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The significance of clinical and morphological characteristics of spinal cord astrocytomas in the choice of surgical tactics

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Objective — to determine the factors affecting the dynamics of the neurological status in the postoperative period in patients with intramedullary spinal cord astrocytomas (SCA) in order to improve the results of their surgical treatment.

Materials and methods. Between 2010 and 2019, we conducted a retrospective study on the surgical treatment outcomes of 39 SCA patients operated on at the SI "Romodanov Neurosurgery Institute of the National Academy of Medical Sciences of Ukraine". The age of the patients ranged from 19 to 67 years, with an average age of 41.4 years. Out of the total, 25 patients (64%) were men and 14 patients (36%) were women. We observed cervical localization in 11 (28%) clinical cases, thoracic localization in 25 (64%), and conus medullaris in 3 (8%). All patients underwent a comprehensive clinical and instrumental examination using magnetic resonance imaging with intravenous enhancement, computed tomography, and spondylography. The dynamics of neurological symptoms were evaluated using the modified McCormick before surgery, at the time of the patient's hospital discharge, and during follow-up examinations.

Results. Total removal of SCA was performed in 7 (18%) patients, subtotal in 25 (64%), and partial in 7 (18%). Pilocytic astrocytoma (PA) (World Health Organisation (WHO) grade I) was detected in 19 (49%) patients, diffuse astrocytoma (DA) (WHO grade II) in 17 (43%), and anaplastic astrocytoma (AA) (WHO grade III) in 3 (7%). Partial regression of neurological symptoms was noted in 29 (74%) patients, the neurological status remained at the preoperative level in 6 (15%) patients, and a slight increase in the neurological deficit was noted in 4 (10%) patients. Age < 60 years is significantly more frequently associated with the growth of PA, while age > 60 years is significantly more frequently associated with the growth of AA. The duration of anamnesis (< 1 year and > 1 year) and the degree of radicality of the operation were identified as significant factors that can influence the neurological status in the late postoperative period, mainly in patients with PA and DA. However, such factors as tumour location and the degree of infiltration of nearby structures are not statistically significant. AA is associated with an unfavourable prognosis across all important criteria.

Conclusions. The most important determinants of SCA prognosis are preoperative and postoperative neurological condition, resection extent, and histological grade. Patients with minor neurological damage at the time of surgery, those under the age of 60, and those with highly differentiated SCA had the greatest surgical treatment outcomes. Assessment of the preoperative neurological status and determination of the histological type of the tumour are important factors in choosing the optimal surgical tactics, which can improve treatment outcomes and the quality of life in SCA patients.

Keywords
intramedullary spinal cord astrocytomas, surgical treatment, neurological symptoms.

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Primary spinal cord tumours overage about 4—8 % of all central nervous system tumours [1, 2, 5, 29]. Depending on the location, they are divided into extradural, intradural extramedullary, and intramedullary [2, 7, 8]. The share of intramedullary spinal cord tumours (IMSCT) does not exceed 20 % among all primary spinal cord tumours, while in children, IMSCT occurs two times more commonly than in adults. Spinal cord gliomas in adults account for 90 % of all IMSCT, and their histology is mainly represented in 60 % of cases by ependymomas and in 30 % of cases by astrocytomas [2, 5, 7, 8, 13]. Less common types of IMSCT are hemangioblastomas (3—8 %), primary lymphomas of the Central Nervous System (CNS) (0.5—2.0 %) etc. [5, 7—10].

Intramedullary spinal cord astrocytomas (SCA) account for approximately 30 % of all primary IMSCT in adults, and up to 60 % of all IMSCT in children [1, 8]. The prevalence of SCA in the population is about 0.045—0.22 per 100,000. For example, in the USA, approximately 136 SCAs are diagnosed annually [3, 8, 10, 11, 28]. A predominant localization of SCA is in the cervical and thoracic parts of the spinal cord. Unlike brain astrocytomas, most intramedullary SCAs are highly differentiated histological variant pilocytic astrocytomas (PA) (World Health Organisation (WHO) grade I) and fibrillary diffuse astrocytomas (DA) (WHO grade II) [16]. PA has a prevalence in all age groups but is significantly more commonly diagnosed in children and somewhat more often in young and middle-aged adults, while DA is most commonly found in adults (5). In elderly and senile patients ≥ 65 years, anaplastic astrocytomas (AA) (WHO grade III) and not otherwise specified (NOS) astrocytoma have significantly higher levels than in more younger groups (5) [1, 5, 9].

The past decades have seen an increasing interest in identifying the genomic profile of SCA [12, 13, 28]. Detection of target genes or biomarkers can improve the prognosis of the disease and treatment strategies and may represent novel targets for individual or genetic therapy. The WHO classification of CNS (2016, 2021) included molecular markers and defined new subtypes of IMSCT based on genetics [16, 17, 28, 35].

The choice of optimal tactics for surgical treatment of intramedullary SCA is an urgent problem in modern neurosurgery, given the small prevalence of this pathology and its unsatisfactory functional consequences in the postoperative period [1, 2, 13, 23, 24, 26]. The effectiveness of radio- and chemotherapy for the treatment of SCA is limited [1, 4, 14]. But new investigations in the sphere of gene mutations in IMSCT can open new opportunities in targeted therapy. The diagnosis of IMSCT, mainly SCA, includes a detailed clinical and neurological examination, magnetic resonance imaging of the spine and spinal cord (MRI) with intravenous enhancement, computed tomography (CT), less often spondylography, and neurophysiological examination [4, 14, 20]. The further choice of treatment tactics depends on several factors: clinical picture, histogenesis of the tumour, anatomical localization, etc. Surgical removal is the primary method of SCA treatment, primarily for treating grade I—II astrocytomas [1, 9, 10, 23, 24, 26]. Adjuvant therapy in the postoperative period can improve the results of SCA treatment after partial removal of the tumour and in the case of recurrences and multifocal lesions, but its effectiveness needs clarification [12, 28].

Surgical tactics must be optimised, as the lack of generally accepted recommendations for the management of SCA patients, despite their low prevalence, leads to mostly unsatisfactory treatment outcomes.

Objective — to determine the factors affecting the dynamics of the neurological status in the postoperative period in patients with intramedullary spinal cord astrocytomas in order to improve the results of their surgical treatment.

Materials and methods

Between 2010 and 2019, we conducted a retrospective study on the surgical treatment outcomes of 39 SCA patients operated on at the SI «Romodanov Neurosurgery Institute of the National Academy of Medical Sciences of Ukraine». The age of the patients ranged from 19 to 67 years, with an average age of 41.4 years. Out of the total, 25 patients (64 %) were men and 14 patients (36 %) were women. Anamnesis ranged from 2 months to 3.3 years (average term — 18 months). We observed cervical localization in 11 (28 %) clinical cases, thoracic in 25 (64 %), and conus medullaris in 3 (8 %).

The dynamics of neurological symptoms were evaluated using the modified McCormick Scale (MMS) before surgery, at the time of the patient's hospital discharge, and during follow-up examinations (Table 1) [5].

Neurovisualization included MRI with intravenous enhancement (in all observations), CT in 7 (18 %) patients and spondylography in 7 (18 %) patients. Contrast was used in order to differentiate SCA from other types of ITSC and demyelinating diseases. The level of tumour extension was classified into less than three involved segments and three or more segments.

Gross total removal (GTR) of SCA was performed in 7 (18 %) patients, subtotal (SR) in 25 (64 %),

Table 1. **Modified McCormick scale for evaluation of neurological functions in spinal cord diseases**

Grade	Neurological status
I	Intact neurologically, normal ambulation, minimal dyesthesia
II	Mild motor or sensory deficit, functional independence
III	Moderate deficit, limitation of function, independent with external aid
IV	Severe motor or sensory deficit, limited function, dependent
V	Paraplegia or quadriplegia, even with flickering movement

and partial removal/biopsy (PR) in 7 (18 %). To prevent the damage to functionally important areas of the spinal cord, electrophysiological monitoring was performed — the recording of somatosensory evoked potentials (SEPs) and, in some cases, motor evoked potentials. Intraoperative ultrasonography was performed to clarify the boundaries and localization of SCA.

According to the WHO Classification (2016) [16] PA (WHO grade I) was detected in 19 (49 %) patients, fibrillary DA (WHO grade II) in 17 (43 %), and AA (WHO grade III) in 3 (8 %). According to the International Classification of Diseases for Oncology, 3rd edition (ICD-O-3), the following histological codes were detected: 9421/1 (pilocytic astrocytoma), 9420/3 (fibrillary diffuse asctocytoma), and 9401/3 (anaplastic astrocytoma). 18 (46 %) patients received adjuvant therapy (radiation and chemotherapy) according to the established protocols [28]. In all patients, catamnesis was present from 2 months to 2 years (M ± 9 months).

The exclusion criteria were defined as the age of patients < 18 years, non-intradural intramedullary astrocytomas, unknown clinical status before and after surgery, non-surgical treatment, unknown WHO grade, not a primary tumour, and no active follow-up.

Statistical analysis

Statistical analysis was carried out using the Fisher extract test to compare the factors of age, duration of anamnesis, location of the tumour, histology, extent of resection, MMS grades in pre- and postoperative periods and during late follow-up etc. We didn't analyse survival rates due to the small number of cases. Statistical analysis was performed using IBM SPSS Statistics 22 for Windows 10. Statistical significance was defined as $p < 0.05$.

Results

Neurological outcomes

The mean duration of symptoms was 18 months, with a range from 2 months to 3.5 years. 20 (51 %) patients were operated on during the first year from the appearance of the first symptoms of the disease; within 1 to 2 years, 13 (33 %) patients; within 2 to 3 years, 3 (8 %) patients, and with a disease history of more than three years, 3 (8 %) patients.

During the **preoperative** assessment of patients' neurological status using the MMS, it was established that 1 (2 %) patient could be assigned to the I grade of neurological status, 25 (64 %) to the II grade, 9 (24 %) to the III grade, 3 (8 %) to the IV grade, and 1 (2 %) to the V grade. During the preoperative examination, the median MMS score was 2.4. Patients with IV and V grades were > 60 years old.

A complex neurological examination of SCA patients revealed that local pain was the most common symptom in 34 (87 %) patients of different age groups. Sensory disorders were observed in 30 (77 %) patients and were manifested mainly by paresthesias, hypoesthesias, and dysesthesias of the conductive and segmental types in the early stages of the disease. Movement disorders in the form of limb paresis of varying severity were diagnosed in 35 (87 %) patients. Functional disorders of the pelvic organs in combination with urinary frequency or incontinence were detected in 26 (67 %) patients and observed, mainly in the late stages of the disease, except for tumours of conus medullaris.

Postoperatively, we classified neurological outcomes as good in patients with grades I—III and poor in patients with grades IV and V. A 1—2 point regression of neurological symptoms was considered an improvement, and changes of more than 2 points compared to the initial status were considered statistically significant. The more objective dynamics of neurological symptoms were observed at the time of discharge from the hospital. 29 (74 %) patients showed partial regression of neurological symptoms, with grade I in 2 (5 %) and grade II in 27 (69 %). 6 (15 %) patients maintained their neurological status at the preoperative level (grade III), while 4 (10 %) patients experienced a slight worsening of their neurological deficit (grade III in 2 and grade IV in 2). There were no fatal cases. The median MMS postoperative period was 2.3. At the late follow-up, 33 (87 %) patients improved their neurological status: up to grade I — 6 (15 %), up to grade II — 24 (62 %), and up to grade III — 3 (8 %). 6 (15 %) patients showed no changes (4 patients — grade III, and 2 patients- grade IV). Persistent motor and sensory disturbances, particularly pelvic organ dysfunction, are unfavourable prognostic factors for functional recovery even with

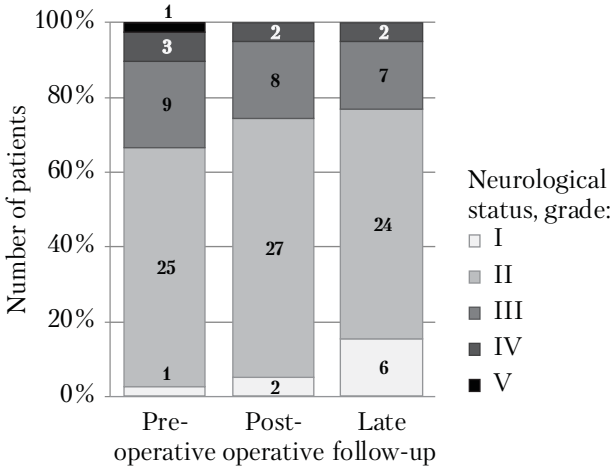

Figure 1. **The dynamics of the neurological status of SCA patients in pre- and postoperative periods according to the MMS**

successful SCA removal. The median MMS at the late follow-up was 2.1 (Fig. 1).

Minimal changes in the median MMS grades of the neurological status in the pre-postoperative periods and during late follow-up (2.4; 2.3; 2.1 respectively) are due to the severity of the pathology and changes within the groups, for example, an increase in the number of patients who can be attributed to grade I according to MMC in the late follow-up.

An interesting trend emerged during the evaluation of the dynamics of neurological symptoms according to the MMS scale in patients with SCA of different histological types in the pre- and postoperative periods. Thus, statistically significant improvement of the neurological status was detected in patients with PA in the late follow-up period in comparison with the preoperative period: increasing the number of patients with grade I according to MMS and decreasing the number of patients with grade II MMS (from 5 % to 25 % vs. from 90 % to 70 %; Fisher test: p = 0.00009). And statistically significant improvement of the neurological status was detected in patients with DA in the late follow-up period in comparison with the preoperative period: increasing the number of patients with grade II according to MMS and decreasing the number of patients with grade III MMS (from 47 % to 65 % vs. from 41 % to 29 %; Fisher test: p = 0.0334) (Table 2).

Radiological findings

Neurovisualization included: MRI with intravenous enhancement (in all observations), CT in 7 (18 %) patients, and spondylography in 7 (18 %) patients. Contrast was used in order to differentiate SCA from other types of IMSCT and demyelinating diseases. The level of tumour extension was

Table 2. **Dynamics of the neurological status of patients with different histological types of spinal cord astrocytomas**

Period	MMS Grade					Fisher's exact test
	I	II	III	IV	V	
Pilocytis astrocytoma (Grade I; n = 19)						
Preoperative	1 (5.3 %)*	17 (89.4 %)	1 (5.3 %)	0	0	p = 0.00009
Postoperative	2 (10.5 %)	17 (89.4 %)	0	0	0	
Late follow- up	5 (26.3 %)	13 (68.4 %)	1 (5.3 %)	0	0	
Diffuse astrocytoma (n = 17)						
Preoperative	0	8 (47.1 %)	7 (41.2 %)	2 (11.8 %)	0	p = 0.0334
Postoperative	0	10 (58.8 %)	7 (41.2 %)	0	0	
Late follow- up	1 (5.8 %)	11 (64.7 %)	5 (29.4 %)**	0	0	
Anaplastic astrocytoma (n = 3) ***						
Preoperative	0	0	1 (33.3 %)	1 (33.3 %)	1 (33.3 %)	
Postoperative	0	0	1 (33.3 %)	2 (66.7 %)	0	
Late follow- up	0	0	1 (33.3 %)	1 (33.3 %)	1 (33 .3%)	

Note. * Comparing the cases with PA of MMS grade I and MMS grade II in preoperative and late follow-up periods.
**Comparing the cases with DA of MMS grade II and MMS grade III in preoperative and late follow-up periods.
*** Because of the small number of cases with anaplastic astrocytoma, they were excluded from the statistical analyses.

classified into less than three involved segments and three or more segments.

All patients underwent MRI pre- and post-operatively. The MRI results revealed that all patients had spinal cord expansion due to SCA. According to the literature, astrocytoma and ependymoma are isointense or hypointense in T1 imaging and hyperintense in T2 imaging [4, 5, 25]. These tumours are well visualised after the introduction of a contrast agent, but a more intense accumulation of contrast is observed in astrocytoma. Unlike ependymoma, SCA is characterised by indistinct edges of the neoplasm, less heterogeneity, and a tendency towards eccentric growth.

Anatomo-topographical and morphological characteristics of SCA

Cervical localization was observed in 11 (28 %) clinical cases, thoracic in 25 (64 %), and conus medullaris in 3 (8 %). A poor preoperative MMS score was detected in 2 (5 %) patients with tumours at the cervical level, in 1 (2 %) patient with a thoracic tumour, and in 1 patient with a tumour in the area of conus medullaris. Post-operatively, the score was clinically but not statistically improved in 7 of all 11 cervical cases (64 %), 14 of all 25 thoracic cases (64 %), and 1 case with a tumour of the conus medullaris. The poor neurological status was in 1 patient with a tumour at the cervical level and 1 patient with a tumour in the area of conus medullaris.

In tumour extension, less than 3 segments were involved in 28 (70 %) cases, and 3 or more segments were involved in 11 (28 %) cases. Preoperatively, 25 (64 %) cases with less than 3 segments received a good score, while 3 (8 %) cases with more than 3 segments received a good score. Postoperatively, all 28 (70 %) patients with less than 3 involved segments improved, while 3 (8 %) patients with 3 or more involved segments received good scores.

Surgical outcomes

The goal of surgical treatment is the total, subtotal, or partial removal of intramedullary tumours, achieving internal decompression of the spinal cord, and creating favourable conditions for further radiation treatment or chemotherapy [16]. The operation must be performed before severe, irreversible symptoms of spinal cord damage have developed.

GTR was achieved in 7 (18 %) cases, ST in 25 (64 %) cases, and PR in 7 (18 %) patients. During operations, we followed the next surgical tactics.

Peculiarities of surgical technique. Surgical treatment of SCA aimed to remove the spinal cord tumour, establish the histogenesis of the tumour, and improve the neurological status of the patients. Electrophysiological monitoring was used to prevent damage to functionally essential areas of the spinal cord — the registration of SEPs and, in some cases, motor-evoked potentials. Intraoperative ultrasonography ensured the identification of neoplasm boundaries and their localization. All patients underwent the procedure in the prone position under general anaesthesia. A microscope was used to examine the tissue, and an ultrasonic aspirator for maximally atraumatic tumour removal.

Before the operation, the limits of surgical access were determined according to the preoperative MRI data, taking into account the localization of the solid part of the tumour, the area of spinal cord edema, and cystic areas. Laminectomy was performed in the projection of the solid component of the neoplasm. The dura mater was dissected linearly along the solid part of the tumour and separated from the sides with sutures (Fig. 2*A*). Taking into account the displacement and rotation of the spinal cord in the presence of SCA, the posterior median sulcus was identified by determining the exit zones of the right and left posterior roots. Large vessels in the myelotomy projection were displaced laterally, and small vessels were coagulated. After dissection of the meninges, atraumatic 7/0 sutures were applied, and traction was performed using ligatures. Using a microscope, a posterior median myelotomy was conducted in the projection of the tumour (Fig. 2*B*). The length of the myelotomy was evaluated segment by segment. In 25 observations, it corresponded to 3—4 segments, in 8 to 1—2 segments, and in 6 to more than four spinal cord segments. In the presence of cysts at the poles of the tumour, they were drained, which subsequently greatly facilitated the removal of the solid part. At the same time, the cystic-solid variant was observed in 21 (54 %), and the solid variant was observed in 18 (46 %) patients. Cysts were located at the poles of the solid part in 15 patients. There were cysts above the solid part in 3 patients and below in 2 patients. Subsequently, the tumour was removed by fragmentation and aspiration using bipolar microcoagulation and an ultrasonic aspirator until the boundaries between the tumour tissue and intact parenchyma appeared in the spinal cord. In the case of infiltrative growth of the tumour and the absence of clear borders between the tumour and the substance of the spinal cord, the operation was limited to the removal of the central mass of the tumour. With a sharp decrease in the amplitude and an increase in the latency of the SEPs, the surgical intervention was stopped due to the threat of deepening the neurological deficit.

Hemostasis was achieved by washing the bed of the removed tumour with saline and H_2O_2 tapes and

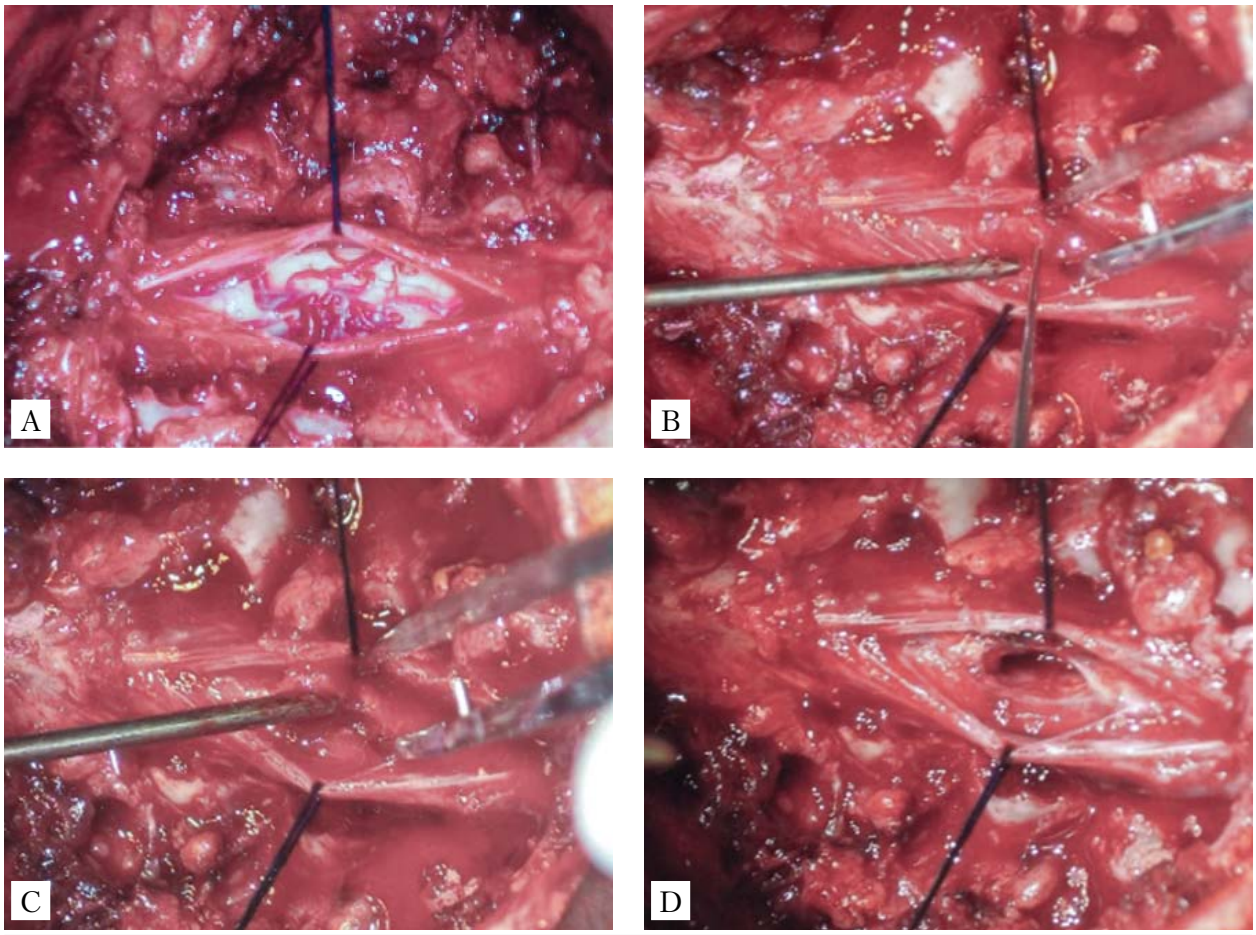

Figure 2. **Intraoperative photos of the stages of intramedullary anaplastic astrocytoma removal at the level of Th8-Th10 vertebrae in a 49-year-old male.** Explanation in the text

using Surgicel strips on the surface of the meninges. The soft meninges were sutured with knotted sutures with 9/0 atraumatic sutures, and the dura was mated with continuous sutures with 6/0 sutures. Soft tissues were hermetically sutured layer by layer (Fig. 2*C, D*).

For 24 (61.5 %) patients, intra-operative neuromonitoring was used, which included assessments of D-wave integrity, somatosensory responses, and motor evoked potentials. This monitoring is crucial for ensuring a safe tissue resection during surgery. Technical difficulties accounted for the absence of neuromonitoring in 15 (38.0 %) cases of the total.

Patients with acute neurological deterioration or those showing signs of surrounding spinal cord tissue involvement on spinal MRI typically received steroids preoperatively.

Early post-operative complications occurred in 4 (10 %) cases: 2 (5 %) cases experienced cerebrospinal fluid leak at the cervical level where dural grafts were used; 1 (2 %) case had a post-operative haematoma with a volume of up to 20 ml, which was treated conservatively; and 1 (2 %) case had *Escherichia* coli meningitis and a low Th10 level. The patients experiencing cerebrospinal fluid leaks were treated prophylactically with lumbar drains. The case of meningitis was managed with antibiotics and the re-insertion of a lumbar drain.

18 (46 %) patients who underwent partial and subtotal resection received adjuvant therapy (radiation (47.6 ± 3.3 Gy) and chemotherapy) according to the established protocols [2, 13].

Late outcomes

An objective prognostic criterion for the results of SCA treatment is the severity of the neurological status in the pre-and postoperative periods. Typically, the worsening of neurological symptoms is noted in the early postoperative period, and the recovery of functions continues for several months after surgery. Low-differentiated SCAs (grades III—IV) have an unfavourable prognosis. Usually, the neurological status does not improve after surgery, and the radicality of tumour resection does not affect the patients' quality of life or overall survival (Fig. 3, 4).

According to the literature, the overall survival rate after surgery for malignant anaplastic SCA

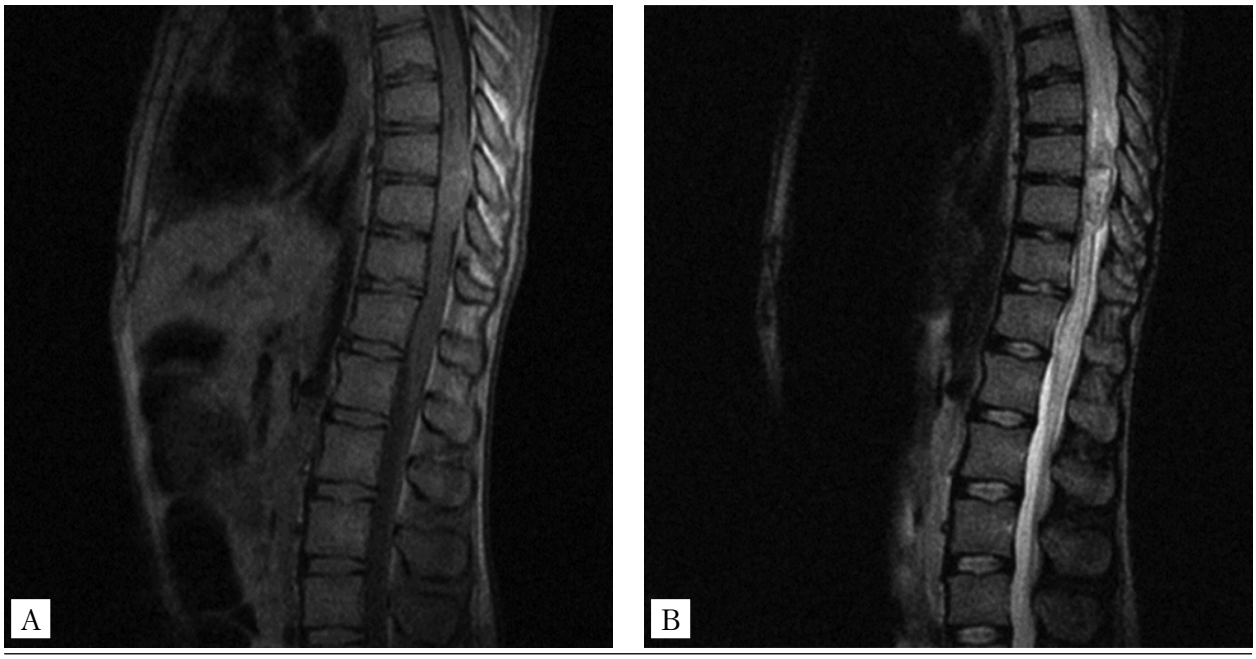

Figure 3. **Presurgical T1-weighted (A) and enhanced T2-weighted (B) MRI images of a spinal cord anaplastic astrocytoma (WHO grade III) on the Th8-Th10 level in a 49-year-old male with symptoms of numbness and weakness in both lower limbs**

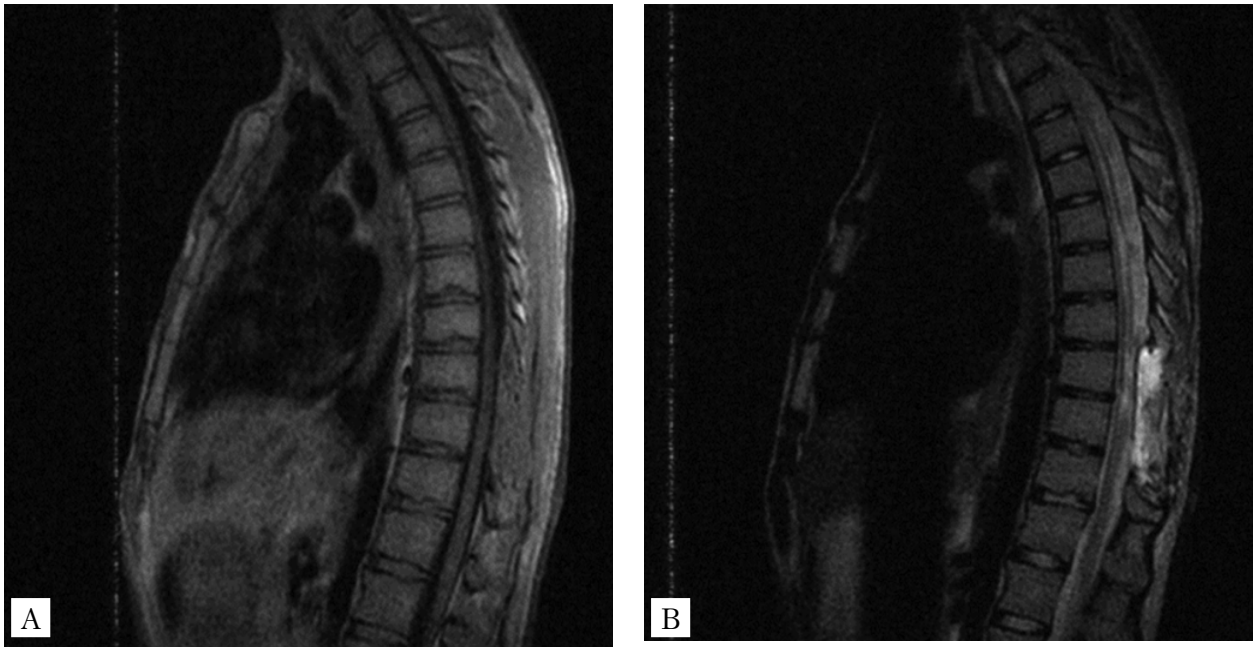

Figure 4. **Postsurgical T1-weighted (A) and enhanced T2-weighted (B) MRI images of a spinal cord anaplastic astrocytoma (WHO grade III) on the Th8-Th10 level in a 49-year-old male 3 weeks after subtotal removal. Clinical symptoms without improvement**

does not exceed 6—8 months in adults and 13 months in children. The overall survival of patients with PA was 22 months, with DA — 18 months, and with AA — 6 months. In patients who underwent combined treatment with radiation and chemotherapy, overall survival increased to 2—5 months [15, 18—23, 25]. In our study, catamnesis was present from 2 months to 2 years (± 9 months) in all patients. Tumour recurrence occurred in 4 (10 %) cases during the first 6 months after surgery. We didn't analyse the survival rate due to the small number of cases, but statistical analysis was carried out using the analysis of variables to compare the factors of age, duration of anamnesis, location of the tumour, extent of resection, MMS grades in pre- and postoperative periods and during late

Table 3. **Clinico-radiological features of 39 intramedullary spinal cord astrocytomas**

Variable	Pilocytis astrocytoma n = 19	Diffuse astrocytoma n = 17	Anaplastic astrocytoma n = 3*	Fisher's exact test
Age, years				
< 60 (n = 31)	19 (100 %)	12 (70.6 %)	0	p = 0.00000
> 60 (n = 8)	0	5 (29.4 %)	3 (100 %)	
Gender				
Male (n = 25)	9 (47.4 %)	13 (76.5 %)	3 (100 %)	p = 0.00003
Female (n = 14)	10 (52.6 %)	4 (23.5 %)	0	
Duration of anamnesis				
≤ 1 year (n = 20)	7 (36.8 %)	10 (58.8 %)**	3 (100 %)	
1—2 years (n = 13)	8 (42.1 %)	5 (29.4 %)	0	p = 0.00286
2—3 years (n = 3)	2 (10.5 %)	1 (5.8 %)	0	
> 3 years (n = 3)	2 (10.5 %)	1 (5.8 %)	0	
Tumour location				
Cervical	10 (52.6 %)	10 (58.8 %)	1 (33.3 %)	
Thoracic	7 (36.8 %)	7 (41.2 %)	1 (33.3 %)	
Conus medullaris	2 (10.5 %)	0	1 (33.3 %)	
Infiltration				
Well-delienated	7 (36.8 %)	5 (29.4 %)	0	p = 0.167
Infiltrative	10 (52.6 %)	11 (64.7 %)	3 (100 %)	
No data	2 (10.5 %)	1 (5.8 %)	0	
Extent of surgical resection				
Gross total resection	4 (21.1 %)	2 (11.8 %)	0	p = 0.00000
Subtotal resection	12 (63.2 %)	6 (35.3 %)	1 (33.3 %)	
Partial/biopsy	3 (15.8 %)***	9 (52.9 %)	2 (66.7 %)	

Note * Because of the small number of cases with anaplastic astrocytoma they were excluded from the statistical analyses both with the category «no data».
** Comparing anamnesis < 1 year and > 1 year in patients with piloctic astrocytoma and diffuse astrocytoma.
*** Comparing partial/biopsy and more radical surgical resection (gross total and subtotal resection) in patients with piloctic astrocytoma and diffuse astrocytoma.

follow-up, etc. in patients with different histological types.

In our study, age < 60 is significantly more frequently associated with the growth of PA, while age > 60 years is significantly more frequently associated with the growth of AA (Fisher test: p = 0.00000). We also observed a higher prevalence of DA in males compared to females, but there was no significant difference in the incidence of PA (76 % and 23 % vs. 47 % and 52 %; Fisher test: p = 0.00003). We also noted a significant difference between the duration of anamnesis < 1 year and > 1 year in patients with PA and DA (Fisher test: p = 0.00003). As for the degree of radicality of the operation, we revealed a significant difference between the number of patients who underwent partial removal / biopsy or more radical surgical resection (gross total and subtotal resection) in patients with PA and DA (85 % and 15 % vs. 47 % and 53 %; Fisher test: p = 0.00000). However, such factors as tumour location and degree of infiltration of nearby structures were not statisticaly significant (Table 3).

Disscussion

Summarising the data from the literature and our results, it should be noted that SCA is a complex pathology for early diagnosis and treatment tactics.

Patients' age has an essential prognostic value in SCA patients [3, 8, 13]. It is important to directly understand the age-adjusted incidence of SCA per 100,000 of people in the population. Thus, according to the comprehensive epidiological review of SCA in the USA, the peak incidence of SCA was observed in the 0—19-year-old age group, while the lowest level was observed in the 20—34-year-old age group for males and in the 35—44-year-old age group for females [28]. The second peak was observed in the 75—84-year-old age group without significant prevalence of sex, with the next decreasing level of incidence in the ≥85-year-old age group [28]. Multiple studies have shown that old age is associated with a worse prognosis, but we must analyse this tendency in the context of the prevalence of initially poor overall and recurrence-free survival in patients older than 65 years in whom AA is mainly diagnosed. So, the duration of the remission period is longer in young patients than in elderly patients due to the prevalence in <60-year-old patients with PA and DA, which are associated with a more favourable prognosis.

It was established that high-grade tumours had poor neurological outcomes. This finding may be due to the fact that high-grade tumours tend to infiltrate normal spinal cord tissue. High-grade tumours require pre- or post-operative radiotherapy, which could result in poor functional outcomes [28]. Preoperative radiotherapy may cause radiation-induced myelopathy and/or myelitis and compromise the spinal cord microvasculature, which leads to spinal cord ischaemia and severe neurological symptoms.

SCA can be well enhanced on contrast MRI of the spine, which improves distinction between more common solid and less common cystic types of the tumour, which are usually more malignant [31—34]. SCA characterised mainly by infiltrative growth, which limits the radicality of their removal and is a reason for possible recurrences, except for juvenile pilocytic SCA [3, 12, 34].

The surgical management protocol for SCA is not absolutely clear [15, 18, 19, 31]. Surgery for low-grade astrocytomas should be aimed at total resection to preserve neurological function and improve ealy and late outcomes. The correlations between the resection volume and the risk of recurrence still need to be studied [26, 27, 30, 31]. To determine the radicality of the surgical intervention, an MRI is performed in the early postoperative period since intraoperative visual control of tumour removal is often not full. Taking into account the peculiarities of the growth of SCA, it should be noted that residual tumour elements may also be present in cases of absence of the tumour according to the MRI data and visual total removal of SCA during surgery [2, 4, 31].

Modern microsurgical techniques, intraoperative electrophysiological monitoring, and ultrasonography increase the volume of plan resection and ensure atraumatic removal of the tumor. Differentiated surgical tactics in SCA consist of the following positions: adequate operative access depending on the location of the tumour, limiting the resection zone in the absence of clear boundaries between the SCA tissue and the intact parenchyma of the spinal cord, and changes in the SEP indicators. In the case of infiltrative growth of the tumour, surgical intervention was limited to the partial removal of SCA.

Thus, our study established that the results of surgical intervention in patients with SCA are directly related to the preoperative neurological condition, the patient's age, and the tumour's histological structure. Preoperative neurological status, persistent motor and sensory disturbances, and pelvic organ dysfunction are the determining predictors of postoperative functional outcomes in SCA. The best results of the surgical treatment were observed in patients with SCA with minimal neurological deficit at the time of surgery, in patients younger than 60 years old, and with highly differentiated SCA. In patients with pronounced clinical symptoms, surgery should be performed as early as possible (just after the tumour is detected).

Conclusions

The most important outcome predictors of SCA are the preoperative and postoperative neurological condition, extent of resection, and histological grade. The best surgical treatment results were observed in patients with minimal neurological deficit at the time of surgery, in patients younger than 60 years, and with highly differentiated SCA.

Age < 60 years is significantly more frequently associated with the growth of PA, while age > 60 years is significantly more frequently associated with the growth of AA. The duration of anamnesis (< 1 year and > 1 year) and the degree of radicality of the operation were identified as significant factors that can influence the neurological status in the late postoperative period, mainly in patients with PA and DA. However, such factors as tumour location and the degree of infiltration of nearby structures are not statistically significant. AA is associated with an unfavourable prognosis across all important criteria.

Therefore, in patients with pronounced clinical symptoms of any histological type of SCA, surgery

should be performed as early as possible after the tumour is detected.

Assessment of the preoperative neurological status and determination of the histological type of the tumour are important factors in choosing the optimal surgical tactics, which can improve treatment outcomes and the quality of life in SCA patients.

Declaration of interests

The authors declare that they have no financial, personal, authorship, or other conflicts of interest that could influence the research and results presented in this article.

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Ethics approval and written informed consent statements

The Commission on Bioethical Expertise and Ethics of Scientific Research at Bogomolets National Medical University concluded that the mentioned research does not contain an increased risk for the research subjects and was planned according to existing bioethical norms and scientific standards regarding the conduct of clinical research involving patients.

Authors contributions

O. I. Troyan: research concept and design; analysis and interpretation of data; A. V. Muravsky: acquisition of data; M. O. Marushchenko: analysis and interpretation of data; M. V. Khyzhnyak: drafting the manuscript.

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Значення клініко-морфологічних особливостей астроцитом спинного мозку у виборі хірургічної тактики

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Мета — визначити чинники, що впливають на динаміку неврологічного статусу в післяопераційний період у пацієнтів з інтрамедулярними астроцитомами спинного мозку (АСМ) для поліпшення результатів їх хірургічного лікування.

Матеріали та методи. Проведено ретроспективне дослідження результатів хірургічного лікування 39 хворих з АСМ, прооперованих у ДУ «Інститут нейрохірургії імені акад. А. П. Ромоданова НАМН України» у 2010—2019 рр. Вік пацієнтів — від 19 до 67 років (середній вік — 41,4 року). Серед пацієнтів переважали чоловіки (64 %). Ріст пухлини в шийному відділі спинного мозку спостерігався в 11 (28 %) випадках, у грудному — у 25 (64 %), у ділянці мозкового конуса — у 3 (8 %). Усім пацієнтам проведено комплексне клініко-інструментальне обстеження з використанням магнітно-резонансної томографії з внутрішньовенним підсиленням, комп'ютерної томографії, спондилографії. Динаміку неврологічної симптоматики оцінювали за модифікованою шкалою McCormick Scale до операції, при виписуванні хворого зі стаціонару та під час контрольних оглядів.

Результати. Тотальне видалення АСМ виконано у 7 (18 %) хворих, субтотальне — у 25 (64 %), часткове — у 7 (18 %). Пілоцитарна астроцитома (ВООЗ grade I) виявлена в 19 (49 %) хворих, дифузна астроцитома (ВООЗ grade II) — у 17 (43 %), анапластична астроцитома (ВООЗ grade III) — у 3 (8 %). У 29 (74 %) хворих зареєстрували частковий регрес неврологічної симптоматики, у 6 (15 %) — неврологічний статус залишився на дооперацийному рівні, у 4 (10 %) — незначне підсилення неврологічного дефіциту. Пілоцитарні астроцитоми статистично значуще частіше формуються у пацієнтів віком < 60 років, тоді як анапластичні астроцитоми — у пацієнтів віком > 60 років. Статистично значущими чинниками, які можуть впливати на неврологічний статус у віддалений післяопераційний період, переважно в пацієнтів із пілоцитарними та дифузними астроцитомами є: тривалість анамнезу (< 1 року та > 1 року) і ступінь радикальності операції, а такі чинники, як розташування пухлини та ступінь інфільтрації прилеглих структур, статистично незначущі. Анапластична астроцитома асоціюється з поганим прогнозом за всіма ключовими чинниками.

Висновки. Найважливішими предикторами наслідків АСМ є дооперацийний і післяопераційний неврологічний статус, ступінь радикальності операції та гістологічний тип. Найкращі результати хірургічного лікування спостерігали в пацієнтів із мінімальним неврологічним дефіцитом на момент операції, в осіб віком до 60 років та хворих із високодиференційованими інтрамедулярними астроцитомами. Оцінка дооперацийного неврологічного статусу та визначення гістологічного типу пухлини є важливими чинниками для вибору оптимальної хірургічної тактики, урахування яких дасть змогу поліпшити результати лікування та якість життя хворих з АСМ.

Ключові слова: інтрамедулярні астроцитоми спинного мозку, хірургічне лікування, неврологічна симптоматика.

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