Laparoscopic Resection of Pelvic Schwannomas: A 9-Year Experience at a Single Center
Chaolin Deng¹, Peipei Wang¹, Yong Liu², Xiyu Sun¹, Xi Zhou², Yan You³, Bin Wu¹

BACKGROUND: Pelvic schwannoma (PS), a type of slow-growing and noninvasive neoplasm that occurs in the pelvis, is relatively rare in adults. However, due to the anatomical structures, surgical excision of the tumors is often difficult using the traditional approach.

METHODS: Data of patients who underwent laparoscopic excision of PS at our hospital between September 2012 and September 2021 were reviewed. All surgeries were performed in the general surgery department. Clinical data were collected from the inpatient and outpatient medical records.

RESULTS: In total, 12 patients (median age, 52 years) underwent laparoscopy for PS without conversion to laparotomy. Eight cases of tumors were located in the presacral space, and the others were found in the lateral wall of the pelvis (N=4). The median operative time was 145 (range, 70–215) minutes, with a median blood loss of 35 (range, 5–200) mL. Among all cases, 3 patients experienced minor postoperative complications. The median postoperative hospital stay was 4 (range, 2–7) days. Moreover, postoperative pathological examinations showed that all PSs were benign. No patient experienced local recurrence during a median follow-up period of 32 (range, 2–106) months.

CONCLUSIONS: Our findings indicate that laparoscopic resection of PS is feasible, which has a significant advantage in enhancing the accessibility of pelvic structures and preserving nerve and vascular integrities.

INTRODUCTION
Schwannomas are almost invariably slow-growing, nonaggressive neoplasms. Histologically, typical schwannomas are composed of intermixed Antoni A components (cellular and arranged in short bundles or interlacing fascicles) and Antoni B areas (less cellular and organized with more myxoid components). Schwannomas are often large at diagnosis and are frequently locally advanced for malignant tumors. Schwannomas are generally located in the head and neck, mediastinum, and extremities and are extremely rare in the pelvis. Patients with pelvic schwannomas (PSs) are usually asymptomatic or have mild, nonspecific symptoms. They may complain of pelvic visceral pain, urgency, or altered bowel habits. Large lesions may lead to intestinal obstruction or urinary retention. Recently, owing to improvements in public health awareness and the broader application of new imaging examination techniques, the detection rates of PSs have increased dramatically.

However, it is difficult to distinguish between benign and malignant schwannomas accurately, and surgery remains the mainstay of treatment strategies for PS. The traditional approach may be anterior (from abdominal), posterior (from perineal), or combined, depending on the location of the tumor and its imaging characteristics. However, the anatomical structures of the pelvis are not readily accessible in traditional laparotomy. In the last few decades, laparoscopy has been gradually applied in the field of pelvic surgery. Laparoscopic surgery can provide magnified vision and a superior high-definition view, which can help reduce nerve or vascular injury and enhance postoperative recovery. We conducted a retrospective cohort study with the largest number of PS cases who had undergone laparoscopic surgery to date, and analyzed our findings within the context of the current literature on the topic. Our study provided a better picture of the feasibility and safety of laparoscopic surgery in patients with PS.

Key words
Laparoscopic surgery
Pelvic schwannoma
Surgical approach
Treatment strategy

Abbreviations and Acronyms
CD: Clavien–Dindo
CT: Computed tomography
MRI: Magnetic resonance imaging
PS: Pelvic schwannoma

From the Departments of ¹General Surgery, ²Orthopedic, and ³Pathology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China
To whom correspondence should be addressed: Bin Wu, M.D.
[E-mail: wubin0279@hotmail.com]
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MATERIALS AND METHODS

Patients

From September 2012 to September 2021, 12 patients with PS underwent laparoscopic resections performed by experienced colorectal surgeons at the Peking Union Medical College Hospital (Beijing, China). None of the patients had a preoperative biopsy. The clinical features and imaging findings, including ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI), were used for preoperative diagnoses. Basic information (age, sex, and body mass index), clinical presentation, physical examination, imaging and tumor characteristics (location, size, and staging), surgical information (operative time, amount of blood loss, and conversion to laparotomy), final pathological diagnosis, perioperative complications (Clavien–Dindo classification of surgical complications were used to assess the postoperative adverse events), length of postoperative hospital stay, and mortality were extracted from inpatient and outpatient medical records. Information was supplemented through a telephone interview with the patient, if necessary. This study was approved by the Ethics Committee of Peking Union Medical College Hospital (SK-1493).

Surgical Procedure

The predominant bowel preparation method was utilized through the use of polyethylene glycol electrolyte powder in the afternoon before the operation, antibiotic prophylaxis was administered to reduce the risk of postoperative infection, and rectal repair or resection could be safely performed. Postoperative interventions included nutritional support and on-demand analgesia.

After general anesthesia, the patients were repositioned in the Trendelenburg position, which facilitated the removal of the small bowel and omentum into the upper abdominal cavity. Five ports were placed during the laparoscopic portion of the surgery. Once the tumor was identified, it was separated from its attachments to the adjacent structures with a harmonic scalpel. Layers of fibrous tissue were carefully incised to reveal the true capsule of the lesion. After the nerve was identified and well protected, the tumor capsule was incised with the hook. Then, the tumor contents were enucleated using grasping forceps until the tumor was removed entirely. For presacral tumors, based on the location of the tumor, an incision was made along the left (or right) side of the mesorectum, exposing the retrorectal space, dissection through the anterior mesorectum and posterior presacral fascia plane was performed to avoid rectal and iliac vessels and venous plexus injury. A laparoscopic retrieval bag was used to prevent spillage and specimen extraction. The drain can be placed in the primary tumor location and brought out through a trocar incision, if necessary.

For tumors at any site, the nerves are carefully separated during surgery to ensure as little damage as possible and are reexamined after complete removal of the tumor to ensure the nerves remain intact. The procedures were performed by senior professors from the colorectal surgery center at this tertiary teaching hospital.

Statistical Analysis

All clinical data were normalized using means and medians for continuous data and counts (percentage) for discrete data. Data management and analysis were performed using SPSS (version 26.0; SPSS Inc., Chicago, Illinois, USA).

RESULTS

Patient and Tumor Characteristics

Twelve patients underwent laparoscopic resection of the PS over the entire study period. Table 1 presents an overview of the patient and tumor characteristics. Most patients were females (n = 10), with a median age of 52 (range, 30–66) years. In this study, the body mass index ranged from 20.4–26.8 (median 23.9) kg/m². Only 3 patients were symptomatic with nonspecific abdominal pain, whereas, the others were detected through health screening. No preoperative neurological symptoms or deficits in patients.

Preoperative pelvic imaging was used to assess the locations by CT or MRI. More than half of the tumors (N = 8) were located in the presacral space (Figure 1A), and the others (N = 4/12) were found in the lateral wall of the pelvis (N = 4, Figure 1B and C). All 12 schwannoma tumors had well-defined, smooth margins. The tumors in 7 patients presented homogeneous density. Nine patients underwent carcinoembryonic antigen tests before surgery, which revealed a negative result. None of the patients had a preoperative biopsy.

Surgical Procedure and Postoperative Course

In all cases, there was no conversion to laparotomy in any patient in this study. Figure 2 shows the screenshots from the surgical videos. The median operative time was 145 (range, 70–215) min. No postoperative mortality was observed. The median blood loss in this study was 35 (range, 5–200) mL. The average blood loss was minimal, and no patient received intraoperative or postoperative blood transfusions.

In our study, minor lower extremity nerve pain in 2 patients (patient nos. 5 and 10) and complete disappearance of symptoms before discharge (CD grade I) were observed. One patient (patient no. 9), who had slight loss of sensory and motor adductor functions in the lower extremity, recovered after 1 month (CD grade II), and distinctive manifestation combined with imaging examinations helps verify the tumor from the obturator nerve. In the patient with presacral schwannoma (patient no. 2), during the preoperative assessment, the tumor closely connected to the rectum, and tumor resection with anterior resection of the rectum combined with ileostomy was performed. The patient underwent abdominal water-soluble contrast enema and abdominal CT scan 3 months after the surgery, revealing the absence of rectal fistula and restoration of intestinal continuity.

Pathological Examination and Follow-Up

The median diameter of the tumors was 41 (range, 30–100) mm. The Final pathological examination showed that all tumors were benign and consistent with the preoperative radiological diagnosis. Immunohistochemistry revealed intense staining with S100, confirming the diagnosis of schwannoma (Figure 3). The postoperative hospital stay time ranged from 2–7 (median, 4) days. Following surgical resection, with a median follow-up of 32 (range, 2–106) months, no local recurrence was observed.
Table 1. Perioperative Findings of 12 Patients Undergoing Laparoscopic Approach for Pelvis Schwannoma

| Case | Age (Years), Sex | BMI (kg/m²) | Presentation | CEA | Diameter (mm) | Homogeneity | Operative Time (minute) | Blood Loss (mL) | PHS (day) | Tumor Location | Postoperative Complication | Follow-Up (month) |
|------|-----------------|-------------|--------------|-----|---------------|-------------|-----------------------|-----------------|-----------|---------------|---------------------------|------------------|
| 1    | 63, F           | 22.7        | None         | None| 63            | Homogeneous | 130                   | 15              | 4         | Presacral     | None                      | 106              |
| 2    | 60, F           | 23.6        | None         | Negative| 30       | Homogeneous | 200                   | 200             | 6         | Presacral     | None                      | 78               |
| 3    | 38, M           | 20.4        | Abdominal pain | Negative| 40      | Hetero/cystic| 140                   | 200             | 5         | Lateral       |                           |                  |
| 4    | 30, F           | 24.2        | None         | None| 30            | Hetero/cystic| 215                   | 5               | 6         | Lateral       |                           |                  |
| 5    | 41, M           | 23.3        | Abdominal pain | Negative| 30      | Hetero/cystic| 160                   | 20              | 4         | Presacral     | Nerve pain               | 38               |
| 6    | 50, F           | 26.8        | None         | Negative| 43       | Homogeneous | 135                   | 50              | 2         | Presacral     | Nerve pain               | 36               |
| 7    | 51, F           | 23.6        | None         | Negative| 47       | Homogeneous | 120                   | 120             | 4         | Presacral     | None                      | 28               |
| 8    | 54, F           | 24.8        | Abdominal pain | Negative| 100     | Homogeneous | 120                   | 10              | 5         | Presacral     | None                      | 26               |
| 9    | 66, F           | 26.4        | None         | Negative| 57       | Hetero/cystic| 165                   | 5               | 5         | Presacral     | None                      | 13               |
| 10   | 57, F           | 26.8        | None         | Negative| 70       | Homogeneous | 160                   | 50              | 7         | Presacral     | None                      | 11               |
| 11   | 65, F           | 25.8        | None         | None| 33            | Homogeneous | 130                   | 50              | 4         | Obturator     | Mild lower extremity sensory and motor deficits | 2                |
| 12   | 35, F           | 23.3        | None         | Negative| 37      | Homogeneous | 100                   | 15              | 4         | Lateral wall of pelvis | None                      | 2                |

BMI, Body mass index; CEA, carcinoembryonic antigen; PHS, postoperative hospital stay.
Moreover, no chronic complications related to the procedure were noted during the entire follow-up.

DISCUSSION

This study’s initial objective was to assess the feasibility and advantages of laparoscopy for the treatment of PS. In total, 12 patients with PS underwent laparoscopic resection at our institution. There was no patient conversion to laparotomy or postoperative mortality. Only 3 patients had minor postoperative complications. Following surgical resection, with a median follow-up of more than 2 years, no local recurrence or other chronic symptoms were recorded. Laparoscopy is a safe and superior technique for patients with PS.

Schwannomas are often found incidentally or present with nonspecific symptoms. Due to its rare occurrence, few physicians with experience treat PS appropriately. With the increasing performance of imaging examinations and new techniques emerging, more asymptomatic patients with schwannoma will be uncovered. In this study, all tumors were benign. However, malignant schwannomas can arise incidentally or transform to malignant schwannomas in patients with type II neurofibromatosis. The optimal treatment strategies for malignant schwannoma remain controversial, and the 5-year survival rate remains poor after receiving adjuvant chemotherapy or radiation. High-risk patients diagnosed with neurofibromatosis and von Recklinghausen’s disease may require earlier detection to avoid malignant transformation. The narrow space of the pelvic

Figure 1. MR images of patients (A) Benign presacral schwannoma in a 63-year-old woman (patient no. 8). MR images show homogeneity and independence from the sacrum. T1-weighted images after administration of contrast medium show enhancement of the solid elements of the tumor. (B) Left-side lateral wall of schwannoma in a 35-year-old woman (patient no. 12). MR images show a homogeneous, well-defined spherical mass that is isointense on T1-weighted imaging and hyperintense on T2-weighted imaging. (C) Right-side lateral wall of pelvis schwannoma in a 65-year-old woman (patient no. 11). MR images are isointense on T1-weighted imaging, and T2-weighted MR images show a central high signal within the mass (considering penetration effects). MR, magnetic resonance.
cavity may compress the surrounding tissues when the tumor enlarges, which will probably lead to corresponding clinical symptoms, so we recommend early removal after detection.

With the development of imaging technologies, preoperative diagnosis is more accurate than ever. This is another reason to avoid preoperative biopsy. Spiral CT scans and MRI, especially...
sagittal plane images, are beneficial in defining PS. Its primary objective is to demonstrate the characteristic features of the tumor, contributing to the differentiation between benign and malignant tumors, and correct diagnosis. The specific radiologic features of schwannomas have not been described in detail. However, MRJ findings may show calcification, isointense signal on the adjacent skeletal muscle on T1-weighted images, hyperintense signal on T2-weighted images, heterogeneous contrast enhancement due to hemorrhagic changes, and cystic appearance. Recent research has established that MRJ for malignant disease has a sensitivity and specificity of 81% and 83%, respectively, and could assess the surrounding tissue planes. In this study, all patients who underwent MRJ examinations showed well-defined smooth margins. In addition, MRJ provides assessment of adjacent structure invasion of the sacrum, pelvic sidewall, and pelvic viscera, or other organs. Second, the tumor size was evaluated in 3-dimension. Finally, the internal signal characteristics and tumor margins were used to reveal tumor morphology. Based on our experience, preoperative MRJ is one of the best and most frequently used imaging techniques for assessing PS.

The tumor location in the sacrum, its relationship with the pelvic sidewall or adjacent viscera, tumor type or tumor stage, and tumor size were used to determine the surgical approach for pelvic tumors. Previous research reported that the excision rate was higher (77%) when combined with anterior or posterior techniques for PS. In addition, a single method was associated with an increased risk of damage to neighboring typical anatomic structures. In our experience, the laparoscopic procedure could be performed in patients with any PS, as long as the tumor does not invade a vital organ, making it intractable. Recently, patients underwent 3-dimensional (3D) laparoscopy instead of 2D laparoscopy, providing a more detailed 3D vision, which is more useful in identifying and sparing the nerves or vessels in the pelvis. In addition, laparoscopy offers additional technical advantages that are particularly important in pelvic surgery, that is, more accurate dissection, minor tissue trauma, less pain, shorter hospitalizations, and better cosmetic results. For example, the most distal dissection is often challenging to complete under direct view with laparotomy in a narrow male pelvis. Several positional changes are required to complete the operation safely in traditional approaches. The technical benefit of laparoscopy is to overcome the difficulties caused by complex pelvic anatomicies, such as the presacral space or the use of cautery near the obturator nerve. Cutting and placing a clip on the obturator nerve during traditional excisional surgery with a restricted field of view may cause accidental injury. In this study, approximately half of the tumors were located in the presacral space. The creation and maintenance of a pneumoperitoneum performed in laparoscopic surgery help clear visibility on the dissection plane when entering the presacral area. Laparoscopy can detect and repair the tissue with the same mini-incision if undesired organ trauma occurs. Moreover, laparoscopy provides visualization for the hemostasis of iliac vessels and the venousplexus in the presacral space. In addition, the magnified view of the laparoscope offers better visualization of the autonomous nerves that exist in this area. It allows more precise preservation, significantly reducing the risk of erectile dysfunction and/or urinary incontinence due to accidental injury to the autonomic nerves of the pelvis or the autonomic neurovascular bundles.

Complete surgical resection is the standard treatment for schwannomas. However, controversy exists over the complete removal and preservation of maximal neurologic function. Regarding the extent of resection, the research to date has detected an increase in the risk of neurologic deficit for complete excision with adjacent tissue. However, complete excision resulted in lower local recurrence and malignant transformation rates. Another study noted a 16% recurrence rate with subtotal removal in sacral schwannoma resection. Enucleation of the PS as the main surgical strategy was used in all patients in this study. The primary treatment for PS consists of maximal safe resection with preservation of neurologic function. Although intraoperative nerve protection has been enhanced, perioperative complications occurred in 3 patients. Patients had grade I or grade II perioperative complications and recovered within 1 month without permanent neurological deficits. Based on the follow-up data from this trial, none of the patients experienced recurrence. Based on a combination of clinical signs, symptoms, and outpatient consultations information, intraoperative surgical manipulation may still cause slight damage to the nerve, and postoperative local tissue edema may aggravate the patient’s clinical symptoms. Therefore, it is imperative to raise our surgical standards and combined multidisciplinary care is recommended for these patients to reduce the incidence of perioperative complications and accelerate postoperative recovery. A neurosurgeon with extensive experience in nerve sheath tumor surgery would play a crucial role in obtaining better neurological outcomes on a larger scale. In patients with benign PS, postoperative follow-up is recommended to complete imaging of the primary tumor site at 3 months and 1 year to rule out postoperative recurrence and malignant transformation. All perioperative complications and follow-up data indicated that enucleation for PS under laparoscopy is feasible.

Laparoscopic pelvic tumor surgery requires technical dexterity and a long learning curve. The prevention of most congenital injuries depends on specialized training, whereas, the incidence of complications is directly related to the surgeon’s experience. Existing research recognizes the critical role of intraoperative neuromonitoring to decrease neural tissue damage. The pelvis is a narrow space and it is made up of complex anatomical structures with complicated multi-organ nature across multi-systems. If the tumor is adjacent to vital organs or tissues, such as iliac vessels, ureter, sacral plexus, etc. will require the assistance of a specialist surgeon. The preoperative combination of the tumor’s adjacent features will significantly influence the preoperative preparation, the choice of surgical approach, and the specific intraoperative surgical strategy. Intraoperative involvement of a specialist surgeon is required when it is necessary to ensure surgical safety and better quality of life for the patient. In addition, multidisciplinary services are an important component of postoperative follow-up, adjuvant therapy, and long-term monitoring. Given the complexity and specialized tumor locations of such surgery, treatment should be performed by an experienced surgeon in the management of retrorectal tumors, and each patient should consult a vascular surgeon, orthopedic surgeon, urologist, and neurosurgeon, if necessary.
The generalizability of these results is subject to certain limitations. For instance, its small retrospective studies from a single-center design may introduce ascertainment bias. Unfortunately, the study did not include laparotomy for PS as a control. The sample size of this study was small owing to its low incidence rate. Nevertheless, the study described the most extensive series of laparoscopic approaches for PS to date. A multicenter study is needed to involve large randomized, controlled trials that could provide more definitive evidence of the benefit of laparoscopy in patients with PS.

CONCLUSIONS
In conclusion, as a retrospective cohort study of the largest number of PS cases, who had undergone laparoscopic surgery to date, the empirical findings in this study provide a new understanding of the laparoscopic approach for PS. Laparoscopy has shown a clear-cut positive effect as a minimally invasive procedure, lower complication rates, and shorter recovery times compared to traditional surgical procedures.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT
Chao lin Deng: Data curation. Writing — original draft. Pei pei Wang: Visualization. Yong Liu: Investigation. Xi Yu: Sun: Investigation. Xi Zhou: Investigation. Yan You: Resources. Investigation. Bin Wu: Conceptualization. Project administration. Supervision. Funding acquisition.

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