venous thrombosis: Within 7 days after the surgery, it was diagnosed based on clinical symptoms (e.g., limb swelling and pain), elevated D-dimer (>500 μg/L), and confirmation via color doppler ultrasound showing venous dilation and intraluminal thrombus [25].

(10) Hyponatremia/Hypokalemia: It were defined as serum sodium <135 mmol/L and serum potassium <3.5 mmol/L, respectively, within 48 hours after surgery [26].

Inclusion, exclusion, drop out and withdrawal criteria

Inclusion criteria: (1) Patients with thoracic paravertebral dumbbell-shaped tumors; (2) Patients who had received thoracoscopic resection through the transthoracic posterior approach or patients who had received traditional posterior median approach; (3) The patient had no serious systemic diseases (such as coagulation dysfunction, cardiac or pulmonary insufficiency, etc.); (4) The patient's age ≥18 years; (5) All patients and their family members were informed consent.

Exclusion criteria: (1) Patients with other serious nervous system diseases (such as cerebral infarction, brain tumor, multiple sclerosis, etc.); (2) Patients with malignant signs (such as blurred boundaries, invasive growth, severe bone destruction); (3) Patients whose tumors extensively invaded important structures and were not expected to be able to safely remove the tumor site through surgery; (4) Patients who couldn't tolerate general anesthesia; (5) Patients with a history of thoracic surgery or radiotherapy; (6) Pregnant women.

Drop out and withdrawal criteria: (1) Patients who have lost contact due to changes in contact information, difficulties in traveling, and a decrease in subjective willingness; (2) Patients who voluntarily withdraw from the study; (3)

Patients who also participated in other studies during this research period.

Postoperative ambulation and discharge criteria

Postoperative ambulation criteria for patients: Comprehensive assessment based on the surgical method, tumor nature, and individual recovery status [27]. Usually, patients need to stay in bed for about one week after the surgery. If the surgical involved segments were few and there were no serious complications (such as cerebrospinal fluid leakage, nerve injury), patients could gradually attempt to sit up and stand by the bedside under the guidance of the doctor, then transition to short-distance walking. Initially, patients need to wear braces for protection and avoid spinal twisting or weight-bearing. If the tumor invaded multiple segments or the patient had a poor physical condition, the bed rest period should be extended to more than two weeks. Before getting out of bed, it was necessary to ensure that the wound had healed well, there were no signs of infection, and the spinal stability was confirmed through imaging.

Discharge criteria for patients: The patient's condition iwas stable, the surgical incision had healed well without infection, and they had basic daily activity capabilities and could take care of themselves [28]. Usually, after 1 to 2 weeks of postoperative recovery, after assessment of pain relief, no deterioration in neurological function, and after the patient and their family members had mastered key points such as wound care, medication use, and activity restrictions, they could be discharged with the approval of the doctor.

Imaging examinations

All patients received comprehensive imaging examinations before the operation, including the magnetic resonance imaging (MRI) scan and the computed tomography (CT) scan.

MRI scan: This MRI examination was conducted using a magnetic resonance imaging device. The scanning sequences included T1WI and T2WI in sagittal, axial, and coronal orientations, as well as enhanced T1WI. The scanning parameters were conventional sequences with a slice thickness of 3-4 millimeters and a slice interval of 0.5 millimeters. The plain scan T1WI showed iso-signal or low signal (**Figure 2A**), the plain scan T2WI showed high signal (**Figure 2B**), and the enhanced T1WI showed a clearly and unevenly enhanced mass (**Figure 2C**), indicating that the patient had a thoracic paravertebral dumbbell-shaped nerve sheath tumor.

CT scan: The thin-layer CT examination was carried out using a multi-row spiral CT machine. The scanning parameters were set as follows: tube voltage 120 kV, tube current 220-300 mAs, matrix 512×512, and slice thickness 0.625-1.0 mm. Based on the original data obtained from the above thin-layer scanning, combined with the three-dimensional reconstruction technology of the computer workstation, the location, size, adjacency relationship with the vertebral bodies and internal organs of the patient's tumor, as well as the presence of bone erosion and other conditions, could be accurately determined (**Figure 3**).

Surgical method

Preoperative preparation: Before the operation, patients need to fast and refrain from drinking for more than 8 hours, establish an intravenous access, and receive antibacterial prophylactic medication. In the operating room, microscopes, electrocoagulation equipment, thoracic camera systems, and neurophysiological monitoring devices were prepared.

Anesthesia and Position: After the patient entered the operating room, routine monitoring of vital signs was conducted. General anesthesia was achieved through tracheal intubation under intravenous induction. Tracheal intubation was performed after the induction. The anesthesia was maintained by continuous intravenous infusion of propofol and remifentanil combined with inhalation of sevoflurane. The patient was placed in a standard prone position, with soft pads supporting the chest and pelvis to avoid abdominal compression. The head was kept in a neutral position. The limbs were properly fixed to avoid nerve and blood vessel compression. After the patient's position was set and before the surgery began, baseline monitoring of somatosensory evoked potential (SEP) and motor evoked potential (MEP) was established outside the sterile area and continuously monitored during the opera-

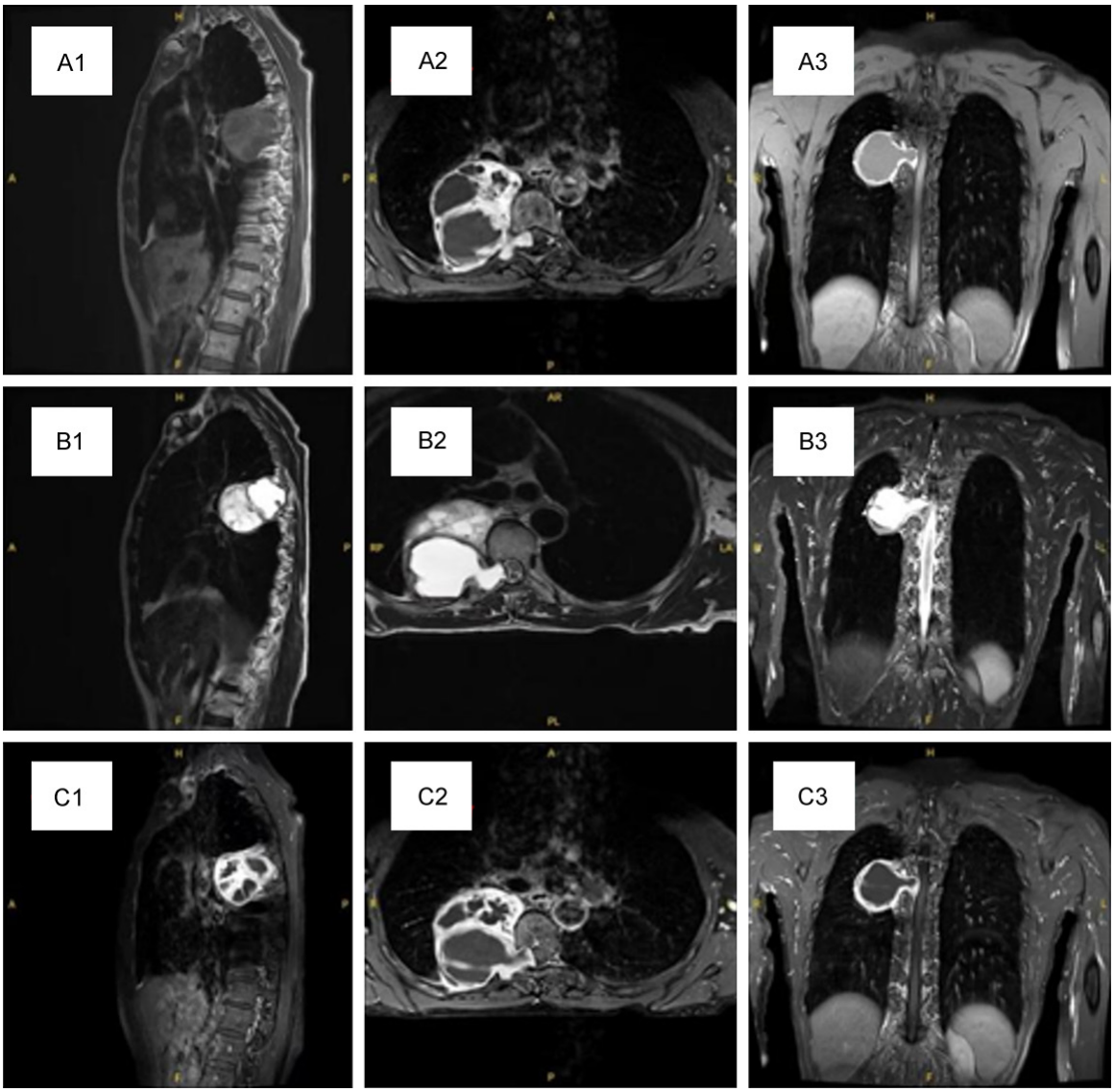

Figure 2. MRI scan images. (A1-A3) were MRIt1-weighted images: there was an irregularly shaped tumor next to the thoracic spine, communicated outside the foramen, and the tumor body partially protrudes into the chest cavity, showing uneven hypointensity (A1 was the T1 sagittal position, A2 was the T1 axial position, and A3 was the T1 coronal position). (B1-B3) were MRIt2-weighted images: the tumor presents mixed and heterogeneous hyperintensities, the paravertebral tumor was located outside the foraminal communication, and the tumor partially protruded into the thoracic cavity (B1 was T2 sagittal, B2 was T2 axis, and B3 was T2 coronal). (C1-C3) were MRI-enhanced t1-weighted images: the paravertebral tumor was located outside the intervertebral foramen, and the tumor body partially protruded into the chest cavity, and the tumor was obviously unevenly enhanced (C1 was the enhanced sagittal position, C2 was the enhanced axial position, and C3 was the enhanced coronal position).

tion, providing real-time feedback on the spinal cord function status for the surgeon.

Control group: The control group underwent traditional posterior midline approach surgery to remove the thoracic paravertebral dumbbell-shaped schwannoma. The surgical process included incision and exposure, lamina and intervertebral foramen handling, tumor resection, spinal stability assessment, and postoperative management [29]. Incision and exposure: A longitudinal incision of 8.00-12.00 cm was made on the midline of the thoracic vertebrae in the back. The skin, subcutaneous tissue, nuchal ligament, or supraspinous ligament was sequentially incised. A monopolar electrosurgical knife was used to dissect the paravertebral muscles (spinous muscles, semispinal

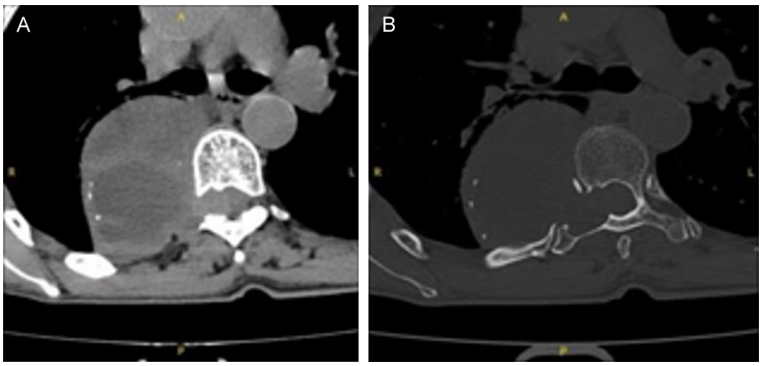

Figure 3. CT images: The tumor was located inside and outside the intervertebral foramen, showing low density, partially protruding into the thoracic cavity, and partially eroding the thoracic spine appendages (A was the CT soft tissue window, B was the CT bone window window).

muscles, multifidus muscles, etc.) to fully expose the lamina, articular processes, and transverse processes. Laminar and intervertebral foramen handling: Perform the laminectomy using bone forceps or high-speed drills, the extent of which was determined by the size of the tumor. Usually, the affected vertebra segment and the adjacent vertebrae above and below need to be removed. Expand the intervertebral foramen, and if necessary, remove part of the facet joints to fully expose the tumor inside and outside the intervertebral foramen. Tumor resection: Carefully separate the tumor capsule under the microscope. For the part within the spinal canal, perform a complete dissection along the capsule. For the part in the intervertebral foramen, it is necessary to significantly enlarge the intervertebral foramen, and sometimes it is necessary to remove part of the transverse process or costal head. For the part in the thoracic cavity, enter the thoracic cavity through the enlarged intervertebral foramen, or make another thoracic incision to enter the thoracic cavity for tumor resection. Spinal stability assessment: During the operation, the stability of the spine is evaluated. If more than 50% of the intervertebral joints were removed or the vertebral bodies were severely damaged, a pedicle screw internal fixation surgery was required to restore the stability of the spine. Postoperative management: Thoroughly stop the bleeding, suture the incision layer by layer, and routinely apply antibiotics after the operation to prevent infection. Closely observe the changes in neurological function and the healing of the incision.

Experimental group: The experimental group underwent thoracoscopic resection through the transthoracic posterior approach, aiming to remove the dumbbell-shaped nerve sheath tumor adjacent to the thoracic vertebrae. The surgical process consisted of the following four steps: incision and channel establishment, intraspinal operations under a microscope, thoracoscopic-assisted operation, and postoperative management [30]. Incision and channel establishment: Based on the preoperative imaging localization, a longitudinal incision of 3.00-4.00 cm was made 2.00-3.00 cm lateral to the spinous process of the affected vertebra in the thoracic segment of the back (**Figure 4A**). The skin and subcutaneous tissue were sequentially incised while protecting the paravertebral muscles. Using the muscle space separation technique, the incision was entered along the interspace between the multifidus and longissimus muscles to avoid extensive muscle dissection. The working channel was established, and a series of expanders were used to gradually expand it, finally inserting a 22 mm working cannula to establish a stable surgical channel (**Figure 4B**). Intraspinal operations under a microscope: Under the surgical microscope, the soft tissues within the intervertebral foramen and the spinal canal were cleared, exposing the tumor within the intervertebral foramen. The relationship between the tumor and the nerve roots was carefully separated. For tumors originating from the nerve roots, the nerve root function was evaluated under electrophysiological monitoring. If the nerve root function was completely lost, the nerve root and the tumor could be removed together. If there was still function, the nerve root would be retained while the tumor was removed as much as possible. Fine instruments such as ultrasonic aspirators and bipolar electrocoagulation devices were used to remove the tumor tissue within the spinal canal. Thoracoscopic-assisted operation: The patient was positioned in the lateral position. Three 1.00 cm incisions were made at the 5th to 7th intercostal spaces to establish an artificial pneumothorax (pressure 8-12 mmHg). A thora-

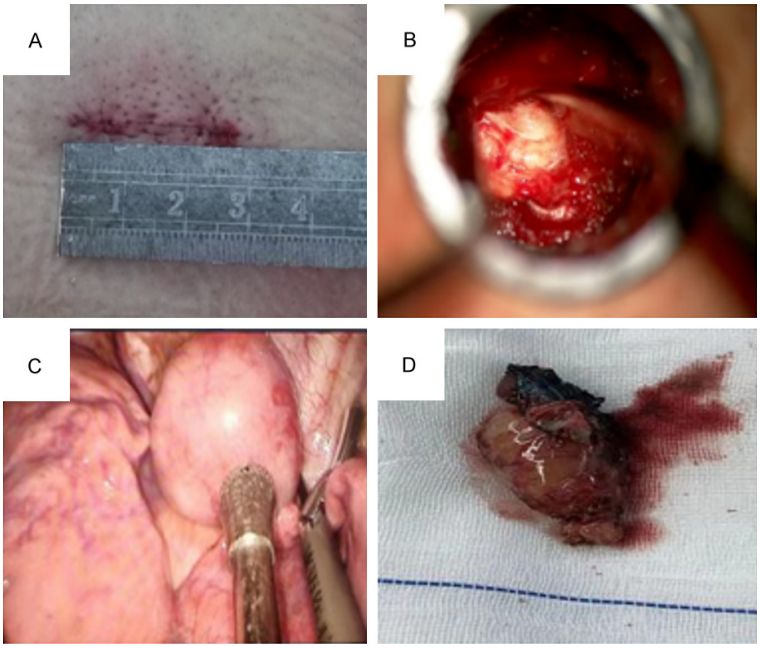

Figure 4. Images of thoracoscopic resection through the transthoracic posterior approach of thoracic paravertebral dumbbell-shaped schwannoma. (A) was the image of the surgical incision; (B) was the image of the operation under the back channel; (C) was the image for thoracoscopic operation; (D) was the image of the tumor that has been surgically removed.

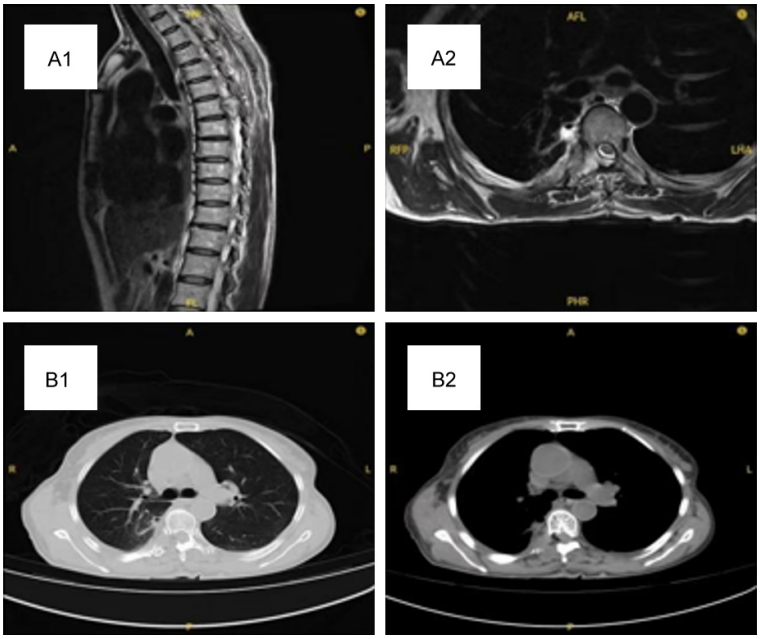

Figure 5. The postoperative images. (A1, A2) were the MRI images and (B1, B2) were the CT images.

coscope was inserted to observe the relationship between the tumor and the internal structures of the thoracic cavity. Under the direct vision of the thoracoscope, instruments such as electrocoagulation hooks and ultrasonic scalpels were used to separate the adhesions between the tumor and the lungs, mediastinum, etc (**Figure 4C**). For tumors with a rich blood supply, the blood supply vessels were first treated, and then the tumor tissue in the thoracic cavity was completely removed (**Figure 4D**). After the thoracic cavity operation was completed, the thoracic cavity was thoroughly rinsed to confirm no active bleeding. A thoracic drainage tube was left in place. Postoperative management: Thorough hemostasis was achieved. Gelatin sponge was used to fill the intervertebral foramen to prevent cerebrospinal fluid leakage. The incision was sutured layer by layer, and a subcutaneous drainage tube was left in place. Close observation of neurological function was conducted after the operation, and MRI and CT scans were taken regularly to assess the lung re-expansion status (**Figure 5**).

Postoperative follow-up: Postoperative follow-up was conducted through outpatient check-ups, which were carried out at 12, 24, and 36 months after the surgery. All patients' Japanese Orthopaedic Association (JOA) score, visual analogue scale (VAS) score, the 36-Item Short Form Health Survey (SF-36) score, American Spinal Injury Association (ASIA) impairment scale grade, McCormick scale grade, and the occurrence of postoperative complications were collected.

Research indicators

Baseline data: The baseline data of the patients at the time of admission were collected.

Baseline data included age, disease duration, gender, body mass index (BMI), weight, height, maximum tumor diameter, tumor-involved segments, Eden morphological classification, history of diabetes, history of hypertension, history of coronary heart disease, smoking history, alcohol consumption history, and preoperative medication situation (compound neomycin sulfate, celecoxib capsules, mecobalamin tablets). The Eden morphological classification used in this study included four types [31]: Type I referd to the tumor involving both the inside and outside of the dura mater, with the tumor body located within the spinal canal; Type II referd to the tumor involving both the inside and outside of the dura mater, with the tumor extending through the intervertebral foramen to the paravertebral region; Type III referd to the tumor located outside the dura mater, with the tumor extending through the intervertebral foramen to the paravertebral region; Type IV referd to the tumor located in the intervertebral foramen and paravertebral region.

Primary outcome indicator: The total number of patients who developed complications after undergoing a thoracoscopic resection through the transthoracic posterior approach or the traditional posterior median approach after the entire follow-up period ended was collected, and the total incidence rate was calculated. Total incidence rate = (number of patients with at least one complication/total number of patients) ×100%.

Secondary outcome indicator: The surgical conditions of the patients during the operation process were collected. The surgical conditions included the average operation time, postoperative ambulation time, average hospital stay, average incision length, and average blood loss of the patients. The average operation time referred to the total duration from the start of the incision to the end of the surgery. The postoperative ambulation time referred to the time interval from the end of the surgery to the first time one could get out of bed with the assistance of medical staff or family members. The average hospital stay referred to the number of days from the end of the surgery to discharge. The average blood loss referred to the amount of blood lost during the surgery.

The degree of surgical resection of the patients during the operation process was collected. The degree of surgical resection included the complete resection and subtotal resection of the patients. Complete resection referred to the complete removal of the tumor and the potentially affected tissues around it, with no residual cancer cells visible to the naked eye or under a microscope, and the pathological examination of the surgical margin was negative [32]. Subtotal resection referred to the presence of visible residual tumor, or the tumor appeared to have been completely removed under naked-eye observation, but there were still cancer cells remaining at the margin under a microscope [33].

The pathological results of the patients' tissue after the surgery were collected. The postoperative pathological results included the occurrence of schwannomas, neurofibromas, spinal meningeal tumors, fibrosarcomas, cell proliferation, mucoid cartilaginous tissue, ganglion cell tumors, and hemangiomas in patients. After the tissue specimen was isolated, it was immediately sent to the pathology department, rapidly frozen and solidified in an environment of about -20°C, then cut into thin slices using a cryostat, stained with rapid hematoxylin and eosin (H&E), and examined under a microscope by a pathologist to preliminarily assess the type and nature of the lesion.

The efficacy indicators of the patients before the surgery, at 3 months of postoperative follow-up, at 6 months of postoperative follow-up, and at 12 months of postoperative follow-up were collected, respectively. The efficacy indicators included the JOA score, VAS score, SF-36 score, ASIA grade, and McCormick scale grade of the patients.

(1) JOA [34]: This indicator was used to reflect the severity of the patient's neurological dysfunction. The doctor conducted a comprehensive assessment of the patient's upper limb movement, lower limb movement, sensory function, and bladder function through questioning and clinical examination, and assigned corresponding scores based on the standardized terms of the JOA scale. The total score was 17 points. The lower the score, the more severe the damage to the thoracic spinal cord function.

(2) VAS [35]: This indicator was used to represent the changes in a patient's pain level. The

patient marked the corresponding position on a ruler with a scale of 0 to 10 according to the degree of pain. The distance between this point and the "0" end was the score value. The total score was 10 points. 0 points indicated no pain, 1-3 points indicated mild pain, 4-6 points indicated moderate pain, and 7-10 points indicated severe pain.

(3) SF-36 [36]: This indicator was used to comprehensively assess the health-related quality of life. The SF-36 score was collected through 8 dimensions (physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health) of the questionnaire items. The score for each dimension was converted to a 0-100 scale using a standardized formula. Finally, the scores of each dimension were summed up or analyzed separately to assess the overall health status and quality of life. The higher the score, the better the health condition.

(4) ASIA scale [37]: This indicator was an internationally recognized gold standard for assessing and classifying the severity of spinal cord injuries. The doctor assessed the patient's sensory function, motor function, and sacral retention status, and then graded the patient according to the ASIA scale. It included grades A to E. Grade A represented the complete injury with no sensory or motor function remaining. Grade B represented the incomplete injury with sensory function remaining but no motor function. Grade C represented the incomplete injury with motor function remaining, but the muscle strength of key muscles is less than grade 3. Grade D represented the preserved motor function, and the muscle strength of key muscles is ≥ grade 3. Grade E represented the normal condition with normal sensory and motor functions.

(5) McCormick scale [38]: This indicator was used to quickly and comprehensively assess the functional status of patients with spinal cord diseases (such as tumors). The doctor made a comprehensive assessment through clinical examinations (such as muscle strength tests, sensory evaluations, and observation of urination functions) to determine the grade. McCormick scale included levels I-V. Level I indicated normal neurological function with slight sensory impairment. Level II indicated mild motor or sensory dysfunction but normal function. Level III indicated moderate motor or sensory dysfunction with limited function. Level IV indicated severe motor or sensory dysfunction with severely limited function. Level V indicated paraplegia or quadriplegia.

The total number of patients who had recurrent thoracic dumbbell-shaped schwannomas at the 36 month of the follow-up time after surgery was collected, and the total recurrence rate was calculated. Total recurrence rate = (total number of recurrences/total number of patients) ×100%.

Statistical analysis

Statistical analysis was conducted using SPSS 26.0 software. The measurement data were expressed in the form of mean ± standard deviation (x±s), and normality tests and homogeneity of variance tests were performed. Measurement data that followed a normal distribution were compared between groups using t-tests, while those that did not follow a normal distribution were compared using the Mann-Whitney U rank sum test. Count data were expressed as the number of cases (%), the χ^2 test was used for group comparison. The differences in a certain indicator between different groups and at different time points were compared using repeated measures analysis of variance (such as JOA, VAS, SF-36 scores). For comparisons of ordered categorical variables (such as ASIA classification and McCormick grade), the Mann-Whitney U test was used for comparisons between two groups, and the Kruskal-Wallis H test was used for comparisons among multiple groups. The comparison of two-level data was conducted using the Mann-Whitney U rank sum test, and the comparison of data with three or more levels was conducted using the Kruskal-Wallis H rank sum test. A difference was considered statistically significant when $P<0.05$.

Results

Comparison of postoperative complications between the experimental group and the control group

The incidence rate of postoperative complications of the experimental group and the control group are shown in **Table 2**. During the follow-up period, the total incidence rate of severe postoperative complications in the experimen-

Table 2. Comparison of postoperative complications between the experimental group and the control group

Indicator	Experimental group (n=130)	Control group (n=135)	X^2	*P*
Severe postoperative complications [n (%)]	3 (2.3)	7 (5.2)		
Mild postoperative complications [n (%)]	9 (6.9)	25 (18.5)		
Total incidence [*n* (%)]	12 (9.2)	32 (23.7)	10.018	0.002

Table 3. Comparison of surgical conditions between the experimental group and the control group

Indicator	Experimental group (n=130)	Control group (n=135)	*t*	*P*
Average operation time (min)	217.33±14.32	274.67±16.57	-30.09	<0.001
Postoperative ambulation time (days)	2.37±1.25	4.92±1.72	-13.76	<0.001
Average length of hospital stay (days)	13.68±3.75	15.49±4.04	-3.776	0.115
Average incision length (cm)	3.9±1.54	9.13±2.50	-13.404	<0.001
Average blood loss (ml)	206.67±13.56	360.67±18.31	-77.573	<0.001

Table 4. Comparison of surgical outcomes between the experimental group and the control group

Indicator	Experimental group (n=130)	Control group (n=135)	X^2	*P*
Extent of resection [n (%)]			31.309	<0.001
Total resection	127 (97.7)	99 (73.3)		
Subtotal resection	3 (2.3)	36 (26.7)		

tal group was 2.5%, the incidence rate of mild postoperative complications was 6.9%, and the total incidence rate of complications was 9.2%; while for the patients in the control group, the incidence rate of severe postoperative complications was 5.2%, the incidence rate of mild postoperative complications was 18.5%, and the total incidence rate of complications was 23.7%. The total incidence rate of postoperative complications in the experimental group was lower than that in the control group (*P*< 0.05).

Comparison of surgical conditions between the experimental group and the control group

The basic information of the surgery is shown in **Table 3**. In the experimental group, the average operation time was 217.33±14.32 minutes, postoperative ambulation time was 2.37±1.25 days, average incision length was 3.9±1.545 cm, and the average blood loss was 206.67± 13.56 ml. However, in the control group, the average operation time was 274.67±16.572 minutes, postoperative ambulation time was 4.92±1.72 days, average incision length was 9.13±2.50 cm, and the average blood loss was 360.67±18.31 ml. The average operation time, postoperative ambulation time, average incision length, and average blood loss of the patients in the experimental group were all lower than those in the control group, and the differences were statistically significant (*P*<0.05). The average length of hospital stay of the patients in the experimental group was 13.68±3.75 days, while that of the patients in the control group was 15.49±4.04 days. Although the average length of hospital stay of the patients in the experimental group was shorter than that of the control group, the difference was not statistically significant (*P*>0.05).

Comparison of the degree of surgical resection between the experimental group and the control group

The comparison of the degree of surgical resection between the two groups is shown in **Table 4**. The total resection rate of patients in the experimental group was 97.7%, while that of patients in the control group was 73.3%. There was a statistically significant difference in the degree of surgical resection between the two groups (*P*<0.05).

Table 5. Comparison of postoperative pathological results between the experimental group and the control group

Indicator	Experimental group (n=130)	Control group (n=135)	X^2	*P*
Pathology results [*n* (%)]			4.810	0.683
Schwannoma	78 (60.0)	87 (64.4)		
Neurofibroma	10 (7.7)	11 (8.1)		
Spinal meningioma	9 (6.9)	6 (4.4)		
Fibrosarcoma	7 (5.4)	3 (2.2)		
Hyperplasia	3 (2.3)	6 (4.4)		
Myxochondroid tissue	8 (6.2)	11 (8.1)		
Ganglioneuroma	6 (4.6)	5 (3.7)		
Hemangioma	9 (6.9)	6 (4.4)		

Comparison of postoperative pathological results between the experimental group and the control group

The postoperative pathological results of the experimental group and the control group are shown in **Table 5**. The difference in pathological results between the two groups did not have statistical significance (*P*>0.05).

Comparison of JOA, VAS, and SF-36 scores between the experimental group and the control group

The JOA, VAS, and SF-36 scores of the two groups were compared before and after the surgery (12 months, 24 months, and 36 months), as shown in **Tables 6**-**8**. From **Tables 6**-**8**, it could be seen that there was no statistically significant difference in the JOA, VAS, and SF-36 scores between the two groups in the preoperative period (*P*>0.05). The study found that there was were interaction effect of JOA scores, VAS scores, and SF-36 scores between the time factor and the grouping factor (*P*< 0.05). At postoperative 12 months, 24 months, and 36 months, the JOA scores of the experimental group were 6.28±0.71, 11.74±1.07, and 15.31±2.14, respectively; the SF-36 scores of the experimental group were 32.79±4.71, 47.74±6.32, and 76.28±7.07, respectively; the VAS scores of the experimental group were 2.12±0.81, 1.76±0.57, and 0.52±0.14, respectively. The JOA and SF-36 scores of the experimental group at each follow-up time point after surgery were higher than those of the control group (*P*<0.05), while the VAS scores were lower than those of the control group (*P*<0.05), indicating a grouping effect. In addition, the JOA and SF-36 scores of both groups increased with the extension of the follow-up time (*P*<0.05), while the VAS scores decreased with the extension of the follow-up time (*P*<0.05), indicating a time effect.

Comparison of ASIA and McCormick grades between the experimental group and the control group

The ASIA classification and McCormick classification of the two groups of patients before and after the surgery (12 months, 24 months, 36 months) are compared, as shown in **Tables 9**, **10**. In preoperative period, there was no statistically significant difference in the ASIA classification and McCormick classification between the two groups (*P*>0.05). From **Table 9**, the study found that the ASIA classification of the experimental group and the control group increased with the extension of the follow-up time (*P*<0.05), and the ASIA classification after the surgery was higher than that before the surgery (*P*<0.05). From **Table 10**, the study found that the McCormick classification of the experimental group and the control group decreased with the extension of the follow-up time (*P*<0.05), and the McCormick classification after the surgery was lower than that before the surgery (*P*<0.05).

Comparison of postoperative recurrence results between the experimental group and the control group

During the 36 month follow-up time, there were no recurrence cases in the experimental group or the control group. The total recurrence rates for both groups were 0.

Discussion

The thoracic paravertebral dumbbell-shaped tumor is difficult to removed surgically due to its special anatomical structure, growth location, and growth pattern [39]. The traditional surgical approach is the posterior midline approach, which causes significant trauma to the patient and seriously affects the postoperative recovery and quality of life [8]. With the continuous development of minimally invasive surgical

Table 6. Comparison of JOA scores between the experimental group and the control group

Follow-up time	Experimental group (n=130)	Control group (n=135)	*t*	*P*
Preoperative period (score)	3.25±0.23	3.22±0.35	0.890	0.374
Postoperative 12 months (score)	6.28±0.71	5.04±0.65	14.748	<0.001
Postoperative 24 months (score)	11.74±1.07	8.32±0.94	27.417	<0.001
Postoperative 36 months (score)	15.31±2.14	11.73±2.01	14.061	<0.001
F_{Time}/P_{Time}		3704.153/<0.001		
F_{Group}/P_{Group}		46329.903/<0.001		
$F_{Interaction}/P_{Interaction}$		134.093/<0.001		

Table 7. Comparison of VAS scores between the experimental group and the control group

Follow-up time	Experimental group (n=130)	Control group (n=135)	t	P
Preoperative period (score)	4.61±1.32	4.57±1.17	0.103	0.918
Postoperative 12 months (score)	2.12±0.81	3.59±1.02	-13.813	<0.001
Postoperative 24 months (score)	1.76±0.57	2.92±0.89	-11.973	<0.001
Postoperative 36 months (score)	0.52±0.14	1.85±0.73	-20.436	<0.001
F_{Time}/P_{Time}		645.307/<0.001		
F_{Group}/P_{Group}		9801.794/<0.001		
$F_{Interaction}/P_{Interaction}$		36.281/<0.001		

Table 8. Comparison of SF-36 scores between the experimental group and the control group

Indicator	Experimental group (n=130)	Control group (n=135)	*t*	*P*
Preoperative period (score)	17.44±4.71	18.32±4.79	-1.536	0.126
Postoperative 12 months (score)	32.79±4.42	26.14±4.11	12.700	<0.001
Postoperative 24 months (score)	47.74±6.32	40.21±6.14	9.862	<0.001
Postoperative 36 months (score)	76.28±7.07	59.72±6.85	19.329	<0.001
F_{Time}/P_{Time}		3933.218/<0.001		
F_{Group}/P_{Group}		46690.875/<0.001		
$F_{Interaction}/P_{Interaction}$		110.086/<0.001		

channels [40], choosing the appropriate surgical approach method to achieve complete tumor resection with smaller trauma is of great significance [41]. In this study, the thoracic paravertebral dumbbell-shaped schwannoma of the patient was removed using the thoracoscopic resection through the transthoracic posterior approach. This study found that this method was significantly superior to the traditional surgical method in terms of basic surgical conditions, surgical results, surgical efficacy, and the total incidence of postoperative complications.

The total incidence rate of postoperative complications in the experimental group was lower than that in the control group. This was because a series of postoperative complications, such as back pain and fasciitis, were triggered due to the trauma of the surgery in the control group [42]. The thoracoscopic resection through the transthoracic posterior approach of the experimental group narrowed the range of muscle anatomy, preserved the posterior spinal cord ligament complex [43], and reduced the occurrence of postoperative complications [44]. Incision length, blood loss, postoperative ambulation time, and hospital stay of the thoracoscopic resection through the transthoracic posterior approach were all lower than those of the traditional posterior median

Table 9. Comparison of ASIA grading between the experimental group and the control group

Follow-up time	Experimental group (n=130)					Control group (n=135)					*Z*	*P*
	A	B	C	D	E	A	B	C	D	E		
Preoperative period [*n* (%)]	9 (6.9)	43 (33.1)	35 (26.9)	35 (26.9)	8 (6.2)	11 (8.1)	45 (33.3)	39 (28.9)	36 (26.7)	4 (3.0)	-0.629	0.530
Postoperative 12 months [*n* (%)]	4 (3.1)	26 (20.0)	23 (19.2)	37 (28.5)	40 (30.8)	8 (5.9)	30 (22.2)	32 (23.7)	32 (23.7)	33 (24.4)	-1.656	0.098
Postoperative 24 months [*n* (%)]	0 (0.0)	18 (13.8)	17 (13.1)	35 (26.9)	60 (46.2)	2 (1.5)	21 (15.6)	24 (17.8)	34 (25.2)	54 (40.0)	-1.296	0.195
Postoperative 36 months [*n* (%)]	0 (0.0)	7 (5.3)	10 (7.7)	23 (17.7)	90 (69.2)	0 (0.0)	12 (8.9)	13 (9.6)	27 (20.0)	83 (61.5)	-1.428	0.153
H			129.235					117.747				
P			<0.001					<0.001				

Table 10. McCormick spinal cord function grading between the experimental group and the control group

Follow-up time	Experimental group (n=130)				Control group (n=135)				*Z*	*P*
	I	II	III	VI	I	II	III	VI		
Preoperative period [*n* (%)]	38 (29.2)	42 (32.3)	35 (26.9)	15 (11.5)	41 (30.4)	44 (32.6)	33 (24.4)	17 (12.6)	-0.167	0.867
Postoperative 12 months [*n* (%)]	54 (41.5)	49 (37.7)	21 (16.2)	6 (4.6)	44 (32.6)	51 (37.8)	31 (23.0)	9 (6.7)	-1.834	0.067
Postoperative 24 months [*n* (%)]	87 (66.9)	26 (20.0)	17 (13.1)	0 (0.0)	79 (58.5)	31 (23.0)	22 (16.3)	3 (2.22)	-1.536	0.125
Postoperative 36 months [*n* (%)]	111 (85.4)	13 (10.0)	6 (4.6)	0 (0.0)	104 (77.0)	19 (14.1)	12 (8.9)	0 (0.0)	-1.774	0.076
H		104.673				80.219				
P		<0.001				<0.001				

approach surgery. This indicated that the thoracoscopic resection through the transthoracic posterior approach was superior to the traditional posterior median approach surgery [13], and this result was similar to the current experimental result [45]. The main reason for this phenomenon was that the traditional posterior midline approach requires extensive dissection of the paravertebral muscles [8], and the exposure range usually included the affected vertebrae and the adjacent vertebrae above and below [46]. However, the thoracoscopic resection through the transthoracic posterior approach used a small incision and channel expansion technique, entering along the gap between the multifidus and longus muscles [47], which could reduce damage to the spine, spinal attachments, muscles, and nerve roots, shorten the operation time and postoperative ambulation time, reduce intraoperative bleeding, and avoid the large trauma caused by dissection of the above muscles [13, 48].

The extent of total tumor resection in the experimental group was higher than that of in the control group, which was similar to the previous research report [49], this surgical method had a significant advantage in enhancing the completeness of tumor removal. This might be due to the fact that traditional surgery often requires blind operation through enlarged intervertebral foramina when dealing with tumors in the thoracic cavity [50], resulting in greater trauma, longer muscle traction time, and lower resection rate [46]. In contrast, the strategy of transthoracic posterior thoracoscopic combined with microsurgery adopted in this study fundamentally optimized the surgical approach through the anatomical route. This method uses the thoracoscopic approach from the anterior-lateral side to directly enter the thoracic cavity, avoiding extensive damage to the posterior muscle groups, thereby effectively reducing muscle injury during the operation and the occurrence of postoperative pain. Moreover, the thoracoscopic system could provide a high-resolution, magnified three-dimensional view, enabling the surgeon to clearly identify the fine anatomical relationships between the tumor and adjacent lung tissue, aorta, superior vena cava, sympathetic chain, and intercostal nerve and vascular bundles [51]. Based on this, combined with intraoperative nerve monitoring technology, the nerve function status could be evaluated in real time, further ensuring the safety of the surgery. At the same time, the microscopic approach through the intervertebral space to treat intradural tumors could achieve precise resection while maximizing the protection of the dural sac, spinal cord, and nerve roots [52]. The combination of these two technologies has enabled the complete visualization of operations across both the inside and outside of the spinal canal, ensuring the intact removal of the tumor capsule and clear boundaries, and significantly improving the overall tumor resection rate [30].

The JOA scores and SF-36 scores of the patients in the experimental group were all higher than those in the control group after the operation (12 months, 24 months, and 36 months). Both the JOA and SF-36 scores increased with the extension of the follow-up period. This might be due to the fact that the traditional posterior median approach often requires the removal of part of the articular facet joints or even the transverse processes [46], while the combined approach retained these key structures, thereby reducing the potential impact of postoperative spinal biomechanical changes on neurological function [53], In addition, the lateral position provided an ideal surgical field exposure for thoracoscopic procedures, facilitating a more thorough nerve decompression. The process of adjusting the intraoperative position from the prone position to the lateral position was completed under the close supervision of the anesthesia team. By optimizing the ventilation strategy, maintaining hemodynamic stability, and recalibrating the baseline of neuroelectrophysiological monitoring after position fixation, the safety of the surgery was effectively guaranteed [54]. These factors collectively contributed to the improvement of the patients' neurological functions and quality of life. The study also found that the VAS scores of the patients in the experimental group after the operation (12 months, 24 months, and 36 months) were lower than those in the control group, and the VAS scores decreased with the extension of the follow-up time. This might be because the traditional posterior median approach requires extensive dissection of the paravertebral muscles, leading to chronic low back pain [6]. However, the thoracoscopic resection through the transthoracic posterior approach avoids chronic low back pain caused by mus-

cle-originated chronic low back pain by protecting the integrity of the paravertebral muscles, nerve innervation, and blood supply, and maximizing the preservation of bony structures [47, 55]. Moreover, the study also found that the ASIA grades and McCormick grades of the patients in the experimental group improved with the extension of the follow-up time. This was mainly because the thoracoscopic resection through the transthoracic posterior approach was a minimally invasive surgery that could completely remove tumors or lesion tissues through small incisions and precise operations [56], avoiding the severe damage to muscles, nerves, and spinal stability caused by traditional open surgeries [57]. After the operation, patients recovered quickly, had less pain, and the compression on the spinal cord and nerve roots was effectively relieved [58]. As time goes by, the patients' motor function and daily living ability will gradually improve [59].

During the 36 month follow-up time, the total recurrence rates of both the experimental group and the control group were 0. This preliminary result indicated that both surgical methods can achieve effective tumor control within the short-term follow-up period [60]. However, a 36 month follow-up time was insufficient for assessing the long-term recurrence of thoracic paravertebral dumbbell-shaped schwannomas, as recurrence might occur 5 or 10 years after the surgery [61]. Further long-term follow-up studies will be necessary to clarify the long-term oncological outcomes of the two surgical procedures.

In conclusion, thoracoscopic resection through the transthoracic posterior approach for the removal of the thoracic paravertebral dumbbell-shaped schwannoma was a safe and effective minimally invasive surgical method. During the operation, this method has a lower total incidence rate of postoperative complications, shorter surgical time, smaller incision length, less bleeding, shorter postoperative ambulation time, shorter total hospital stay, higher total resection degree, good therapeutic effect, and there is no recurrence within a short period. It can provide an effective treatment option for patients with thoracic paravertebral dumbbell-shaped schwannomas. However, this study also had some limitations. Firstly, the sample size was relatively small, which may affect the reliability of the results. Therefore, larger sample size studies are needed in the future to verify these findings. Secondly, the longest follow-up time was 36 months, which had certain limitations in evaluating the long-term efficacy and long-term recurrence of this surgical method. Future studies can extend the follow-up time to observe the long-term efficacy of thoracoscopic resection through the transthoracic posterior approach. Moreover, the study design was a retrospective study, which might have selection bias. Future research can conduct multicenter, prospective, randomized controlled trials to ensure the reliability and persuasiveness of the results.

Conclusion

Compared with the traditional posterior median approach surgery, the thoracoscopic resection through the transthoracic posterior approach of thoracic paravertebral dumbbell-shaped schwannoma had the advantages of lower total incidence rate of postoperative complications, shorter average operation time, smaller incision length, less bleeding, shorter postoperative ambulation time and total hospital stay, higher total resection degree, better clinical efficacy, and no recurrence in the short term. This method was a safe and effective minimally invasive surgical approach, which can provide a reference for the treatment of tumor patients.

Disclosure of conflict of interest

None.

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