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# Minimally Invasive Tubular Retractor Surgery for Intradural Extramedullary Spinal Tumor Reduces Postoperative Degeneration of Paraspinal Muscle

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## Abstract

**Background** Minimally invasive surgery (MIS) using a tubular retractor has been increasingly utilized in spinal surgery for degenerative conditions with the benefit of paraspinal muscle preservation. This benefit has not been previously reported for intradural extramedullary tumors using the MIS approach. In this study, we aimed to compare the degree of postoperative fatty degeneration in paraspinal muscle between MIS with tubular retractor (MIS) and open laminectomy (Open) for intradural extramedullary spinal tumors.

**Methods** This was a retrospective review conducted in a tertiary neurosurgical center from 2015 to 2019. The degree of paraspinal muscle fatty degeneration, as measured by Goutallier grade on postoperative magnetic resonance imaging (MRI), was analyzed, and the degree of excision, tumor recurrence rate, and chronic pain were compared between the two surgical approaches.

**Results** Among 9 patients in the MIS group and 33 patients in the Open group, the rate of gross total resection was comparable (MIS: 100.0%, Open: 97.0%, $p = 1.000$). The degree of paraspinal muscle fatty degeneration was significantly reduced in the MIS group (median Goutallier grade 1 in MIS group vs. median Goutallier grade 2 in Open group, $p = 0.023$). There was no significant difference in the tumor recurrence rate, complication rate, and chronic pain severity. A consistent trend of reduced analgesic consumption was observed in the MIS group, though not statistically significant.

**Conclusions** Minimally invasive tubular retractor surgery is an effective approach for appropriately selected intradural extramedullary spinal tumors with significantly reduced postoperative fatty degeneration in paraspinal muscle.

**Keywords**

- laminectomy
- magnetic resonance imaging
- minimally invasive surgical procedures
- paraspinal muscles
- spinal neoplasms

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## Introduction

Intradural extramedullary spinal tumors are pathologies that potentially cause severe neurological symptoms and functional impairment in adult patients. A recent epidemiological study in Hong Kong suggested an increasing trend of pathologically confirmed intraspinal schwannoma and meningioma, with annual case numbers of 0.70 per 100,000 population per year and 0.50 per 100,000 population per year respectively.[1] Open laminectomy (Open) for intradural extramedullary spinal tumor has been traditionally performed using midline incision and periosteal dissection for paraspinal muscles.[2] Minimally invasive surgery (MIS) was increasingly used for spinal procedures with adequate decompression and long-term stabilization achieved.[3,4] The reduced muscle dissection and retraction, minimized multifidus muscle detachment from the spinous process, preservation of the dorsolumbar fascia, and limited bony structure removal attribute to the mechanical and biological stability of the spinal column.[4] Reduced multifidus muscle signal change was observed in patients who received posterior lumbar interbody fusion by MIS.[5] The feasibility of MIS for intradural spinal pathologies has been evaluated in previous studies with evidence of reduced intraoperative blood loss, reduced risk of cerebrospinal fluid (CSF) leak, and shortened postoperative length of stay.[6–8] However, there was no published evidence in the literature suggesting the benefit of the MIS approach on the preservation of paraspinal muscles for intradural spinal pathologies. We started the MIS for intradural spinal tumors in our hospital in 2015, and this study was the first of its kind to review the difference in the degree of paraspinal muscle degeneration between the two surgical approaches by the postoperative magnetic resonance imaging (MRI) studies.

## Patients and Methods

This was a single-center retrospective cohort study comparing the fatty degeneration of paraspinal muscle for patients with intradural extramedullary spinal tumors who underwent MIS with tubular retractor (MIS) or Open. The test hypothesis was whether MIS could reduce paraspinal muscle fatty degeneration on postoperative MRI. The study was conducted with coherence to the STROBE guideline.[9] The retrospective study protocol was approved by the Institutional Research Ethics Committee with the patient consent waived, as this research was based on secondary analysis of existing data and images with no additional risk to patients.

We retrospectively reviewed consecutive patients who underwent surgeries for excision of intradural extramedullary spinal tumor in a tertiary neurosurgical center in Hong Kong using the Clinical Data Analysis and Reporting System from the hospital database from January 1, 2015, to December 31, 2019. Patients with intradural extramedullary spinal tumors as confirmed by preoperative contrast MRI who underwent surgical excision, either by MIS or Open, and subsequently assessed in neurosurgical clinic with postoperative MRI performed were included. The feasibility of an intradural spinal tumor for MIS was based on the morphology, size, and craniocaudal expansion. Based on our experience, lesions that could not be managed by MIS include tumors with craniocaudal expansion more than two vertebral segments, craniocaudal size greater than 3.5 cm, or tumors with extraforaminal extension, that is, dumbbell-shaped lesions. Patients with no postoperative imaging or history of previous spinal surgery at the level of index lesion, by either MIS or open approach, would be excluded. The lesions with final pathologies being not intraspinal neoplasm which include degenerative disease, infection, or hematoma were also excluded. Intradural tumors with long craniocaudal expansion or extraforaminal expansion were not amenable to the MIS approach and were treated by Open in our practice. These cases were further excluded to achieve a matched comparison between MIS and Open.

Demographic data, including patient's age at operation, gender, and duration of preoperative symptoms, were retrieved. Patients' neurological symptoms were summarized from the admission notes and the neurological deficits were assessed by neurosurgeons and physiotherapists independently. The sizes of the lesions were retrieved from the formal preoperative MRI reports with transverse (TS), anteroposterior (AP), cranial-caudal (CC) diameters measured in centimeters. Intraoperative blood loss, operation time, the degree of excision (gross total resection or partial resection), tumor histology, and the World Health Organization (WHO) grade, and Simpson's grade of excision for meningioma cases were retrieved from operation records and pathology reports. The primary outcome in our study was the postoperative paraspinal muscle fatty degeneration, as assessed on the MRI taken at approximately postoperative 1 year. The fatty degeneration of paraspinal muscle was assessed from the axial T1-weighted noncontrast MRI. The amount of fatty infiltration to the transversospinalis muscle, including rotatores, multifidus, and semispinalis was graded by Goutallier classification from 0 to 4, as shown in ►**Table 1**.[10–12] Two individual assessors were blinded to the operation records and graded the degree of fatty degeneration independently. Cases with differences in the Goutallier grade would be referred to the senior author for assessment. Postoperative limb power was graded by physiotherapist and neurosurgeon independently using the Medical Research Council grade and the lower grade was adopted as the postoperative neurological status.[13] The change in the Medical Research Council (MRC) grade was calculated using postoperative MRC grade minus the preoperative MRC grade for the most affected myotome, and any case, with a decrease in the power postoperatively, was regarded as a new neurological deficit. Persistent neurological deficit was defined as any new neurological deficits lasting more than 2 weeks after the operation. Preoperative and postoperative functional status of patients was assessed by the Japanese Orthopedic Association (JOA) scoring system and its modifications for cervical myelopathy (total 17 points), thoracic myelopathy (total 11 points), and back pain (total 29 points) for cervical, thoracic, and lumbar lesion, respectively.[14–16] Postoperative JOA score was assessed at 6 months after surgery and change

**Table 1** Illustration of Goutallier grading criteria by postoperative imaging in MIS and Open cases

| Goutallier grading | Case illustration | Description | Surgery |
|---|---|---|---|
| Grade 0 | ►**Fig. 1A** | No fat infiltration visible in the paraspinal muscle | MIS |
| Grade 1 | ►**Fig. 2A** | Fatty streaks infiltration in the paraspinal muscle | Open |
| Grade 2 | ►**Fig. 2B** | Fatty infiltration in the paraspinal muscle with fat less than muscle | Open |
| Grade 3 | ►**Fig. 2C** | Fatty infiltration in the paraspinal muscle with fat equals to muscle | Open |
| Grade 4 | ►**Fig. 2D** | Fatty infiltration in the paraspinal muscle with fat more than muscle | Open |

Abbreviations: MIS, minimally invasive surgery; Open, open laminectomy.

of JOA score was calculated by postoperative score minus preoperative score. Postoperative complications, including urinary tract infections, postoperative hemorrhage, pseudomeningocele, CSF leakage, central nervous system (CNS) infection, the need for a second surgery, deep venous thrombosis, persistent neurological deficit, and severe morbidity or mortality were reviewed. Any recurrence or residual tumor from the most recent MRI would be recorded. Complete excision was defined as gross total excision as declared intraoperatively with the subsequent postoperative MRI showing no residual or recurrence of the tumor. Chronic pain was assessed in the neurosurgical clinic and patients were inquired for the presence of persistent pain for more than 12 weeks at the operative level. The severity of pain was categorized into mild, moderate, and severe by patient and the usage of analgesics, including nongabatinoids (i.e., paracetamol, nonsteroidal anti-inflammatory drugs) or gabatinoids (i.e., gabapentin and pregabalin) analgesics were recorded. Strong opioids were generally not prescribed in the outpatient clinics in our practice. Patients with a concomitant spinal disease at or adjacent to the operative level were excluded from the pain analysis.

## Preoperative Evaluation, Operative Techniques, and Postoperative Surveillance

For each patient referred or admitted to our neurosurgical unit for symptomatic intradural spinal tumors, a comprehensive clinical, physical, and functional assessment was performed by neurosurgeons, physiotherapists, and occupational therapists. The surgical candidates were further discussed in the preoperative meeting with the diagnostic MRI reviewed by the operating team, including neurosurgical consultants, neurosurgical specialists, and neurosurgical trainees. The operative approach (either MIS or Open) was decided by the aforementioned lesion characteristics. The surgeon's expertise was considered for lesions suitable for both MIS and open surgery.

All open surgeries and MIS procedures were performed with the prone position under general anesthesia with standard intraoperative monitoring. For open surgery, a midline skin incision and subperiosteal dissection were performed for lamina exposure. After removal of the spinous process, laminectomy was performed with the underlying dura exposed. Intraoperative ultrasound was used as an adjunct to decide the adequacy of exposure. Dura was then opened in the midline and the lesion was debulked, dissected, and removed under the microscope. The dural attachment was cauterized if present and primary dural closure with 6-O Prolene (Ethicon, United States) was performed after hemostasis. The muscular fascia and skin were closed with 2-O Vicryl (Ethicon, United States) and 3-O Ethilon (Ethicon, United States) or skin staplers (Covidien, Ireland). The MIS surgery was performed via a paramedian incision. The blunt dissection was then directed toward the lamina and the dilator tubes were sequentially inserted from the smallest size until the tubular retractor system (Medtronic, United States) could be adequately inserted. Fluoroscopy was used to confirm the accuracy of the operating trajectory after the tubular retractor was inserted. Hemilaminectomy was performed in the MIS group with Kerrison Rongeur (Integra, Germany) and high-speed drills (Medtronic, United States). The tumor was then debulked, dissected, and removed. Dura attachment site was cauterized if present. Primary dural closure was then performed with 6-O Prolene (Ethicon, United States). A fibrin sealant, Beriplast P (CSL Behring, Germany) was routinely utilized to prevent CSF leakage. The muscle fascia was then closed with 2-O Vicryl (Ethicon, United States) and the skin was apposed with 3-O Ethilon (Ethicon, United States).

The patient was monitored in the neurosurgical unit after the operation and intensive rehabilitation was provided considering the physical status and functional requirement for an individual patient. Postoperative MRI was arranged and the patient was subsequently reviewed in the outpatient clinics. The duration from operation to MRI depended on the patient's neurological symptoms, tumor pathologies, and imaging availability. Most patients received their first postoperative MRI from 6 to 18 months after the operation. Subsequent surveillance imaging would be arranged in an approximate 2-year interval.

## Statistical Analysis

The fatty infiltration of paraspinal muscle was compared between the two surgical approaches by Mann–Whitney *U*-test as for other ordinal categorical data, including limb power and chronic pain severity. Continuous data, including symptoms duration, lesion size, operative time, blood loss, and follow-up duration were expressed in mean ± standard deviation and compared using an independent *t*-test. Categorical data were analyzed by Pearson's Chi-square test or Fisher's exact test as appropriate. Statistical significance was defined at a *p*-value of less than 0.05. Sample size estimation

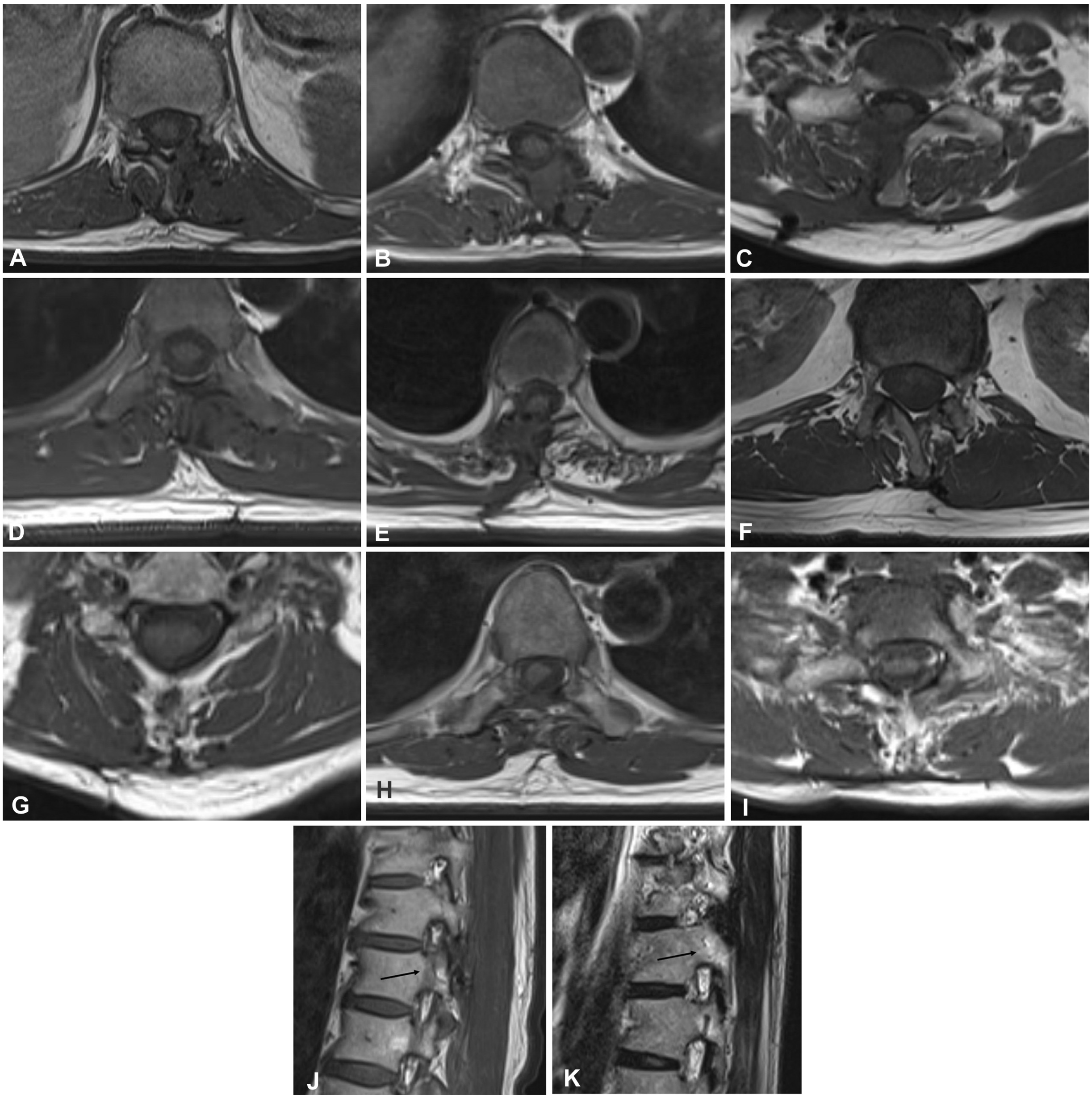



**Fig. 1** (**A–K**) Postoperative T1-weighted magnetic resonance imaging at the operative level for patients who underwent minimally invasive surgery for intradural extramedullary spinal tumors. (**A–D**) Cases with Goutallier grade 0 in MIS group, (**E**) the case with Goutallier grade 1 in MIS group. (**F–H**) Cases with Goutallier grade 2 in MIS group and patient in (**H**) received open surgery for epidural hematoma after MIS. (**I**) The case with Goutallier grade 3 in the MIS group. Facet joints were preserved in all cases. The facet joints were obscured by the axial cutting in (**A, B**), and the corresponding sagittal image (**J, K**) suggested intact facet joints respectively (the operative level was indicated by the *black arrow*).

was performed for the primary outcome at a significance level of 0.05, power of 0.80, and standard deviation of 0.80 as for nonparametric comparison, and two median grade differences in Goutallier grade could be detected by eight patients per treatment group.[17] The statistical analyses were performed by IBM SPSS Statistics for Macintosh (Version 26.0. Armonk, New York, United States: IBM Corp).

## Results

A total of 59 patients underwent spinal surgery with the preoperative diagnosis of intradural extramedullary spinal tumor from January 1, 2015, to December 31, 2019. Seventeen cases were excluded, including four cases with dumbbell-shaped tumors, six cases with craniocaudal size more than 3.5 cm, one case with a previous operation, five cases with final pathology being not a neoplasm (including one case of tuberculosis, two cases of capillary hemangioma, one case of histiocytosis, and one case of synovial cyst), and one case with no postoperative imaging. There were 42 patients including 14 male and 28 female patients. The age at operation was $62.4 \pm 14.3$ years among all patients. Limb weakness (71.4%) was the most common neurological symptom, followed by numbness (28.6%) and neuropathic pain (26.1%). A total of nine MIS and 33 open surgeries were performed. The final pathology included 25 meningiomas and 17

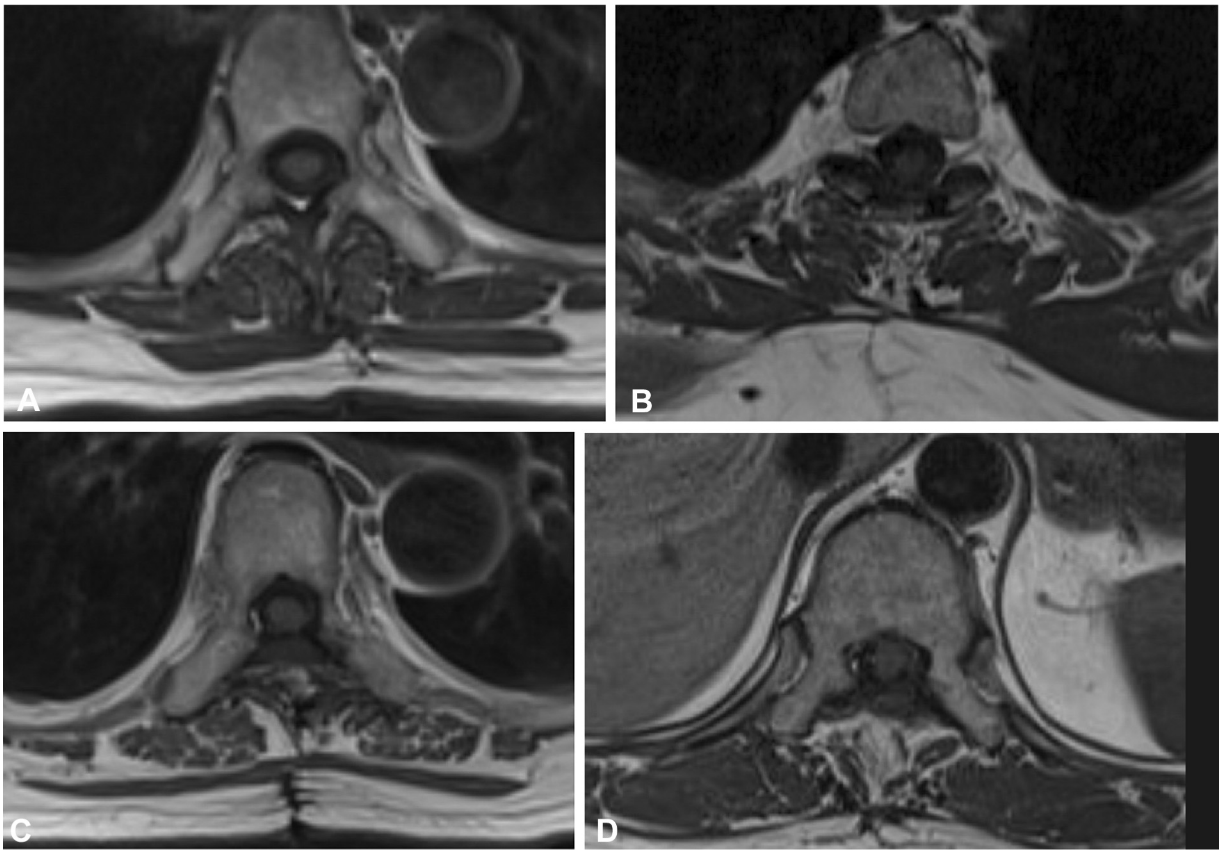



**Fig. 2** (**A–D**) Postoperative T1-weighted axial magnetic resonance imaging at the operative level for patients who underwent open laminectomy for intradural extramedullary spinal tumors. The degree of paraspinal muscle fatty degeneration was Goutallier grade 1 in (**A**), grade 2 in (**B**), grade 3 in (**C**), and grade 4 in (**D**).

schwannomas, and all meningiomas were of WHO grade I. The thoracic lesions were most common (71.43%), followed by cervical lesions (19.05%) and lumbar lesions (9.52%). The demographics of the patients, tumor sizes, and histology of lesions for the MIS group and Open group were listed in ►**Table 2**. There were no significant differences in age at surgery, preoperative limb power, lesion locations, sizes and pathologies, duration of neurological symptoms, and preoperative JOA scores. No paraspinal muscle degeneration existed on preoperative imaging.

The intraoperative time, blood loss, degree of excision, postoperative complication, neurological status, and length of stay were listed in ►**Table 3**. There were no significant differences in the intraoperative blood loss and operation time. Partial excision was performed in one patient with schwannoma in the open surgery group, as there was severe adhesion between the posterior part of the spinal cord and the tumor, and intraoperative motor evoke potential signal was affected by further dissection. Gross total excision was achieved for the other patients. No facet joints were involved during the surgeries in each group. All meningioma cases received Simpson grade II excision. There was no significant difference in postoperative limb power between the MIS group and the open group, with an overall one-grade improvement in MRC grade (MIS median = 1, Open median = 1, $p = 0.527$). The postoperative JOA scores and change of JOA scores were comparable in both groups. There was one patient in the MIS group complicated with postoperative epidural hematoma with laminectomy performed for clot evacuation. This patient suffered from a persistent neurological deficit with lower limb power of grade 2 compared with grade 5 preoperatively. The lower limb power of this patient subsequently improved to grade 4 after physiotherapy training. There was one patient who developed CSF leakage after Open with a second operation for dura repair performed. The patient subsequently recovered after the antibiotic treatment without persistent neurological deficit. There was no mortality case in our case cohort.

The results for paraspinal muscle degeneration were shown in ►**Table 4**. The postoperative images for cases operated with the MIS approach were shown in ►**Fig. 1A–K** and cases in the open surgery group were shown in ►**Fig. 2A–D** for illustration. The paraspinal muscle fatty degeneration was significantly reduced in the MIS group compared with the open group (MIS median Goutallier grade 1, range: 0–3; Open median Goutallier grade 2, range: 1–4, $p = 0.023$), as shown in ►**Fig. 3**. In the subgroup analysis, the differences in the degree of muscle degeneration remained significant for thoracic lesions (MIS median Goutallier grade 0, range: 0–2; Open median Goutallier grade 2, range: 1–4, $p = 0.002$), as shown in ►**Table 5**.

One patient with small residual enhancing nodules of 0.3 cm was noted in the MIS group. This patient was known to have multiple intraspinal neurofibromas. The patient with

**Table 2** Demographics, clinical assessment, and imaging characteristics between the MIS and Open groups

| | | Whole group | | MIS | | Open | | Statistics | *p* |
|---|---|---|---|---|---|---|---|---|---|
| Mean age at operation (y) | Mean ± SD | 62.4 | ± 14.3 | 59.8 | ± 14.8 | 63.2 | ± 14.3 | T | 0.553 |
| Gender | *n* (%) | | | | | | | Fisher | 0.133 |
| Male | | 14 | 33.3% | 5 | 55.6% | 9 | 27.3% | | |
| Female | | 28 | 66.7% | 4 | 44.4% | 24 | 72.7% | | |
| Neurological symptoms | *n* (%) | | | | | | | Fisher | |
| Limb weakness | | 30 | 71.4% | 4 | 44.4% | 26 | 78.8% | | 0.090 |
| Limb numbness | | 12 | 28.6% | 3 | 33.3% | 9 | 27.3% | | 0.699 |
| Neuropathic pain | | 11 | 26.1% | 4 | 44.4% | 7 | 21.1% | | 0.209 |
| Asymptomatic | | 2 | 4.8% | 1 | 11.1% | 1 | 3.0% | | 0.387 |
| Duration of neurological symptoms (mo) | Mean ± SD | 8.0 | ± 7.5 | 14.1 | ± 11.6 | 6.4 | ± 5.4 | T | 0.108 |
| Preoperative limb power by MRC grading | *n* (%) | | | | | | | MWU | 0.413 |
| Grade 0 | | 0 | 0.0% | 0 | 0.0% | 0 | 0.00% | | |
| Grade 1 | | 1 | 2.4% | 0 | 0.0% | 1 | 3.03% | | |
| Grade 2 | | 2 | 4.8% | 2 | 22.2% | 0 | 0.00% | | |
| Grade 3 | | 12 | 28.6% | 1 | 11.1% | 13 | 39.4% | | |
| Grade 4 | | 16 | 38.1% | 1 | 11.1% | 11 | 33.3% | | |
| Grade 5 | | 11 | 26.2% | 5 | 55.6% | 8 | 24.2% | | |
| Lesion location | *n* (%) | | | | | | | Fisher | 0.962 |
| Cervical | | 8 | 19.0% | 2 | 22.2% | 6 | 18.2% | | |
| Thoracic | | 29 | 69.1% | 6 | 66.7% | 23 | 69.7% | | |
| Lumbar | | 5 | 11.9% | 1 | 11.1% | 4 | 12.1% | | |
| Preoperative JOA score | Mean ± SD | | | | | | | T | |
| Cervical | | 11.9 | ± 2.0 | 11.5 | ± 2.1 | 12.0 | 2.2 | | 0.804 |
| Thoracic | | 7.0 | ± 2.2 | 8.2 | ± 2.1 | 6.7 | 2.2 | | 0.185 |
| Lumbar | | 17.0 | ± 6.4 | 8.0 | – | 19.3 | 4.6 | | 0.119 |
| Lesion size (cm) | Mean ± SD | | | | | | | T | |
| Transverse | | 1.46 | ± 0.50 | 1.37 | ± 0.41 | 1.48 | ± 0.53 | | 0.523 |
| Anteroposterior | | 1.19 | ± 0.33 | 1.24 | ± 0.35 | 1.17 | ± 0.33 | | 0.643 |
| Craniocaudal | | 1.73 | ± 0.58 | 1.81 | ± 0.54 | 1.70 | ± 0.60 | | 0.604 |
| Pathology | *n* (%) | | | | | | | | 0.124 |
| Meningioma | | 25 | 61.9% | 3 | 33.3% | 22 | 66.7% | | |
| Schwannoma | | 17 | 38.0% | 6 | 66.7% | 11 | 33.3% | | |
| Follow-up durations (mo) | Mean ± SD | 42.4 | ± 19.5 | 34.6 | ± 11.6 | 44.5 | ± 20.7 | | 0.075 |

Abbreviations: Fisher, Fisher's exact test; JOA, Japanese Orthopaedic Association; MIS, minimally invasive surgery; MRC grading, medical research council grading; MRI, Magnetic resonance imaging; MWU, Mann–Whitney *U*-test; Open, open surgery; SD, standard deviation; T, independent *t*-test.
Note: Statistical significant was set at $p < 0.05$.

partial excision of the schwannoma in the open group, due to severe adhesion to the spinal cord, had a residual lesion of 0.3 (AP), 0.4 (TS), and 1.8 cm (CC) was noted on the postoperative imaging. Another patient in the open group had a recurrent enhancing nodule of 0.4 cm noted in the postoperative MRI. There was no significant difference in the residual or recurrent rate between the two groups (MIS, 11.1% vs. Open, 6.1%, $p = 0.525$) and a complete excision rate was 88.9% in the MIS group and 93.9% in the open surgery group, respectively.

Eight patients in the MIS group and 32 patients in the Open group were eligible for pain analysis. Excluded cases were one patient in the MIS group with new spinal bony metastasis and one patient in the Open group with lumbar spine degeneration and orthopaedic instrumentation performed. The distribution of patients with chronic

**Table 3** Intraoperative details, postoperative length of stay, and complications for MIS and Open groups

| | | MIS | | Open | | Statistics | *p* |
|---|---|---|---|---|---|---|---|
| Blood loss (mL) | Mean ± SD | 150 | ± 112 | 166 | ± 87 | T | 0.697 |
| Operation time (min) | Mean ± SD | 192 | ± 71 | 200 | ± 55 | T | 0.732 |
| Length of stay (d) | Mean ± SD | 11.6 | ± 15.8 | 10.3 | ± 9.3 | T | 0.830 |
| Degree of excision | | | | | | Fisher | |
| Gross total excision | | 9 | 100.0% | 32 | 97.0% | | 1.000 |
| Partial excision | | 0 | 0.0% | 1 | 3.0% | | |
| Postoperative power by MRC grading | *n* (%) | | | | | MWU | 0.861 |
| Grade 0 | | 0 | 0.0% | 0 | 0.0% | | |
| Grade 1 | | 0 | 0.0% | 0 | 0.0% | | |
| Grade 2 | | 2 | 22.2% | 1 | 3.0% | | |
| Grade 3 | | 1 | 11.1% | 1 | 3.0% | | |
| Grade 4 | | 0 | 0.0% | 12 | 36.3% | | |
| Grade 5 | | 6 | 66.6% | 19 | 57.6% | | |
| Change in MRC grading | Median (mean rank) | 1 | 13.80 | 1 | 16.42 | MWU | 0.527 |
| Postoperative JOA Score | Mean ± SD | | | | | | |
| Cervical | | 13.5 | ± 3.5 | 15.3 | ± 1.4 | T | 0.804 |
| Thoracic | | 10.5 | ± 0.8 | 9.8 | ± 1.2 | | 0.142 |
| Lumbar | | 12.0 | – | 27.5 | ± 0.60 | | – |
| Change of JOA score | Mean ± SD | | | | | | |
| Cervical | | 2.0 | ± 1.4 | 3.3 | ± 1.4 | T | 0.383 |
| Thoracic | | 2.3 | ± 1.8 | 3.1 | ± 1.7 | | 0.375 |
| Lumbar | | 4 | – | 8.3 | ± 4.2 | | – |
| Major complications | *n* (%) | – | | | | Fisher | |
| Urinary tract infection | | 0 | 0.0% | 1 | 3.0% | | 1.000 |
| Postoperative hemorrhage | | 1 | 11.1% | 0 | 0.0% | | 0.214 |
| Pseudomeningocele | | 0 | 0.0% | 1 | 3.0% | | 1.000 |
| CSF leakage | | 0 | 0.0% | 1 | 3.0% | | 1.000 |
| CNS Infection | | 0 | 0.0% | 1 | 3.0% | | 1.000 |
| Need of second surgery | | 1 | 11.1% | 1 | 3.0% | | 0.407 |
| Deep vein thrombosis | | 0 | 0.0% | 0 | 0.0% | | 1.000 |
| Persistent neurological deficit | | 1 | 11.1% | 1 | 3.0% | | 0.407 |
| Mortality | | 0 | 0.0% | 0 | 0.0% | | 1.000 |

Abbreviations: CSF, cerebrospinal fluid; CNS, central nervous system; Fisher, Fisher's exact test; JOA, Japanese Orthopaedic Association; MRC, Medical Research Council; MIS, minimally invasive surgery; MWU, Mann–Whitney *U*-test; Open, open surgery; SD, standard deviation; T, independent *t*-test.

pain after MIS and Open surgery was comparable as shown in ►**Table 4**. One patient in the MIS group with three patients in the Open surgery group had persistent moderate pain after surgery. The patient in the MIS group with moderate pain was the complicated case with open laminotomy performed for evacuation of epidural hematoma. No patients in the MIS group required regular gabapentinoids for pain control, while three patients in the Open group required these strong analgesics ($p = 0.502$).

## Discussion

Currently, there is limited literature on the clinical evidence of paraspinal muscle preservation from the MIS approach, and this is the first study to describe a significant reduction in paraspinal muscle fatty degeneration with MIS for intradural extramedullary spinal tumors. Ohtori et al reported that fatty infiltration was the most common type of paraspinal muscle signal change on postoperative MRI.[18] He et al suggested that there was an association of low back pain

**Table 4** Assessment outcomes from postoperative magnetic resonance imaging and pain conditions for minimally invasive surgery group and open surgery group

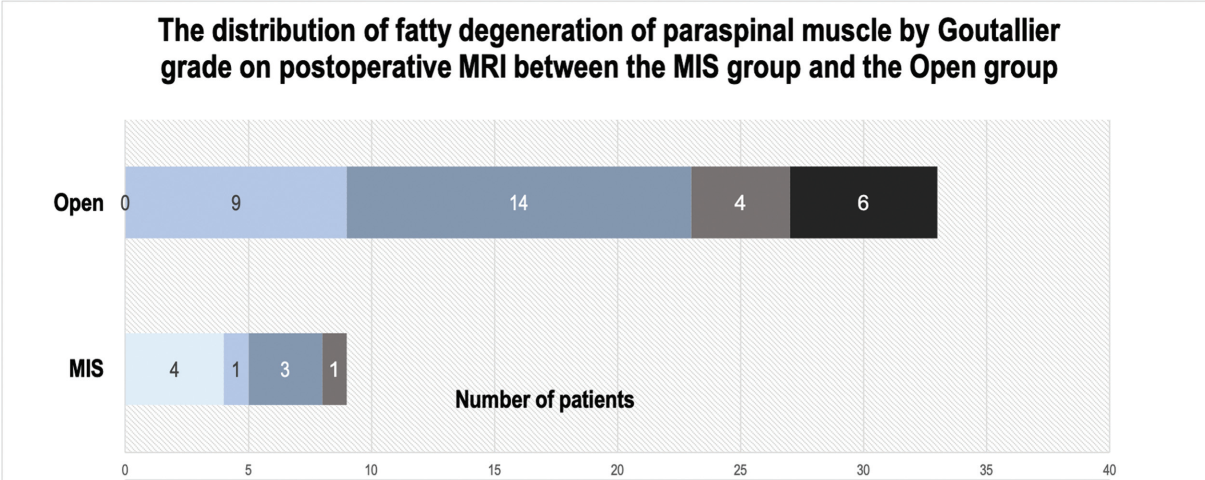
| | | MIS | | Open | | Statistics | *p* |
|---|---|---|---|---|---|---|---|
| Paraspinal muscle fatty degeneration on MRI | Median (mean rank) | 1 | 13.61 | 2 | 23.65 | MWU | 0.023[b] |
| | *n* (%) | | | | | | |
| Goutallier grade 0 | | 4 | 44.4% | 0 | 0.0% | | |
| Goutallier grade 1 | | 1 | 11.1% | 9 | 27.3% | | |
| Goutallier grade 2 | | 3 | 33.3% | 14 | 42.4% | | |
| Goutallier grade 3 | | 1 | 11.1% | 4 | 12.1% | | |
| Goutallier grade 4 | | 0 | 0.0% | 6 | 18.2% | | |
| Duration from operation to assessment MRI (mo) | Mean ± SD | 12.4 | ± 9.6 | 15.9 | ± 9.9 | T | 0.355 |
| Residual or recurrent tumor on most recent MRI | *n* (%) | | | | | Fisher | 0.525 |
| Residual/recurrent rate | | 1 | 11.1% | 2 | 6.1% | | |
| Complete excision rate | | 8 | 88.9% | 31 | 93.9% | | |
| Maximal diameter of residual tumor (cm) | | 0.3 | | 1.8 | | | |
| Maximal diameter of recurrent tumor (cm) | | – | | 0.4 | | | |
| Duration from operation to most recent MRI | | 19 | ± 16.5 | 26.1 | ± 19.3 | T | 0.308 |
| Chronic pain | *n* (%)[a] | | | | | MWU | 0.697 |
| No pain | | 6 | 75% | 21 | 65.6% | | |
| Mild pain | | 1 | 12.5% | 8 | 25.0% | | |
| Moderate pain | | 1 | 12.5% | 3 | 9.4% | | |
| Severe pain | | 0 | 0.0% | 0.0% | 0.0% | | |
| Regular use of analgesics | *n* (%)[a] | | | | | Fisher | |
| Gabapentinoids | | 0 | 0.0% | 3 | 9.4% | | 0.502 |
| Nongabapentinoids | | 1 | 12.5% | 4 | 18.8% | | 0.694 |
| Any analgesics | | 1 | 12.5% | 6 | 18.8% | | 0.569 |

Abbreviations: Fisher, Fisher's exact test; MIS, minimally invasive surgery; MRI, magnetic resonance imaging; MWU, Mann–Whitney *U*-test; Open, open surgery; SD, standard deviation; T, independent *t*-test.
[a]Pain analysis was performed in 8 patients in MIS group and 32 patients in the open group.
[b]$p < 0.05$.

with decreased size of muscle cross-sectional area on axial scan and increased fat infiltration in the paraspinal muscle after spinal surgery for degenerative diseases.[19] Fan et al reported a significantly reduced muscle atrophy for patients who underwent posterior lumbar interbody fusion at postoperative 6 months with minimally invasive approach.[5] In our study, we used Goutallier grade as a qualitative assessment for the degree of fatty degeneration of paraspinal muscle. In the subgroup analysis for tumors at different levels of spinal canals, paraspinal atrophy was significantly reduced for thoracic lesions, and a trend of reduced paraspinal muscle atrophy was observed for cervical lesions and lumbar lesions, though not statistically significant. Larger sample size in each subgroup might further demonstrate the differences in paraspinal muscle atrophy. The Goutallier grade was evidenced to be a reliable measurement and it was intimately correlated with the quantified computerized measurements.[10] The interpretation of the postoperative MRI based on Goutallier grade was less time-consuming and more cost-effective compared with computer-based analysis from our experience.

The efficacy of MIS for intradural spinal tumors has been reported.[20–22] Gandhi et al, Berbeo et al, and Formo et al suggested that the MIS approach was feasible for intradural spinal tumors without increased risk of neurological deficit or incomplete tumor removal.[7,21,23] Wong et al showed that MIS approach had less intraoperative blood loss with a comparable rate of adverse events (MIS, 8.0% vs. Open, 19.2%, $p = 0.24$) and similar tumor recurrence rate (MIS, 4.0% vs. Open, 3.8%, $p = 0.98$).[24] Zhuang et al further concluded that the MIS surgery with tubular retractor allowed more functional improvement and pain reduction at postoperative 6 months.[25] En bloc resection of the intradural extramedullary spinal tumor with its dural attachment




| | MIS | Open |
|---|---|---|
| Grade 0 | 4 | 0 |
| Grade 1 | 1 | 9 |
| Grade 2 | 3 | 14 |
| Grade 3 | 1 | 4 |
| Grade 4 | 0 | 6 |

**Fig. 3** The degree of postoperative paraspinal muscle fatty degeneration by Goutallier grade between the minimally invasive surgery (MIS) and the open surgery (Open) group. (MIS median Goutallier grade 1, mean rank = 13.61, Open median Goutallier grade 2, mean rank = 23.65, $p = 0.023$ by Mann–Whitney *U*-test). MRI, magnetic resonance imaging; Open, open laminectomy.

theoretically achieves the best oncological outcome. However, a hard tumor consistency, ventral site of dural attachment, and poor arachnoid plane often limit en bloc resection. Tumor debulking or removal in a piecemeal fashion is inevitable in these cases and central debulking reduces unnecessary traction to the spinal cord and widens the surgical corridor during subsequent dissection. In addition, it remains controversial whether Simpson grade I excision for intraspinal meningioma is obligated in all cases. In the meta-analysis of Barber et al, Simpson grade I excision of intradural meningioma was evidenced to have increased unexpected neurological deficits and complication rates.[26] The recurrence rates between Simpson grade I and II excisions were not significantly different in Barber et al and Kobayashi et al.[26,27] We aimed for primary dural closure in our open surgery and MIS to avoid complications including pseudomeningocele or CSF leak. In our cohort, we observed a comparable complete excision rate in the MIS group and the number of recurrences or residual tumors was not significantly different. Therefore, the MIS approach is not inferior to the open approach in terms of oncological efficacy. Further study with a longer observation period may examine the difference in tumor recurrence rate between these two approaches.

A higher volume of perioperative blood loss (MIS = 133.7 ± 161.7 vs. Open = 558.8 ± 631.8 mL, $p < 0.01$) was noted in the open surgery group in Wong et al. This difference could be attributed to the inclusion of larger tumors and more difficult operations in the open surgery group in their study.[24] In the subgroup analysis of tumors less than 2 cm in Raygor et al, there was no significant difference in the perioperative blood loss.[8] In our study, we excluded tumor size larger than 3.5 cm in craniocaudal measurement, more than two vertebral levels of extension, or lesion with extraforaminal extension for a justifiable comparison for the two approaches. We agreed with Raygor et al that the perioperative blood loss (MIS = 150 ± 112 vs. Open = 166 ± 87 mL, $p = 0.697$) and the length of stay (MIS = 11.6 ± 15.8 vs. Open = 10.3 ± 9.3 days, $p = 0.830$) were similar between the two surgical approaches.[8] The length of stay was prolonged in our study because of the two complicated cases which required a second surgery.

The percentage of patients with mild-to-moderate degree of pain was similar between the two surgical groups, while a consistent trend of a lower rate of regular analgesic consumption was noted in the MIS group, though not statistically significant. Future studies with larger case numbers and assessment of pain at different postoperative periods, (i.e., immediate postoperative, short term, and long term) could further delineate the benefit from the MIS approach.

## Limitations

There were certain limitations in our retrospective study. First, the MIS for intradural spinal tumors was a new era in our hospital with a limited number of surgeries performed, thus the two groups were of different sample sizes. The annual case number of intradural spinal tumors was 1.2 per 100,000 population per year in Hong Kong, and there would be 60 patients with operations performed in this 5-year interval, considering the 1 million population in our catchment area.[1] Thus, we have largely included a representative group of patients with this disease. Second, the timing of postoperative MRI was difficult to be universal for all patients, as unfortunately the waiting time for patients in our hospital is relatively long due to resource limitation. A temporal relationship for the signal change in the paraspinal

**Table 5** Subgroup analysis for paraspinal muscle fatty degeneration on MRI by different levels of the tumors

| | | MIS | | Open | | Statistics | *p* |
|---|---|---|---|---|---|---|---|
| Paraspinal muscle fatty degeneration on MRI | Median (mean rank) | 2.5 | 3.75 | 3 | 4.75 | MWU | 0.604 |
| Cervical lesions | *n* (%) | | | | | | |
| Goutallier grade 0 | | 0 | 0.0 | 0 | 0.0 | | |
| Goutallier grade 1 | | 0 | 0.0 | 2 | 33.3 | | |
| Goutallier grade 2 | | 1 | 50.0 | 0 | 0.0 | | |
| Goutallier grade 3 | | 1 | 50.0 | 1 | 16.7 | | |
| Goutallier grade 4 | | 0 | 0.0 | 3 | 50.0 | | |
| Paraspinal muscle fatty degeneration on MRI | Median (mean rank) | 0 | 6.17 | 2.0 | 17.30 | MWU | 0.002[a] |
| Thoracic lesions | *n* (%) | | | | | | |
| Goutallier grade 0 | | 4 | 66.7 | 0 | 0.0 | | |
| Goutallier grade 1 | | 1 | 16.7 | 6 | 26.1 | | |
| Goutallier grade 2 | | 1 | 16.7 | 14 | 60.9 | | |
| Goutallier grade 3 | | 0 | 0.0 | 2 | 8.7 | | |
| Goutallier grade 4 | | 0 | 0.0 | 1 | 4.3 | | |
| Paraspinal muscle fatty degeneration on MRI | Median (mean rank) | 2 | 2.00 | 3.5 | 3.25 | MWU | 0.468 |
| Lumbar lesions | *n* (%) | | | | | | |
| Goutallier grade 0 | | 0 | 0.0 | 0 | 0.0 | | |
| Goutallier grade 1 | | 0 | 0.0 | 1 | 25.0 | | |
| Goutallier grade 2 | | 1 | 100.0 | 0 | 0.0 | | |
| Goutallier grade 3 | | 0 | 0.0 | 1 | 25.0 | | |
| Goutallier grade 4 | | 0 | 0.0 | 2 | 50.0 | | |

Abbreviations: MIS, minimally invasive surgery; MRI, Magnetic resonance imaging; MWU, Mann–Whitney *U*-test; Open, open surgery.
[a]$p < 0.01$.

muscle was not available in the current study. Third, despite a continuing effort, we have not completely collected the postoperative pain scores at the different time points for all the cases, which could provide more information on the natural relationship between chronic pain and paraspinal muscle fatty degeneration. Nevertheless, with more patients being treated with MIS approach in our unit, we would provide further results on the long-term outcomes of the MIS.

## Conclusion

Minimally invasive tubular retractor surgery is an effective surgical approach for appropriately selected intradural extramedullary spinal tumors, with a high complete excision rate and comparable intraoperative blood loss. Compared with open surgery, minimally invasive spine surgery significantly reduces postoperative paraspinal muscle fatty degeneration. A consistent trend of reduced regular analgesics consumption was observed for patients with MIS and further studies with a larger number of patients may reveal the short- and long-term effects in postoperative pain reduction by this minimally invasive approach.

### Availability of Data and Material

The data that support the findings of this study are available on request from the corresponding author, under the regulations from the Research Ethics Committee of Kowloon Central/Kowloon East (Ref: KC/KE-21–0150/ER-3) under the Hong Kong Hospital Authority.

### Ethical Approval

This research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. The study protocol was reviewed and was approved by the Research Ethics Committee of Kowloon Central/Kowloon East (Ref: KC/KE-21–0150/ER-3).

### Consent to Participate

This retrospective study protocol and statistical methods were reviewed and approved by the Research Ethics Committee of Kowloon Central/Kowloon East (Ref: KC/KE-21–0150/ER-3) with the patient consent waived.

### Funding

None.

**Conflict of Interest**

The authors listed in this study have no conflict of interest to declare.

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