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Technical Note & Surgical Technique

Characteristic and surgical results of multisegment intramedullary cervical spinal cord tumors☆

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ABSTRACT

Background: To evaluate the clinical characteristic, microsurgical treatment and outcomes of patients with multi-segment intramedullary cervical spinal cord tumors (MSICCT).
Materials and methods: Prospective single center cohort study. 63 patients underwent microsurgery for MSICCT. Pre and postoperative function were assessed using the modified McCormick's grade, IJOA scoring system, and analyzed using the appropriate statistical tests.
Results: 41 males, 22 females, three spinal segments were involved in 22(35%) cases, four or more in 41(65%) of cases. Majority of the tumors were ependymoma (54%), followed by astrocytoma (low grade 25%, high grade 8%). McCormick's grade: I&II in 40 patients (64%). There was no statistical difference between preoperative and three-month postoperative IJOA scores ($P = 0.76$), indicating no significant neurological deterioration after surgery. The extent of surgical resection was highly correlated to histological tumor type of MSICCT ($\chi^2 = 34.82$, $P = 0.0001$) and three-month postoperative IJOA scores ($F = 2.62$, $P = 0.006$). There is a high proportion of total resection in ependymomas, haemangioblastomas, cavernomas and schwannoma, whereas, we only achieved partial resection in most gliomas.
With a mean follow up of 5.5 years (3 months–more than 12 years), clinical outcome improved or stabilized in 91% of cases (80% improved, 11% stabilized, 9% deteriorated).
Conclusion: This series of MSICCT showed that high extent of surgical resection could be achieved in most ependymomas with good long-term outcome. Astrocytomas, in contrary remained challenging with 25% achieved gross total resection. Overall, compared to previous surgical series, we showed encouraging improvement in the clinical outcome of these patients managed surgically.

1. Introduction

Intramedullary spinal cord tumors are rare, accounting for 4–10% of all central nervous system tumors [1–2]. Astrocytomas and ependymomas are the most frequently encountered, in up to 70% of all spinal intramedullary tumors [1,3]. Multisegment involvement where the intramedullary tumor length occupying 3 or more vertebral body levels is considered as multi-segment intramedullary spinal cord

Abbreviations: IJOA, Improved JOA (Japanese Orthopaedic Association score for patients with cervical myelopathy) scoring system; MSICCT, multi-segment intramedullary cervical spinal cord tumors; CSF, cerebrospinal fluid; CT, computed tomography; MRI, magnetic resonance imaging; GTR, Gross Total Resection; STR, Subtotal Resection,; PR, Partial Resection,; LGG, Low Grade Glioma,; HGG, High Grade Glioma.

☆ Our institution and all authors have agreed to submit the manuscript to *Interdisciplinary Neurosurgery: Advanced Techniques and Case Management*. The protocols for our clinical studies were approved by the Patients and Ethics Committee of Peking University Third Hospital.

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tumor (MSICT) [4], and has a much lower incidence (about 1 MSICT for every 10 spinal tumors) [5–6].

Intramedullary tumors of the cervical spinal cord, especially the multisegment types are challenging surgical lesions. Aggressive surgical removal of these tumors is still controversial due to the high risk of neurological impairment including respiratory dysfunction, motor deficit leading to quadraparesis. Recently, however, with advances in neuroimaging and intraoperative technologies, the management of intramedullary spinal cord tumors has evolved into a more aggressive surgical resection with better long-term results [4,7].

The aims of this study were to characterize the histological classification, location, extent of tumor removal, neurological function, and the prognosis of patients with multi-segment intramedullary cervical cord tumors (MSICCT).

2. Materials and methods

This prospective cohort study was performed on 63 consecutive cases with MSICCT who underwent microsurgery in the neurosurgery department of Peking University Third Hospital between March 2002 and April 2013. Ethics approval were obtained from the Research Ethics Board, and written informed consent was completed for the patients or guardians for surgical operation, medical photography and inclusion in the clinical study.

Baseline demographic data, clinical and radiological presentation, and intraoperative observations were evaluated. Preoperative neuroimaging including Magnetic Resonance Imaging (MRI) was performed in all cases. Spinal angiography was performed if the MRI suggested a possible vascular lesion.

2.1. Clinical presentation

The initial presenting symptoms and duration of symptoms prior to surgery were recorded. The presenting symptoms were categorized into (1) sensory disturbance, (2) pain, (3) limbs weakness, (4) breathing difficulty.

2.2. Evaluation of neurological functions

The Modified McCormick scale [8] (Table 1) and improved JOA [9] (IJOA) scoring system (Table 2) was used to evaluate preoperative and postoperative neurological function of patients. IJOA [4] was based on the JOA scoring system with an addition of scoring sphincteric function as either normal, slightly dysfunctional, severely dysfunctional, or incontinence. Short-term prognosis was assessed by IJOA difference (postoperative IJOA score minus preoperative IJOA score). Postoperative IJOA scores were evaluated 2 weeks after the operation. The short-term prognosis of patients was classified into five grades (<-4, -1 to 3, 0, $+1$ to 3, $>+4$) based on the IJOA difference values. The clinical outcomes were independently analyzed by a neurologist blinded to the initial diagnosis and extent of resection.

2.3. Neurosurgical techniques

The operation followed the standard procedures for intramedullary spinal cord tumors. Laminectomy, or laminoplasty were performed over the region of the tumor on the basis of preoperative imaging. After a midline dural incision, the operating microscope was brought into view. A midline myelotomy was then performed and pia retraction obtained by suturing it to the dura. The resection was then modified according to the tumor dissection plane and the severity of the infiltration seen on the preoperative MRI and intraoperative

Table 1
McCormick's clinical/functional classification scheme [8].

Grade	definition
I	Neurologically normal; mild focal deficit not significantly affecting function of involved limb; mild spasticity or reflex abnormality; normal gait
II	Presence of sensorimotor deficit affecting function of involved limb; mild to moderate gait difficulty; severe pain or dysesthetic syndrome impairing patient's quality of live; still functions and ambulates independently
III	More severe neurological deficit; requires cane/brace for ambulation or significant bilateral upper extremity impairment; may or may not function independently
IV	Severe deficit; requires wheelchair or cane/brace with bilateral upper extremity impairment; usually not independent

Table 2
Improved JOA (Japanese Orthopaedic Association score for patients with cervical myelopathy) (IJOA) scoring system [4,9].

Total 20	
Motor function	Sensory function
Upper extremity	*Upper extremity*
0 [Complete disturbance] The patient cannot use chopsticks or a spoon/fork, and cannot fasten a button on his or her own.	0 [Severe disturbance] Complete sensory loss (touch sensation, pain sensation)
1 [Severe disturbance] The patient cannot use chopsticks or write, and can barely use a spoon/fork.	1 [Moderate disturbance] Partial sensory loss ≥ 6/10 (touch sensation, pain sensation); numbness and hypersensitivity.
2 [Moderate disturbance] The patient can pick up a large object with chopsticks but can hardly write. He/she can fasten a large button.	2 [Normal] normal
3 [Slight disturbance] The patient makes awkward use of chopsticks, writes in a clumsy manner, but can fasten button on his/her shirt.	*Trunk*
4 [Normal] Normal	0 [Severe disturbance] Complete sensory loss (touch sensation, pain sensation)
Lower extremity	1 [Moderate disturbance] Partial sensory loss ≥ 6/10 (touch sensation, pain sensation); numbness and hypersensitivity.
0 [Complete disturbance] The patient cannot stand or walk alone	2 [Normal] Normal
1 [Severe disturbance] The patient needs support to walk on a flat surface.	*Lower extremity*
2 [Moderate disturbance] The patient can walk on a flat surface without any support, but needs a handrail to walk up and down stairs.	0 [Severe disturbance] Complete sensory loss (touch sensation, pain sensation)
3 [Slight disturbance] The patient can walk fast, although awkwardly	1 [Moderate disturbance] Partial sensory loss ≥ 6/10 (touch sensation, pain sensation); numbness and hypersensitivity.
4 [Normal] Normal	2 [Normal] Normal
Urinary bladder function	**Ano-rectal sphincteric function**
0 [Severe disturbance] Urinary retention, incontinence	0 [Severe disturbance] Incontinence
1 [Moderate disturbance] Feeling of residual urine, straining of oneself, dull urination, clongation of urination (retarded urination)	1 [Moderate disturbance] Feeling of defecation difficulty, dysporia
2 [Slight disturbance] Retarded urination, pollakisuria	2 [Slight disturbance] Intestinal constipation, coprostasis
3 [Normal] normal	3 [Normal] Normal

findings. Intraoperative neurophysiologic monitoring was used. The pia mater was not normally reattached at the end of the resection [4,7].

Spinal ependymomas originate from the central canal, grow concentrically, and demonstrate a clear plane to normal spinal cord tissue. Ultrasonic aspiration was used to resect the tumor to its interface with the normal cord white mater. This dissection plane between the tumor mass and normal cord tissue was relatively easy to preserve in most cases (Fig. 1).

In spinal astrocytic tumors, in contrast, tumor extension was typically eccentric without any defined plane to normal cord tissue. Due to this intramedullary eccentric mass, the posterior median sulcus was often displaced. Midline myelotomy was used cautiously to identify the posterior median sulcus. The malignant astrocytic tumors in this series, including anaplastic astrocytomas (Fig. 2) and glioblastomas (Fig. 3), mostly invaded through the pia mater or arachnoid. After the extramedullary tumor was removed, the opening of the spinal cord was extended in the midline. The tumor was dissected along the cleavage plane with the spinal cord as much as possible. In areas of obvious infiltration, the tumor was removed layer by layer starting from the

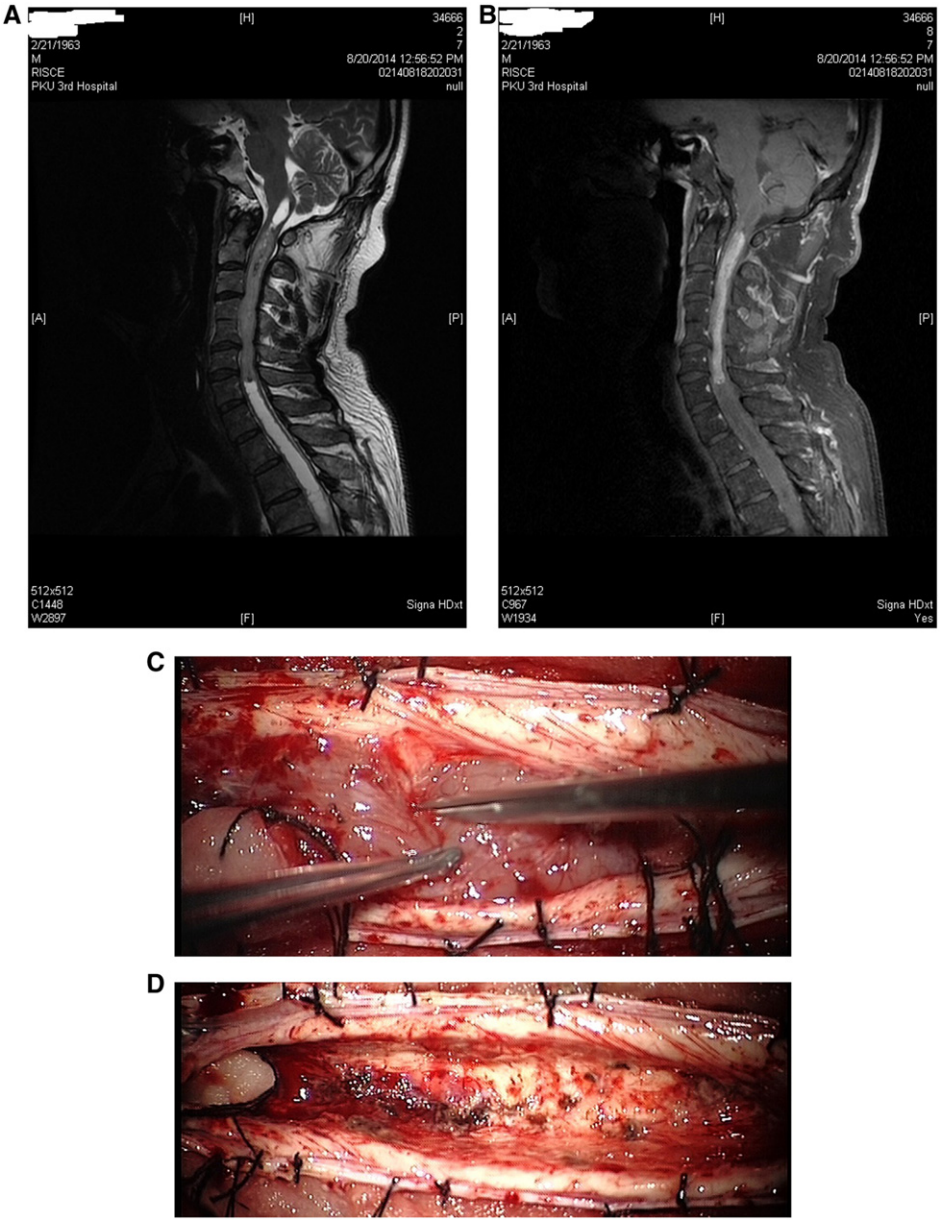


Fig. 1. A 51-year-old male presented with two years history of bilateral upper extremity numbness, a month history of progressive gait deterioration with progressive spastic quadraparesis. MRI showed an intramedullary partially enhancing mass, extending from C1 to C6 with associated syrinx. (A) Sagittal T2-weighted MRI; (B) contrast enhanced sagittal T1-weighted MRI; (C) an intramedullary reddish-brown tumor was shown with a clear dissection plane; (D) surgical cavity obtained after Class II tumor resection; (E–F) two weeks after the operation, an MRI showed residual spinal cord edema with little residual lesion. The patient was able to walk on a flat surface without any support, but needed a handrail to walk up and down stairs one year later. The histological result was an ependymoma (WHO grade II).

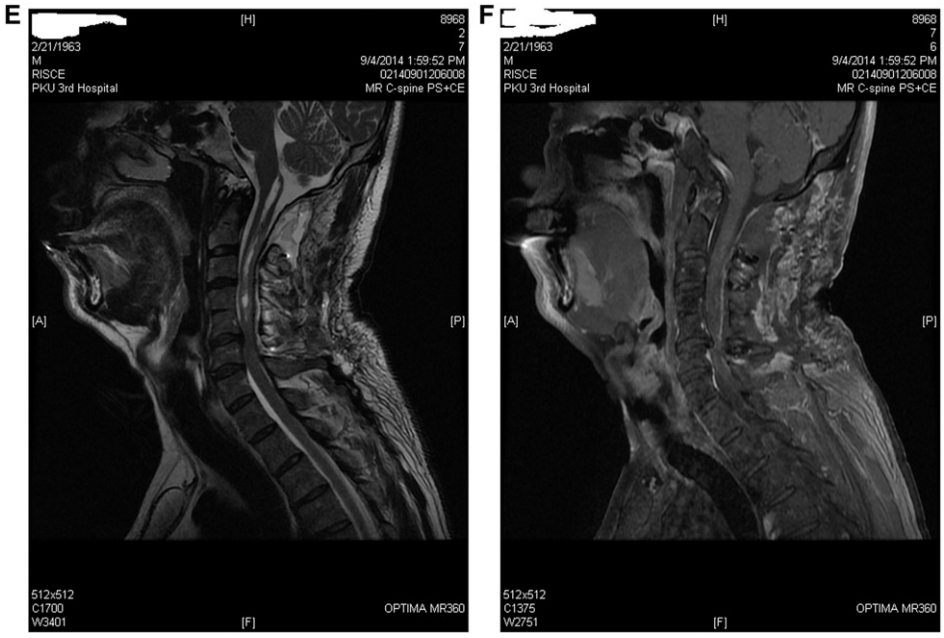


Fig. 1 (*continued*).

innermost layers until white matter was identified. In cases where malignant astrocytoma was suspected at frozen biopsy, complete resection was not attempted. Radiotherapy was then performed.

Some well-defined MSICCTs (including hemangioblastoma (Fig. 4) and schwannoma (Fig. 5)) may partially invade the spinal cord and extrude through the pia mater. In these cases, the draining veins were carefully displaced from the field before the feeding arteries were clipped and then coagulated with bipolar coagulation. Tumors would be removed en bloc. In patients with hemangioblastoma the tumor cyst was not removed. In order to prevent the contents of teratomas from seeding the subarachnoid space, well-defined intramedullary cystic teratomas were shielded with cotton slips before being cut open. The cyst walls of tumors that adhered tightly to the spinal cord were cauterized with bipolar coagulation, rather than separated and removed [10].

The extent of tumor removal was categorized into four different classes according to intraoperative assessment and postoperative enhanced MRI findings. Cases with total resection and without residual tumors on postoperative MRI were classified as Class 1 (Figs. 4 and 5); 80 to 90% tumor resection was defined as Class 2 (Fig. 1); 60 to 80% tumor resection was defined as Class 3 (Fig. 2). All other procedures, including decompression and biopsy of the tumors, were classified as Class 4 (Fig. 3). The cross-section with the longest diameter of tumor was measured under microscope intraoperatively.

2.4. Location and histological classification of tumors

The location of intramedullary cervical cord tumors was determined based on the enhanced MRI scans. The locations were classified as cervical-medullary, cervical, and cervico-thoracic regions. Affected segments of cervical spinal cord were recorded. Based on the postoperative H&E and immunohistochemical staining, the histology of MSICCT was classified as ependymoma, low grade gliomas (including astrocytoma I-II and oligodendrocytoma), high grade gliomas (astrocytoma WHO III–IV), vascular tumors (including hemangioblastomas and cavernomas), teratoma, and schwannoma.

2.5. Postoperative management

Postoperatively, all patients received routine postop dose of Methylprednisolone (10 mg/kg·d) for three days and neurotrophic (monosialotetrahexosylganglioside sodium injection and mecobalamin injection) drugs for at least two months. A neck collar was used to prevent cervical kyphotic deformity. All patients received rehabilitation at local physical therapy centers [4,7].

2.6. Follow-up

The postoperative follow-up with contrast-enhanced MRI scans were performed at two weeks and at six months. Annual surveillance MRI was performed to monitor for disease progression, unless clinically indicated for the investigation to be performed sooner. Disease progression was defined as recurrence in cases of complete tumor removal and regrowth in cases of incomplete tumor removal. The latest clinical outcomes of patients were evaluated according to the neurological status and graded as improved, stabilized, or worsened. For the purpose of this study, all patients have their follow up and outcome assessed by June 1, 2015.

2.7. Statistical analysis

Data analysis was performed using SPSS 17.0 (SPSS, Chicago, USA). Statistical analysis was performed using two-sample Kolmogorov-Smirnov *t*-test for the comparative analysis between preoperative and postoperative IJOA scores; or one-way AVONA test for the histology of the tumors affected, age and postoperative IJOA scores of patients. Mann-Whitney or Kruskai-Wallis tests were used to analyze the characteristics of tumors (such as location, histological classification, diameter grading, and the extent of tumor removal) and other factors of the patients (including gender, initial

symptoms, urine and stool function, IJOA difference, and limbs weakness of patients). Data were expressed as the mean ± standard error, and ranges. *P*-values of less than 0.05 were considered statistically significant.

3. Results

3.1. Clinical factors of patients

Of the 63 patients, 41 were male (65%), 22 were female (35%), with a mean age of 36.6 years (range 5– 64 years). The most common presenting symptom was sensory disturbance (44%, 28/63), followed by pain (29%, 18/63), limbs weakness (25%, 16/63), and breathing difficulty (2%, 1/63). The mean duration of symptoms prior to surgery was 34.3 (range 0.33– 180) months.

3.2. Neurological functions of patients

Preoperative McCormick's grade: I in 18 cases (29%), II in 22 cases (35%), III in 14 cases (22%), IV in 9 cases (14%). Postoperative McCormick's grade: I in 25 cases (40%), II in 18 cases (29%), III in 8 cases (13%), IV in 12 cases (19%). The preoperative IJOA scores of the patients were 14.5 ± 4.01. According to grades of bowel/bladder function, 38 cases (60%) were normal, 11 cases (17%) had slight dysfunction, 8 case (13%) had severe dysfunction, and 6 cases (10%) were incontinent. 55 cases (87%) demonstrated various degrees of limbs weakness, 8 cases (13%) showed lower cranial nerves dysfunction (CN IX–XII). The postoperative IJOA scores at 3 months were 14.4 ± 4.10. There was no statistically significant difference between preoperative and three-month postoperative IJOA scores ($t = 0.34$, $P = 0.76$), indicating no significant neurological deterioration after surgery.

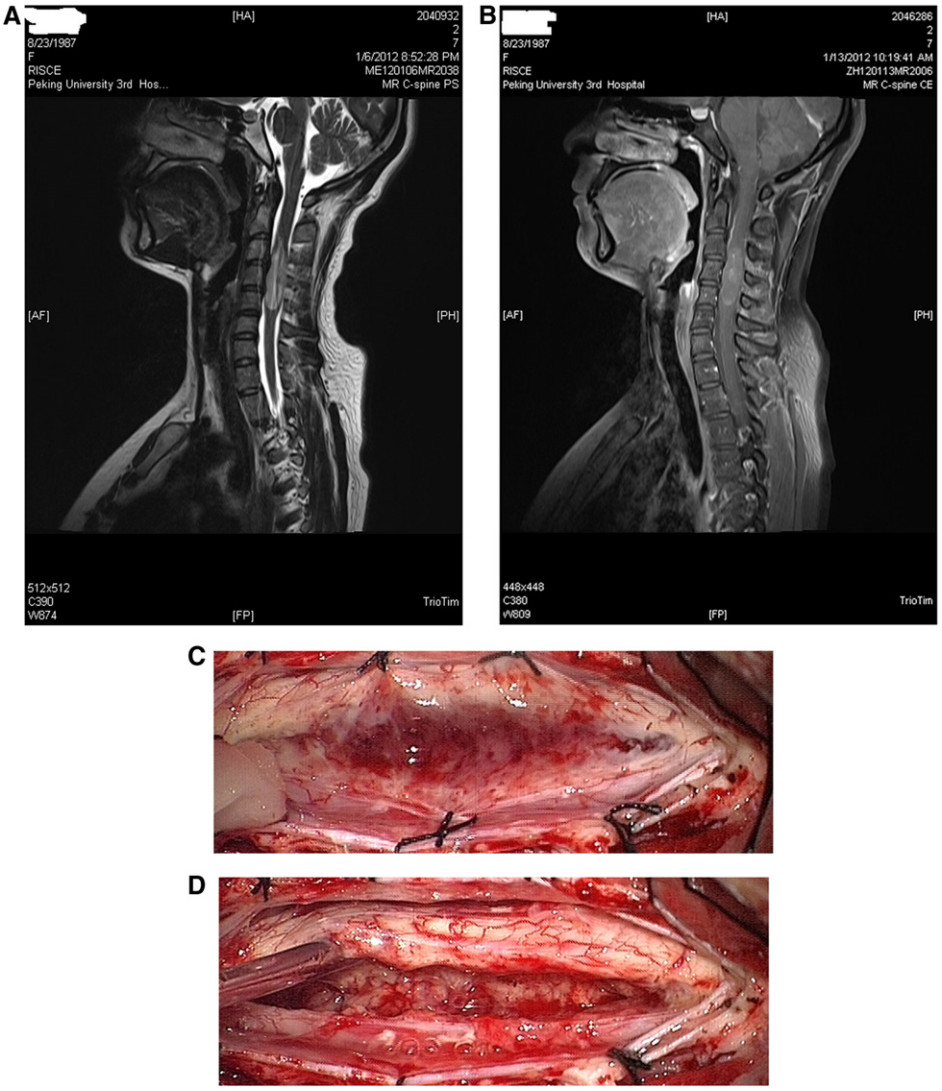


Fig. 2. A 24-year-old female presented with three months history of bilateral hands numbness and right upper extremity weakness. MRI showed an olive-shaped, mildly enhancing intramedullary mass, at C3–5 level without associated syrinx. (A) Sagittal T2-weighted MRI; (B) contrast enhanced sagittal T1-weighted MRI; (C) an intramedullary reddish-brown tumor with no clear dissection plane was encountered; (D) surgical cavity after Class III tumor resection; (E–F) MRI one month after the operation showing spinal cord swelling. The patient was able to pick up large objects with chopsticks but unable to write. She was able to button herself, and walk on a flat surface without any support, but needed a handrail to walk up and down stairs. The histological result was an anaplastic diffuse astrocytoma (WHO grade III).

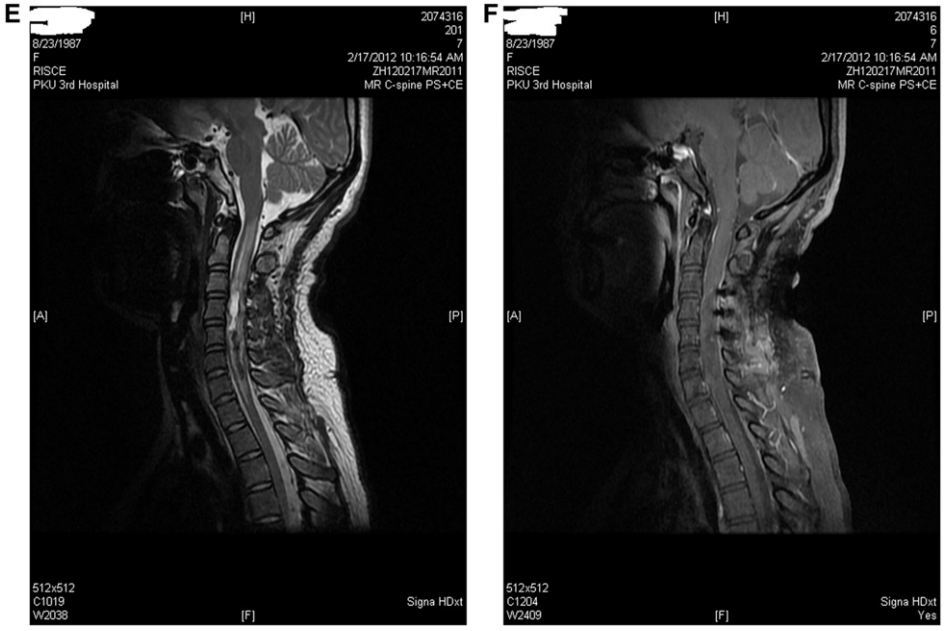


Fig. 2 (*continued*).

3.3. Tumor characteristics

The most common tumor locations were the cervical region (58.7%, 37/63), followed by the cervico-thoracic region (31.8%, 20/63), and the cervicalmedullary region (9.5%, 6/63). Three spinal segments were involved in 22(35%) cases, four in 23 (36.5%) cases, five in 12 (19%) cases, and more than five in 6 (9.5%) cases.

The most frequent histological classification of these tumors was ependymomas (54%, 34/63), followed by low grade gliomas (25%, 16/63), high grade gliomas (8%, 5/63), vascular tumors (two cases with haemangioblastomas and three cases with cavernomas), (8%, 5/63), schwannomas (3%, 2/63) and teratomas (2%, 1/63). Class 1 resection for tumor was obtained in 40 (63.5%) cases, Class 2 resection in 11 (17.5%) cases, Class 3 in 7 (11%) cases, Class 4 in 5 (8%) cases (including three cases with diffuse astrocytoma and two cases with malignant glioma). The mean length of MSICCT was 7.6 ± 3.84 cm.

We found that there was a statistically significant correlation between age groups and tumor types ($P = 0.04$). There was a higher proportion of ependymomas in the adult group whereas teratoma and schwannoma were more common in adolescents. The extent of surgical resection was highly correlated to histological tumor type of MSICCT ($\chi^2 = 34.82$, $P = 0.0001$) and three-month postoperative IJOA scores ($F = 2.62$, $P = 0.006$). There was a high proportion of total resection in ependymomas, haemangioblastomas, cavernomas and schwannoma, whereas, we only achieved partial resection in most gliomas. In addition, the patients with malignant glioma usually had the worst three-month postoperative neurological dysfunction. (Table 3).

3.4. Relation between factors of the patients and characteristics of tumors

The preoperative sphincteric function of male patients was relatively better than the function of female patients. Moreover, the better preoperative sphincteric functions also correlated with better postop neurological function. (Tables 4–5)

3.5. Adjuvant therapy

All 5 cases with malignant gliomas were offered postoperative adjuvant therapy, and 4 patients completed them. In the four cases, only radiotherapy was performed in three cases, and combined radiotherapy with temozolomide was performed in one case.

3.6. Internal fixation and spinal stability

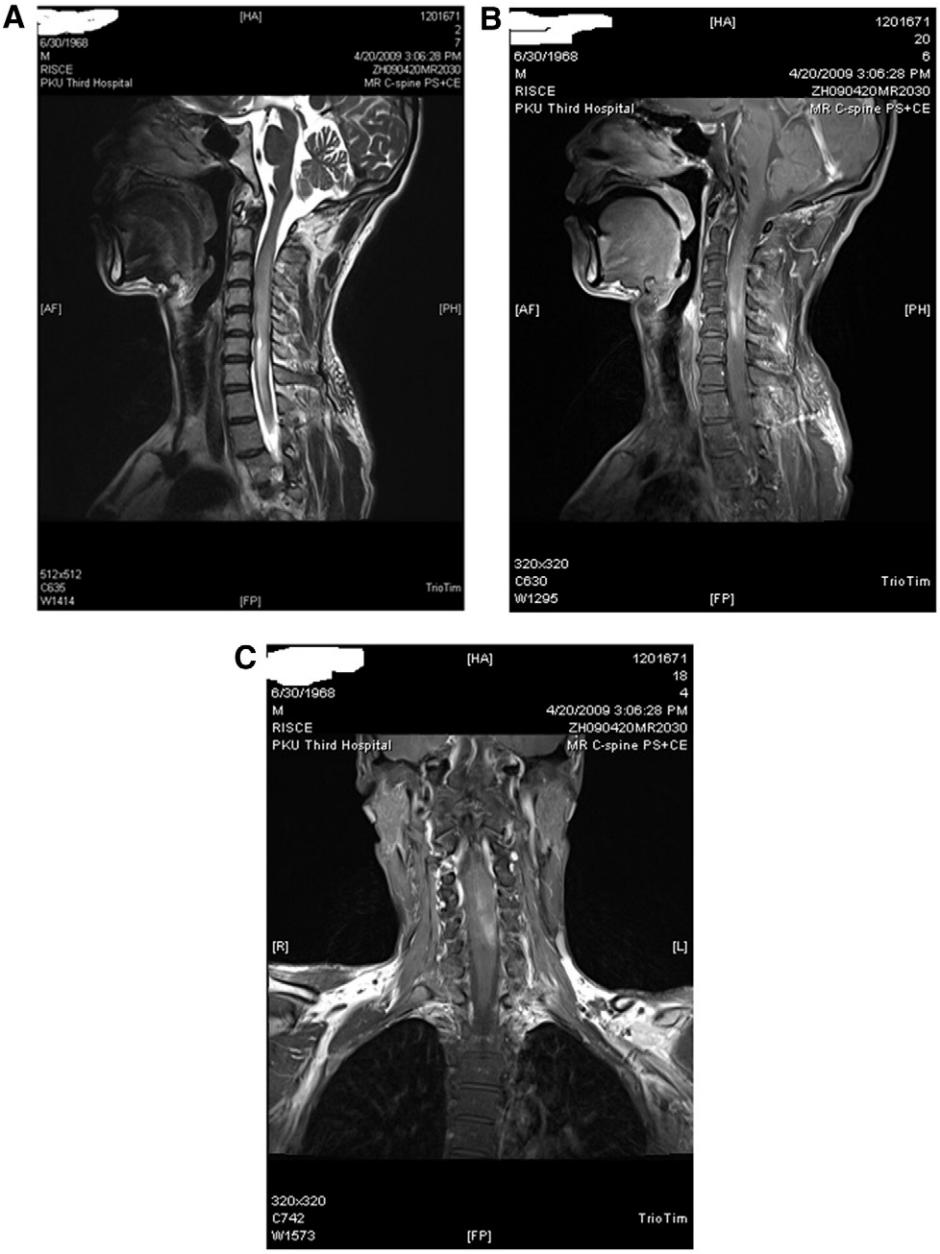
54 (86%) patients had laminectomy, 7 (11%) cases had laminoplasty, 2 (3%) cases had intraoperative spinal fixation. Furthermore, two adult patients with cervical ependymomas involving more than five spinal segments developed cervical kyphotic deformity one year after laminectomies, 1 at the atlanto-axial (C_1 or C_2) spine and the other at cervico-thoracic junction. Both patients also subsequently underwent multilevel spinal fixation.

3.7. Long-term follow-up

The mean follow-up was 66 months (ranging from 3– 146 months). Comparing to the preoperative neurological status, the overall postoperative status presented at the final follow-up improved in 80% of all patients ($n = 50$), unchanged in 11% ($n = 7$), and deteriorated in 9% ($n = 6$). After rehabilitation, significant neurological improvement when assessed at 6 months postop, was obtained in patients with ependymomas, low grade gliomas and vascular tumors.

3.8. Subgroup comparative analysis

The proportion of patients with grade I–II resection was highest for patients with ependymoma (97%), followed by patients with vascular tumors and schwannoma (87.5%). In patients with low grade gliomas, 44% achieved grade I–II resection, while the result was lowest for patients with high grade glioma (only 1 patient, i.e. 20% achieved grade II) resection (Table 3).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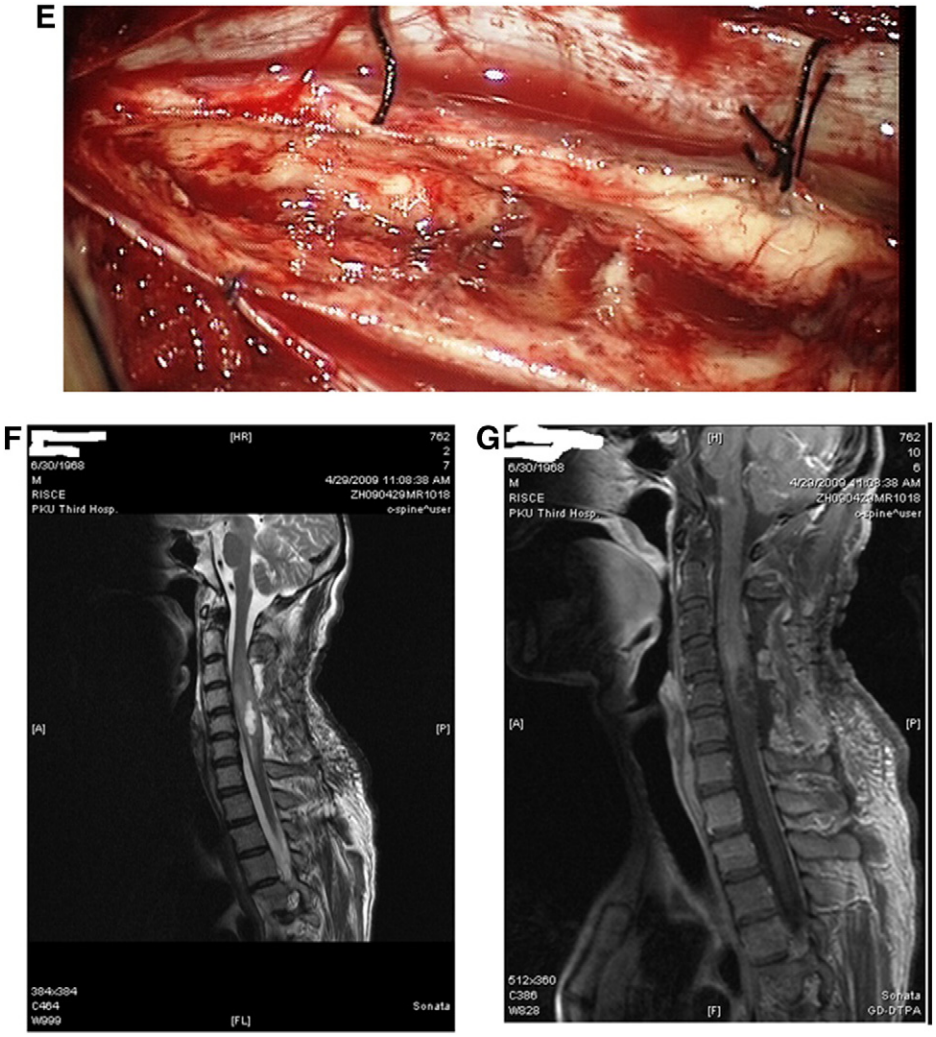

Fig. 3. A 40-year-old fit and well male presented with two months history of progressive left lower extremity weakness. MRI showed an intramedullary mildly enhancing mass, extending from C2 to C7 without associated syrinx. (A) Sagittal T2-weighted MRI; (B) contrast enhanced sagittal T1-weighted MRI; (C) coronal MRI scan showed the asymmetrical mass with greater involvement of the left spinal cord; (D) intraoperatively an intramedullary reddish-yellow tumor was encountered without a dissection plane; (E) surgical cavity after Class IV tumor resection; (F–G) nine months after the operation, an MRI showed spinal cord swelling and residual lesion, and patient live independently. The histological result was a diffuse astrocytoma (WHO grade II).

Preoperative McCormack's grade I–II was seen in 67% of patients with ependymoma, 88% of patients with miscellaneous tumor, but in less than 50% of patients with gliomas (10/21). In the 16 patients with low grade gliomas, 7 (44%) were at least functionally independent preoperatively.

Postoperative McCormack's grade improved in most tumor types except for patients with high grade gliomas (Table 3). 70%, 64% and 100% of patients with ependymomas, low grade gliomas and miscellaneous tumors respectively had McCormack's grade I–II postop.

With a mean follow up of 5.5 years (range 6 months to more than 12 years), the majority of patients with ependymoma, low grade gliomas or miscellaneous tumors stabilized or improved from their neurological and clinical state (Table 3). Only 1 patient each in the ependymoma and low grade glioma subgroup worsened clinically. This was contradictory to 80% of patients with high grade gliomas who worsened over the duration of 5.9 months follow up (range 3–36 months).

3.9. Outcome of patients with spinal malignant gliomas

In this study with 5 cases of high-grade spinal gliomas, the first case was a 35 year-old female with a progressive cervical spinal cord malignant glioma three months after a decompression surgery and biopsy. Five months after the surgery, this patient died of respiratory failure. The second case was a 27 year-old male with a cervical spinal cord diffuse astrocytoma. Two weeks after operation, multiple intracranial tumors were discovered after he presented with subarachnoid haemorrhage. He was lost to follow up 3 months later. The third case was a 49 year-old male with a cervical spinal cord diffuse astrocytoma after a subtotal resection, and combined radiotherapy with temozolomide postop. The latest follow-up result showed clinical and radiological stabilization. The fourth case was a 24 years-old female with a cervical spinal cord anaplastic astrocytoma after a partial resection and radiotherapy. 6 months later, the tumor recurred, she refused further operation or other adjuvant therapy and was lost to follow up. The fifth case was a 25 years-old female with a cervical spinal cord

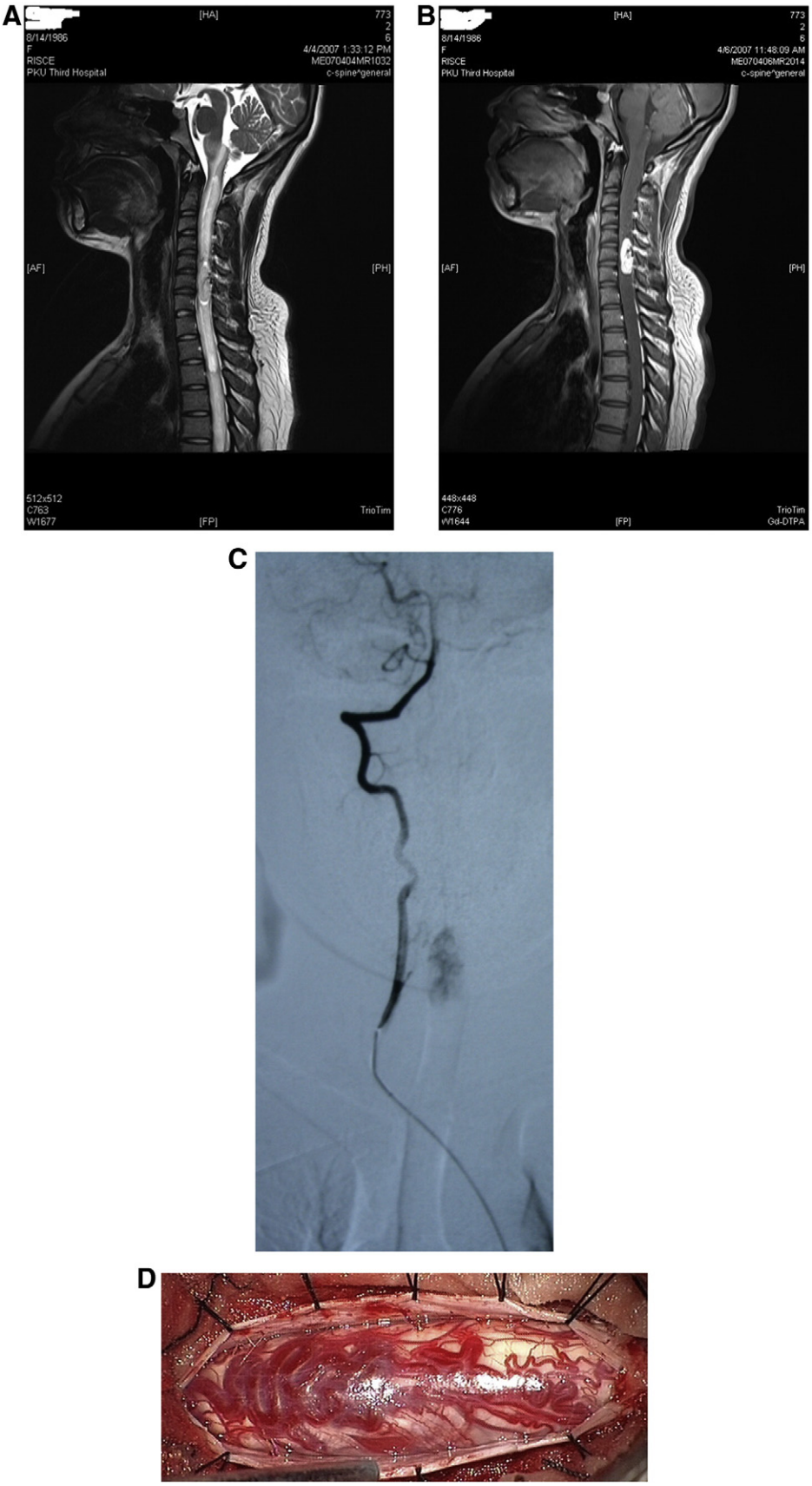

Fig. 4. A 20-year-old female presented with 6 months history of progressive left sided sensory disturbance and weakness. (A) T2-weighted MRI showed an intramedullary well delineated solid mass in the cervical spinal cord at C5–7 level. (B) Post-gadolinium-enhanced sagittal T1-weighted MRI; (C) spinal angiograms showed a 35 mm hypervascular tumor, fed by a radiculopial artery arising from the anterior spinal artery; (D) laminotomy over C5–C7 showed an intramedullary vascular lesion; (E) the vascular tumor was resected completely (Class I resection); (F–G) postop MRI showed spinal cord edema two weeks after the operation; (H–I) 6 months postop MRI showed no residual lesion. (J) Long term MRI at 2 years showed no evidence of tumor recurrence. The patient remained independent and was back to work at last follow-up. The histological result was a hemangioblastoma (WHO grade I).

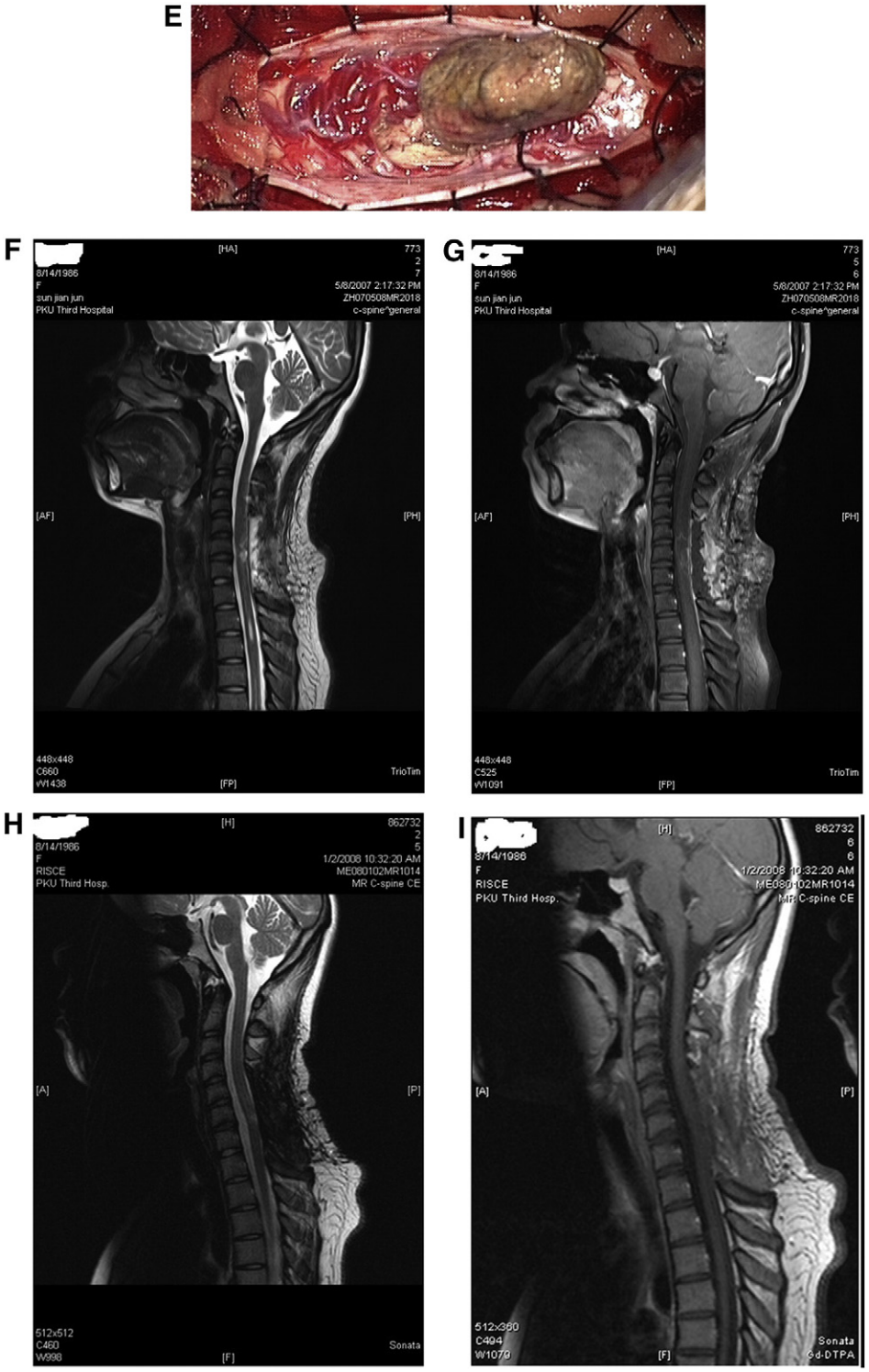

Fig. 4 (*continued*).

glioblastoma after partial resection. She died of severe pneumonia 6 months later.

4. Discussion

In this study, most of the MSICCT were confined to the cervical region (59%), while cervico-thoracic region involvement were found in a third of cases, and less than 10% affected the cervical medullary region. Unsurprisingly, the most frequent tumors were ependymomas (54%), followed by astrocytomas (25% low grade gliomas, 8% high grade gliomas), vascular tumors (8%), schwannomas (3%) and teratomas (2%). In our previous study with multisegment intramedullary spinal cord tumor, we also found that ependymona and astrocytoma were the most common

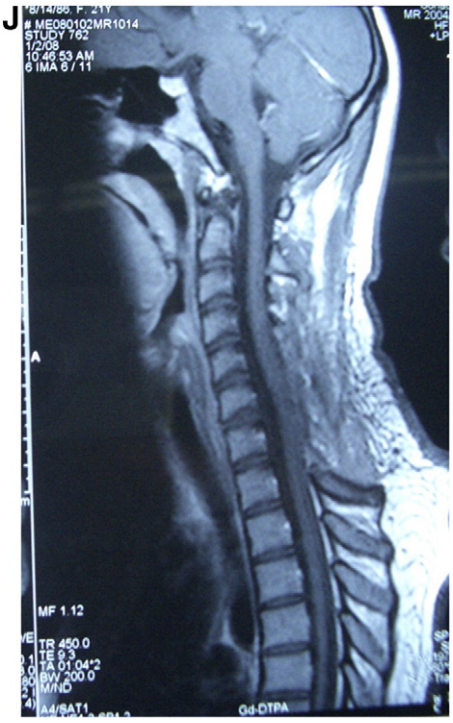

Fig. 4 (*continued*).

tumor types [4,7]. Furthermore, most benign ependymomas were located in the cervical and cervico-thoracic segments, and majority underwent gross total resection [11–13].

The cervical segment is an anatomical bridge between medulla (brainstem) and thoracic spinal cord [14]. The cervical enlargement is a unique feature of the cervical spinal cord, which runs from C5 to T1 spinal cord, due to the large number of neurons concentrated in these segments and relay sensory and motor functions of all four limbs. Based on these anatomical and functional characteristic, patients with multi-segment cervical spinal cord tumor could potentially have worse clinical and neurological outcome compared to spinal intramedullary tumors affecting other regions.

We also found a statistically significant correlation between age groups and tumor types, whereby there was a higher proportion of ependymomas in the adult group, and teratomas and schwannomas were more common in adolescents. In one of our previous study, low grade gliomas, mostly astrocytoma I–II, and neurodevelopmental tumor predominated in younger adolescent and decreased in frequency into adulthood where ependymomas became more predominant [7,15]. In adolescent patients with multi-segments intramedullary spinal cord tumors, the most commonly involved location was the cervicothoracic segments and the conus terminalis, while the most frequent tumors were neurodevelopmental tumors and astrocytomas [16]. Pain with motor weakness and gait deterioration predominated in adolescent and decreased in frequency into adulthood where sensory disturbances became more predominant [17]. Houten et al. [18] also showed that astrocytomas predominated in younger children and decreased in frequency into adulthood where ependymomas became more predominant. Previous studies showed that the age of onset of intramedullary ependymoma was within 30– 50 years old [19–20].

In our series, Class 1 tumor resection for MSICCT was obtained in two-third of cases, while 18% of cases had Class 2 resection, 11% had Class 3 resection and 8% were Class 4 resection (which include three cases with diffuse astrocytoma and two cases with malignant glioma). Unsurprisingly, the extent of tumor resection was dependent on tumor types. Ependymomas, vascular tumors and schwannomas usually achieved gross total resection, while it was difficult to obtain gross total resection for gliomas. Our findings of lower resection rate for high grade spinal gliomas compared to low grade glioma were in keeping with previous studies. According to Kim et al. [21], they reported that 39% of low grade spinal cord gliomas obtained a gross total resection, while the rate was seen in only 20% of high grade gliomas. In addition, Huddart et al. [22] reported distant metastases occurred in 50– 60% of patients with high grade spinal cord glioma. On the other hand, for patients with well delineated intramedullary spinal tumor, the boundaries between tumor and normal spinal cord tissue were distinct and separable. Therefore, total or subtotal resection was obtained more readily, and has been reported in up to 95% of intramedullary ependymomas [4,13,20].

In this series of MSICCT, very high proportions of ependymomas, vascular tumors and schwannomas had gross total resection (nearly 90% of ependymomas, 80% of vascular tumors or schwannomas), while the rate was only 25% for low grade glioma, and none of the high grade gliomas. Furthermore, the patients with high grade gliomas had the worst postop outcome, with 80% worsened at the latest follow up. Lee et al. [23] retrospectively reviewed 69 patients who underwent surgical treatment for intramedullary spinal cord tumors, they found the following outcome for high grade tumor: 42.8% of good outcome, 28.6% of fair outcome and 28.6% of poor outcome. On the other hand, for patients with low grade tumor: 79% of patients showed good outcome, 12.9% showed fair outcome and 8.1% had poor outcome. Fakhreddine et al. [24] retrospectively reviewed charts from a series of 83 patients with histologically confirmed spinal astrocytoma, and found that WHO grade among infiltrative tumors was a significant prognostic indicator for overall survival and progression-free survival in both univariate and multivariate analyses. In the literature, multiple studies also showed that WHO grade was the most consistent and effective prognostic indicator for patients with glial tumors [17,22,25].

The preoperative sphincteric function of male patients was relatively better than the function of female patients. Moreover, the better preoperative sphincteric functions also correlated with better postop neurological function. There were seven patients with severe sphincteric dysfunction in male and female group respectively. However, the ratio (7/22, 32%) in female group was higher than the ratio (7/41, 17%) in male group. In the 7 female patients with sphincteric disturbance, their age ranged from 35 to 51 years and all of them were multipara. Whether the difference noted here could be partly explained by the urethral and pelvic floor anatomy of the gender differences remained speculative [26].

Preoperative functional independence was seen in 67% of patients with ependymoma, 88% of patients with miscellaneous tumor, but in less than half of patients with gliomas. However, postoperatively, the proportions of patients with functional independence in almost all tumor types increased, except in patients with high grade gliomas.

With a mean follow up of 5.5 years (range 6 months to 12 years), majority of patients with ependymoma, low grade gliomas or miscellaneous tumors had neurological and clinical state that stabilized or improved. Only 1 patient each in the ependymoma and low grade glioma subgroup had worsened clinical outcome. For patients with high grade gliomas, their mean follow up was significantly shorter, and despite adjuvant therapy postop, majority of them worsened over a mean follow up of several months.

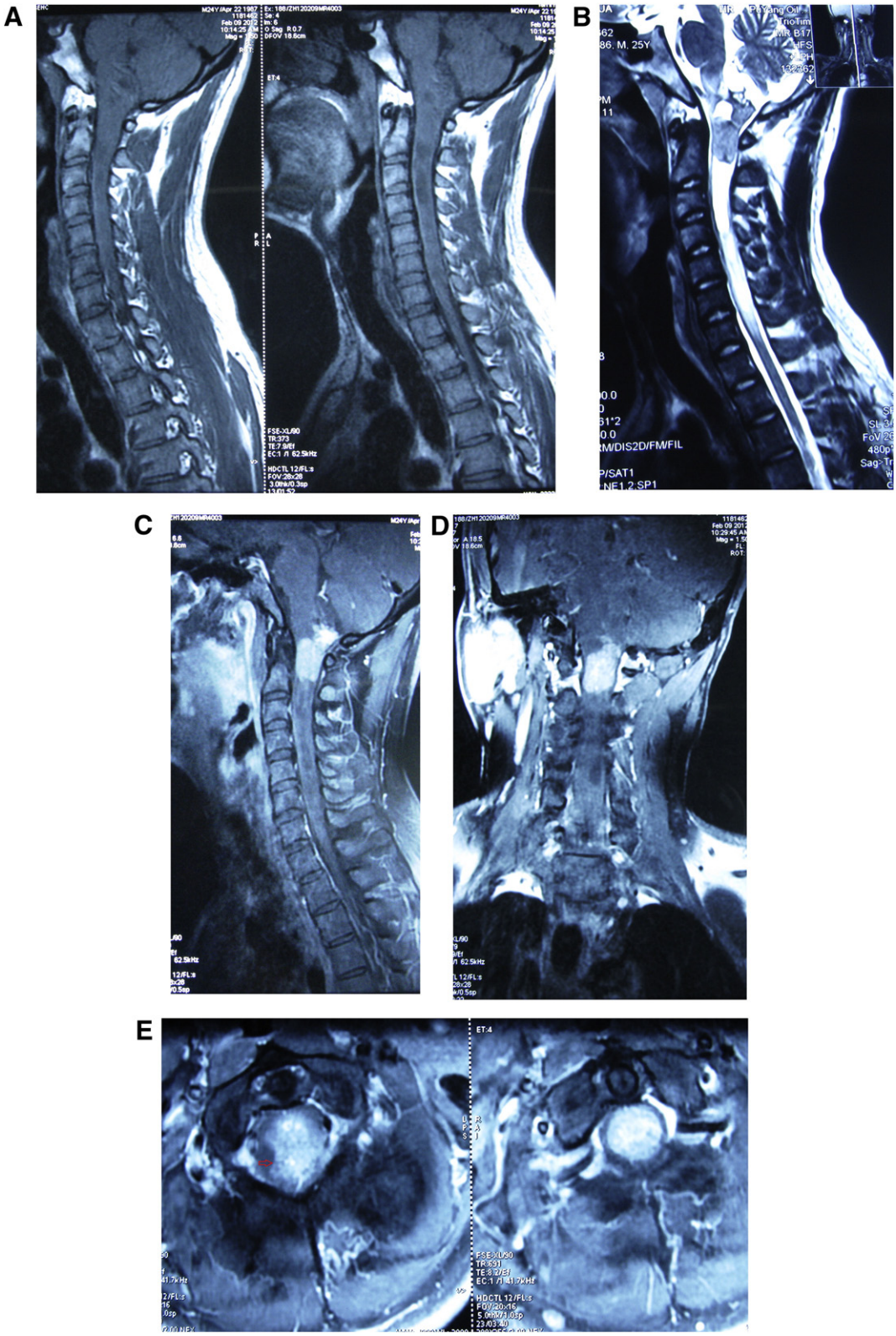

Fig. 5. A 24-year-old male presented with 6 months history of progressive bilateral upper extremity ache, stiffness and weakness. Preoperative bowel/bladder function was slightly impaired. Preoperative McCormack's grade was II. MRI showed a partial intramedullary homogenously enhancing mass extending from C1 to C2 with associated syrinx, and a continuous extramedullary component. (A) Sagittal T1-weighted MRI; (B) Sagittal T1-weighted MRI; (C) contrast enhanced sagittal T1-weighted MRI; (D) contrast enhanced coronal T1-weighted MRI; (E) contrast enhanced axial T1-weighted MRI showed the mass with partial extramedullary extension (red arrow on left image). Vascular anomaly was shown on the surface of C1–2 spinal cord. Partial extramedullary subpial mass showed at the left medullary level. A midline myelotomy was then performed and pia retraction obtained by suturing it to the dura at the C1–2 level. Brownish solid tumor was encountered. The resection was then modified based on the tumor dissection plane. The dissection plane was clear at the C1–2 level, and became less clear at medullary level. The tumor was resected completely. The histological result was a schwannoma. His upper extremity strength improved two weeks after operation. Postoperative McCormack's grade was I. (F–G) Postop MRI showed spinal cord edema; (H) postop contrast enhanced MRI showed no residual lesion two weeks after the operation. (I) axial T2-weighted MRI showed the sign of midline myelotomy (Green arrow).

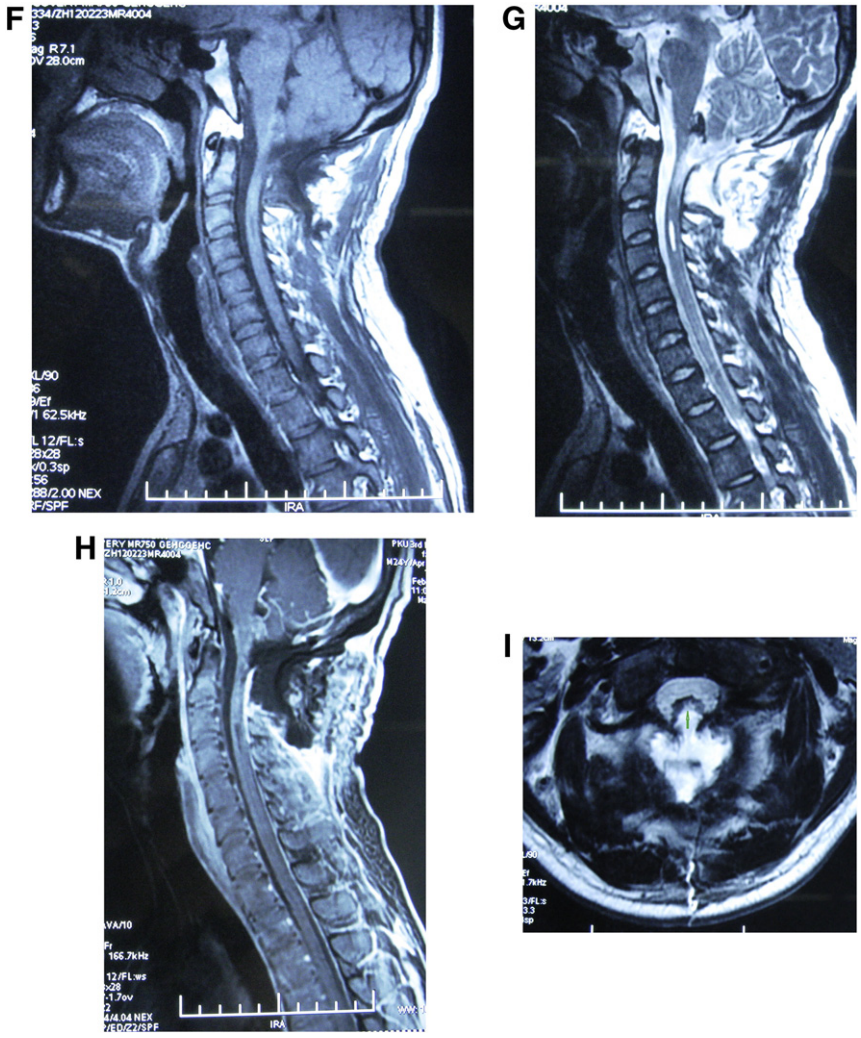

Fig. 5 (*continued*).

In this series, clinical outcome was noted to be improved or stabilized in 91% of cases (80% improved, 11% stabilized, 9% deterioration). In Sandalcioglu et al. [13], they reported 88% of cases with improvement or stabilization (65% improved, 23% stabilized, 12% worsened). In Brotchi et al. [3], they found that the clinical outcome of their patients with intramedullary spinal cord tumor post-surgery were 53% with improvement, 38% stabilization, 9% worsened. Overall it could be speculated that with the advances in neuroimaging, improvement in intraoperative technology and patients selection, better outcome even though modest is now observed compared to historical series. However, we are also fully aware that direct comparison between the series is difficult as previous series included intramedullary spinal cord tumor from various locations with various case mix.

In our series, 86% of patients had laminectomy only, and with a mean follow up of 5.5 years, 2 patients (4%) developed progressive kyphosis that warranted further multilevel spinal fixation. It is possible that the rate of cervical kyphosis might increase in the longer term with serial radiological follow up, but based on our experience so far, less than 20% of our patients overall had laminoplasty or fixation after tumor resection.

5. Conclusion

This series of MSICCT showed that high extent of surgical resection was achievable in most ependymomas with good long-term outcome. Astrocytomas, in contrary remained challenging with 25% achieved gross total resection. Overall, compared to previous surgical series, we showed encouraging improvement in the clinical outcome of these patients managed surgically.

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Table 3
Analysis of various MSICCT tumor subgroups comparing the demographics, pre and postop neurological status, extent of tumor resection, and long-term clinical outcome.

	Ependymoma	Low grade astrocytoma	High grade astrocytoma	Miscellaneous (haemangioblastoma, schwannoma, teratoma)	*p*-value
No of cases	34	16	5	8	
Age	42.1 ± 12.97	31 ± 14.39	32 ± 10.44	26.9 ± 17.89	0.01
Mean	38.7	25.8	25.8	19.9	
Range	19– 64	5– 51	24– 49	7– 63	
M:F	25:9	9:7	2:3	5:3	0.40
Duration of symptoms	40.4 ± 46.37 (months)	24.7 ± 33.0 (months)	3.8 ± 1.92 (months)	42.3 ± 40.66 (months)	0.21
Mean	36.0	27.6	11.3	36.9	
Range	0.3– 180	1– 120	1– 6	2– 120	
No of levels of involvement	4.2 ± 1.25	4.4 ± 1.21	3.4 ± 0.55	3.5 ± 0.76	0.08
	3– 8	3– 8	3– 4	3– 5	
Mean length of tumor	7.9 ± 3.75	8.7 ± 4.85	6.2 ± 1.79	5.4 ± 1.4	0.19
Range	2.5– 18	4– 24	4– 8	2.4– 7	
Extent of resection					0.000
I	30 (88%)	4(25%)	0	6(75%)	
II	3 (9%)	3(18%)	1(20%)	1(12.5%)	
III	1 (3%)	2(13%)	2(40%)	0	
IV	0	7(44%)	2(40%)	1(12.5%)	
Preop McCormack's grade					0.07
I	11(32%)	2(13%)	1(20%)	4(50%)	
II	12(35%)	5(31%)	2(40%)	3(37.5%)	
III	8(24%)	5(31%)	0	1(12.5%)	
IV	3(9%)	4(25%)	2(40%)	0	
Postop McCormack's grade					0.03
I	14(41%)	6(39%)	0	5(62.5%)	
II	10(29%)	4(25%)	1(20%)	3(37.5%)	
III	4(12%)	3(18%)	1(20%)	0	
IV	6(18%)	3(18%)	3(60%)	0	
Preop IJOA	15.4 ± 3.59	13.1 ± 3.83	10.8 ± 6.65	16.0 ± 2.0	0.03
Postop IJOA	15 ± 3.50	14.3 ± 3.57	7.8 ± 5.81	16.5 ± 2.56	0.001
Preop Sphincteric function					0.65
I	22(65%)	8(50%)	3(60%)	5(62.5%)	
II	5(15%)	2(12.5%)	1(20%)	3(37.5%)	
III	4(12%)	4(25%)	0	0	
IV	3(8%)	2(12.5%)	1(20%)	0	
Duration of follow up	(months)	(months)	(months)	(months)	0.001
Mean	32.2	40.3	5.9	27.1	
Range	17– 144	16– 146	3– 36	20– 92	
Latest clinical outcome					0.000
Improved	33	9	0	8	
Stabilized	0	6	1	0	
Worsened	1	1	4	0	

Table 4
The correlation between bladder and bowel sphincteric function and gender of the patients.

	Scoring sphincteric function	I	II	III	IV
Gender	Male	30	4	4	3
	Female	8	7	4	3
Z value	−2.55				
P value	0.01				

Table 5
The relation between scoring sphincteric function and scoring IJOA difference values of the patients.

	Scoring sphincteric function	I	II	III	IV
IJOA difference values	I	0	0	3	0
	II	13	6	5	3
	III	8	3	0	3
	IV	11	1	0	0
	V	6	1	0	0
χ^2 value	14.2				
P value	0.007				

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