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Long-term treatment outcomes of spinal intradural tumors: A 10-year cohort study in Zenica-Doboj Canton, Bosnia and Herzegovina

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ABSTRACT

Introduction: Despite the presence of various constraints, Bosnia and Herzegovina has managed to establish healthcare services in the field of spinal surgery. Limiting factors associated with resource scarcity and a shortage of neurosurgeons may pose challenges, but they are not insurmountable in the context of spinal tumor surgery. This study aims to provide a comprehensive 10-year analysis of intradural spinal tumors in resource-constrained healthcare settings and assess surgical outcomes in these challenging environments.

Methods: A retrospective study was conducted involving 39 patients with intradural spinal tumors in Zenica-Doboj Canton, Bosnia and Herzegovina, from 2011 to 2021. Patients underwent neurological examinations and spinal magnetic resonance imaging scans, followed by post-surgery assessments at 3 and 6 months using the McCormick scale.

Results: Among the 39 patients, tumor distribution was as follows: meningioma (15, 38.5%), ependymoma (3, 7.7%), schwannoma (11, 28.2%), neurenteric cyst (1, 2.6%), primary melanoma (2, 5.1%), lipoma (1, 2.6%), and metastasis (6, 15.4%) ($p < 0.001$). A majority of patients reported localized and radicular pain (37, 94.9%, $p < 0.001$) and paresthesia (33, 84.6%, $p < 0.001$). Motor weakness was noted in 20 (51.3%) patients, while sphincteric dysfunction was reported by 17 (43.6%) patients. The average symptom duration was 397.9 ± 380.9 days, ranging from 14 to 1460 days ($p < 0.001$). Pneumonia and liquorrhea were reported by 1 (2.6%) patient each. Regarding mortality, 1 (2.6%) patient passed away within a 6-month follow-up period ($p < 0.001$), and 2 (5.1%) patients were diagnosed with primary malignant melanoma. Significant improvements in McCormick scores were observed between postoperative and 3-month assessments ($p < 0.001$) and between 3-month and 6-month assessments ($p = 0.024$).

Conclusions: This study offers valuable insights into the management of intradural spinal tumors in resource-constrained healthcare settings. Timely diagnosis and surgical intervention are essential for achieving positive patient outcomes in these challenging environments.

Keywords: Spine; neoplasm; restricted resources

INTRODUCTION

Spinal tumors are rare neoplasms and account for about 15% of central nervous system (CNS) tumors (1). These are most common located extradurally which constitutes 55-60% of all spinal tumors and metastases are the most common type of these tumors. Intradural tumors are rare and constitute about 40-45% of spinal tumors (1-3). The incidence of these tumors is 2-4/100,000 (2). Intradural tumors are classified into intramedullary and extramedullary (4). Intramedullary tumors are very rare and account for 2-4% of all CNS tumors (3). The most common intramedullary tumors are low-grade ependymomas and astrocytomas. Spinal glioblastomas, hemangioblastomas, gangliogliomas, germinomas, primary CNS lymphomas, and melanomas are rarely diagnosed (2,3). Extramedullary tumors are more common than intramedullary ones (1). The most common extramedullary tumors are meningiomas and schwannomas. Metastases, lymphomas, primary melanomas, etc., are very rare (1). Extradural tumors are usually metastatic, but intradural tumors are usually primary. Accordingly, the therapy and prognosis of intra and extradural tumors are significantly different (5). Spinal tumors are clinically manifested by local and radicular pain, motor weakness, and bowel and bladder dysfunction (6). The primary

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treatment modality for spinal tumors is microneurosurgical resection (1,2).

Bosnia and Herzegovina, as a developing country, encounters specific challenges in various aspects of healthcare delivery (7), including the management of spinal tumors. Despite the presence of various constraints, Bosnia and Herzegovina has managed to establish healthcare services in the field of spinal surgery. Limiting factors associated with resource scarcity and a shortage of neurosurgeons may pose challenges, but they are not insurmountable in the context of spinal tumor surgery. The primary objective is to showcase the 10-year experience of managing rare entities like spinal tumors under restricted conditions and assess the surgical outcomes in such challenging environments. Hence, this research holds significant practical implications for countries in the developmental stage, specifically those with low-and middle-income countries (LIMICs).

METHODS

A retrospective study included 39 consecutive patients with intradural spinal tumor. All patients were operated at the Department of Neurosurgery, Cantonal Hospital Zenica, Bosnia and Herzegovina, between January 2011 and December 2021. Only patients with intradural spinal tumors were included in this study. Patients with extradural tumor or other forms of spinal cord compression were excluded from this study. Each patient underwent a detailed clinical and neurological examination. According to the results of the neurological examination, magnetic resonance imaging (MRI) (Siemens Magnetom Avanto 1.5 T, Erlangen, Germany) of the corresponding part of the spine was performed. In this research, we evaluated clinical presentation, neurological findings, and post-operative outcomes in patients with intradural spinal tumors. The study is approved by Ethical Committee of Cantonal Hospital Zenica.

All patients underwent surgery in the prone position under general anesthesia, employing chest and hip rolls to ensure abdominal decompression. The head was positioned in a headrest, except for cases involving cervical spine tumors, where the patient's head was secured in a three-point Mayfield device. A standard posterior approach was utilized to remove the tumor. Before the surgical procedure, the surgical field was washed with a cationic detergent and then disinfected with povidone-iodine, which has been previously demonstrated as an effective and accessible method for preventing post-operative infections (8). Due to resource limitations, disposable cloth materials were utilized to cover the surgical field, and regular checks for sterilization were conducted. The surgical procedure commenced with a longitudinal skin incision, providing adequate exposure of the normal spinal cord above and below the tumor level. Laminectomies were performed, facilitating the visualization of the spinal dura. Subsequently, an operating microscope (OPMI Pentero 900, Carl Zeiss, Oberkochen, Germany) was employed to continue the operation. The dura was longitudinally opened to expose the tumor and spinal cord, and a meticulous microsurgical resection was carried out piece by piece. For intramedullary tumors, a medial myelotomy was performed to access the tumor. In cases where complete tumor removal was not feasible, subtotal resection or biopsy was performed. Oxidized regenerated cellulose (Surgicel™) was used for controlling intraoperative bleeding. The surgical intervention involved the use of a single suture for closing the skin, subcutaneous tissue, fascia, and muscles. Prevention of post-operative cerebrospinal fluid leakage involves autologous grafting with fat tissue (9). Typically, patients were discharged on the 10th day postoperatively.

All patients underwent post-operative physical treatment and had a follow-up by neurosurgeon. A detailed neurological examination was performed 3 and 6 months after the operation. Each patient was evaluated according to the McCormick scale. This scale evaluates the severity of the neurological deficit on a scale of I-V. The McCormick scores were utilized as a classification system to evaluate the neurological status and functional impairment of patients with spinal canal tumors (10,11). These scores were assessed preoperatively, as well as at 3 and 6 months postoperatively, to monitor the patients' progress over time. The grades include Grade I (minimal dysesthesia without pain and intact neurological function), Grade II (mild motor or sensory deficits with functional independence), Grade III (moderate motor deficits with functional limitations but independence with aids), Grade IV (severe motor deficits with significant limitations and the need for walking aids), Grade V (complete paralysis and functional dependence), and W/O (no symptoms or neurological deficits).

Statistical analysis was performed in SPSS software (v. 26.0., Statistical Package for the Social Sciences, Chicago, Illinois, USA). The incidence is determined by utilizing the formula: Incidence = (New Cases)/(Population × Timeframe) (12). This calculation estimates the rate of occurrence of a particular condition or disease. The population figure used in the equation is obtained from official reports provided by the Statistical Agency of Bosnia and Herzegovina. With the Kolmogorov–Smirnov test, it was determined that there are statistically significant deviations in the normality of the distribution of the investigated variables, which is why non-parametric tests were applied. For categorical variables, the Chi-square test was used to test differences between groups. For continuous variables, differences were examined with Kruskal–Wallis H test. Statistical significance was set at $p \leq 0.05$. GraphPad Prism (v. 9.0., GraphPad Software, Inc., San Diego, California, USA) was used for data visualization.

RESULTS

This retrospective study included 39 patients with intradural spinal tumors. Of those, 22 (56.4%) were females and 17 (43.6%) were males ($p = 0.522$), with female: male ratio 1.29:1. The average age was 53.38. The youngest patient was 17 and the oldest 79 years ($p = 0.002$) (Table 1). The estimated incidence rate is 1.01/100,000 population in the Zenica-Doboj Canton.

Among the sample of 39 patients, the localization of tumors was observed in the cervical region for 7 (17.9%) individuals, the thoracal region for 18 (46.3%) individuals, and the lumbosacral region for 14 (35.8%) ($p = 0.943$). In terms of topographic characteristics, the majority of tumors were

TABLE 1. Gender, age, localization, topographic characteristics, clinical presentation, duration of symptoms (in days), duration of neurological deficit (in days) of intradural spinal tumors

Variable	n (%) or M±SD (min-max)	*p*
Gender		
Male	17 (43.6)	0.522
Female	22 (56.4)	
Total	39 (100)	
Age	53.4±14.9 (17-79)	0.002
Localization		
Cervical	7 (17.9)	0.943
Thoracal	18 (46.3)	
Lumbosacral	14 (35.8)	
Topographic characteristics		
Intradural extramedullary	23 (59.0)	<0.001
Intramedullary	3 (7.7)	
Cauda equina	13 (33.3)	
Clinical presentation		
Localized pain		
Yes	37 (94.9)	<0.001
No	3 (7.1)	
Radicular pain		
Yes	37 (94.9)	<0.001
No	2 (5.1)	
Paresthesia		
Yes	33 (84.6)	<0.001
No	6 (15.4)	
Motor weakness		
Yes	20 (51.3)	0.873
No	19 (48.7)	
Sphincteric dysfunction		
Yes	17 (43.6)	0.423
No	22 (56.4)	
Duration of symptoms (days)	397.9±380.9 (14-1460)	<0.001
Duration of neurological deficit (days)		
<2	17 (43.6)	<0.001
2-7	9 (23.1)	
8-14	13 (33.3)	
Histopathological analysis		
Meningioma	15 (38.5)	<0.001
Ependymoma	3 (7.7)	
Schwannoma	11 (28.2)	
Neurenteric cyst	1 (2.6)	
Primary melanoma	2 (5.1)	
Lipoma	1 (2.6)	
Metastasis	6 (15.4)	
Non-Hodgkin lymphoma	3 (7.1)	
Ovarian cancer	1 (2.6)	
Ewing sarcoma	1 (2.6)	
Lung carcinoma	1 (2.6)	

N: Frequency, M: Mean, SD: Standard deviation, Min: Minimal value, Max: Maximal value

classified as intradural extramedullary in 23 (59.0%) individuals, followed by cauda equina tumors in 13 (33.3%) individuals, and a smaller proportion as intramedullary in 3 (7.7%) individuals ($p < 0.001$) (Table 1).

Out of 39 patients, 15 (38.5%) had meningioma, 3 (7.7%) had ependymoma, 11 (28.2%) had schwannoma, 1 (2.6%) had neurenteric cyst, 2 (5.1%) had primary melanoma, 1 (2.6%) had lipoma, and 6 (15.4%) had metastasis ($p < 0.001$), with the following primary origins: 3 (7.1%) had non-Hodgkin lymphoma, 1 (2.6%) had ovarian cancer, 1 (2.6%) had Ewing sarcoma, and 1 (2.6%) had lung carcinoma (Table 1).

Majority of patients, specifically 37 (94.9%), reported the occurrence of localized and radicular pain, indicating a robust statistical difference ($p < 0.001$) (Table 1). Paresthesia was reported by 33 (84.6%) patients ($p < 0.001$). Conversely, the presence of motor weakness did not exhibit a statistical difference ($p = 0.873$), as 20 (51.3%) patients reported experiencing it while 19 (48.7%) did not. Similarly, sphincteric dysfunction was reported by 17 (43.6%) patients, while 22 (56.4%) did not exhibit this symptom. The duration of symptoms experienced by patients with spinal canal tumors was found to be 397.9 ± 380.9 days, ranging from 14 to 1460 days ($p < 0.001$), indicating variation in the length of time patients experienced symptoms. Regarding the duration of neurological deficits, 17 (43.6%) patients had deficits lasting <2 days ($p < 0.001$). Furthermore, 9 (23.1%) patients had deficits lasting between 2 and 7 days, while 13 (33.3%) patients had deficits lasting between 8 and 14 days.

All patients received analgesic medications for pain management. In terms of physical therapy, 23 (59.0%) patients underwent this modality, while 16 (41.0%) did not ($p = 0.337$). Within the 6-month postoperative period, there was a statistically significant difference observed for the occurrence of pneumonia ($p < 0.001$), liquorrhea ($p < 0.001$), and death ($p < 0.001$) among patients with spinal canal tumors. Only 1 (2.6%) patient experienced pneumonia, while the majority of patients, 37 (97.4%), did not. Similarly, liquorrhea was reported in 1 (2.6%) patient, while 37 (97.4%) did not experience it. Regarding mortality, only 1 (2.6%) patient passed away ($p < 0.001$) (Table 2).

Figure 1 depicts a patient with ependymoma. In Figure 1A, a neoplastic formation at the level of C2/C3 can be seen in the lateral MRI profile, confirming its heterogeneity in Figure 1B. Figure 1C shows an intraoperative image before the removal of the intramedullary ependymoma, while Figure 1D displays the spinal cord after complete tumor resection. Postoperative MRI in Figure 1E and F demonstrates no tumor recurrence, which is further supported by the reduction in McCormick scale values from grade V to grade I (Supplement Table 1, No 32).

Two patients (out of 39, 5.1%) had a primary malignant melanoma, one of whom had a fatal outcome within 6 months. In addition, Supplement Table 1 shows that patient No 17 did not express improvement in post-operative monitoring, as the McCormick scale values before surgery, 3 months after surgery, and 6 months after surgery were all grade IV. After the last follow-up in the 6th month, the patient died due to complications. Figure 2A shows a lateral view of the primary melanoma at the level of C5/C6, while Figure 2B reveals its intradural extramedullary localization. Intraoperative image (Figure 2C and 2D) depicts a darkly pigmented neoplastic mass, which histopathological analysis confirmed to be melanoma. Following the histopathological analysis, the patient underwent a thorough examination by a dermatoncologist, during which no primary cutaneous or extracutaneous focus was found.

TABLE 2. Extent of resection, therapy modalities, and post-operative complications within 6 months after surgery

Variable	n (%) or M±SD (min-max)	*p*
Extent of resection		
Gross total	34 (87.2)	<0.001
Subtotal	4 (10.3)	
Biopsy	1 (2.6)	
Therapy modality		
Analgesic medications		
Yes	39 (100.0)	-
No	0 (0.0)	
Physical therapy		
Yes	23 (59.0)	0.337
No	16 (41.0)	
Post-operative complications*		
Pneumonia		
Yes	1 (2.6)	<0.001
No	37 (97.4)	
Liquorrhea		
Yes	1 (2.6)	<0.001
No	37 (97.4)	
Death		
Yes	1 (2.6)	<0.001
No	37 (97.4)	
Total	39 (100.0)	

N: Frequency, M: Mean, SD: Standard deviation, Min: Minimal value, Max: Maximal value

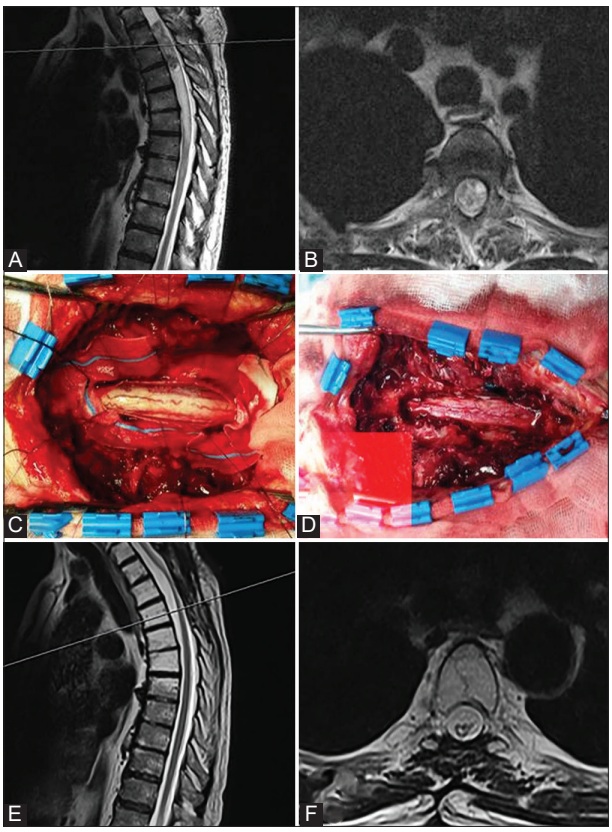

FIGURE 1. Spinal ependymoma resection: (A) Pre-operative lateral magnetic resonance imaging profile showing the neoplastic formation at the level of C2/C3. (B) Magnetic resonance imaging findings revealing tumor heterogeneity. (C) Intraoperative image before the removal of the ependymoma. (D) Post-operative image displaying the spinal cord after complete tumor resection. (E) and (F) 6-month post-operative magnetic resonance imaging verification of the tumor absence.

At the pre-operative stage, 1 (2.6%) patient was classified as Grade I, 5 (12.8%) as Grade II, 11 (28.2%) as Grade III, 11 (28.2%) as Grade IV, 11 (28.2%) as Grade V, and none W/O (without) neurological deficit. After 3 months, the distribution changed, with 16 (41.0%) patients categorized as Grade I, 10 (25.6%) as Grade II, 6 (15.4%) as Grade III, 5 (12.8%) as Grade IV, and none as Grade V, with statistically significant difference compared to first assessment ($p < 0.001$). At the 6-month mark, 16 (41.0%) patients remained in Grade I, 3 (7.7%) were in Grade II, 1 (2.6%) in Grade III, 2 (5.1%) in Grade IV, and none in Grade V, with evident improvement in comparison to second assessment ($p = 0.024$) (Figure 3).

DISCUSSION

The utilization of MRI has contributed to an increased detection and subsequent rise in the incidence of intradural spinal tumors (13). The findings from the study conducted by El-Hajj et al. (14) align with our observations regarding the predominance of females in spinal tumor cases. The male-to-female ratio varied across the studies, ranging from 1:1.5 to 1:14.5 (14-16). This study showed a female-to-male ratio of 1.29:1. In the epidemiological study conducted by Schellinger et al. (17) from 1998 to 2001, an approximately equal number of affected individuals among males and females was reported, suggesting a possible increase in the incidence among the female population.

According to Schellinger et al. (17), the estimated global incidence of spinal tumors is 0.74/100,000 population, with a significantly higher incidence among non-Hispanic Caucasians. In this study, the estimated incidence is 1.01, which is higher compared to the global results reported by Schellinger et al. (17). Interestingly, the neighboring country of Croatia has a higher incidence rate of 1.6/100,000 (18). It is evident that the incidence is higher in developed countries (19), and a possible explanation is the resources available in these countries, which directly impact diagnostic capabilities.

When it comes to age-related epidemiological characteristics of spinal neoplasms, the mean age in this study was 53.38. Ciftdemir et al. (20) state that spinal neoplasms are most common in individuals above 50 years of age, which is consistent with our findings. Schellinger et al. (17) reported a median age of 51 years. Results from Croatia support a younger age at diagnosis compared to our findings, with a mean age of 49.6 years during diagnosis of spinal tumors (18).

Dang et al. (21) reported that the most frequent spinal tumors occur in the cervicothoracic region, with a percentage representation of 57%. Narayan et al. (6) reported the presence of spinal tumors in the cervical region in 48% of cases, which is approximately consistent with our findings (46.3%).

Extradural tumors are the most prevalent (60%), according to Ottenhausen et al. (13), which is consistent with our results (59%). In addition, Benjamin et al. (22) state that approximately 10% of real intramedullary spinal cord tumors develop, compared to 30% of intradural extramedullary tumors.

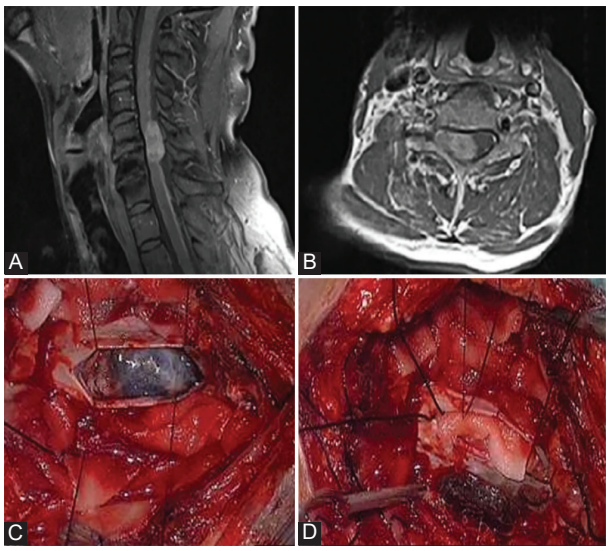

FIGURE 2. Primary extracutaneous melanoma. (A) Lateral view of the primary melanoma at the level of C5/C6, showcasing the tumor's location and extent. (B) Magnetic resonance imaging showing the intradural extramedullary localization of the melanoma, providing radiological insight. (C) Intraoperative image showing the darkly pigmented neoplastic mass, visually confirming melanoma. (D) Post-surgical intraoperative image.

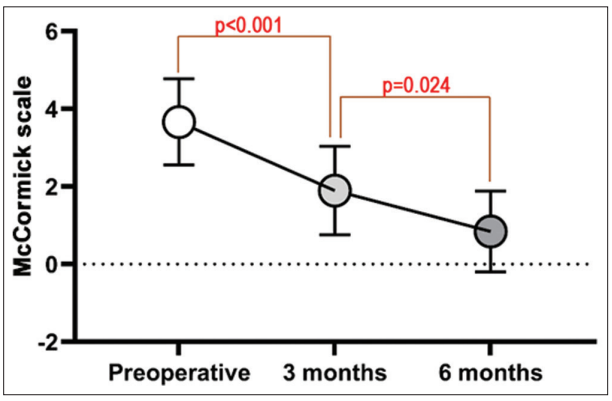

FIGURE 3. Pre-operative and post-operative evaluations with McCormick scale.

The main symptom in patients with spinal tumors is pain, as reported by Ciftdemir et al. (20) and Deol et al. (23), which confirms the results of this study where 94.9% of patients reported localized and radicular pain. Paresthesia was reported by 84.6% of patients in our study, while Narayan et al. (6) reported numbness in 88.6% of patients. A significant sign is motor weakness, which was reported in 51.3% of cases in our study, lower than the results reported by Narayan et al. (6) with a prevalence of 80%. The presence of sphincter dysfunction was observed in 43.6% of the sample, confirming the results of Narayan et al. (6) with a prevalence of 42.5%.

The present study reported a mean duration of symptoms in patients with spinal canal tumors of 397.9 ± 380.9 days or approximately 13.3 ± 12.7 months. A study by Hufana et al. (24) in Singapore found a mean duration of symptoms before surgery of 10.8 months. Studies conducted in Philadelphia by Slipman et al. (25) and in Japan by Kato et al. (26) reported shorter mean durations of 8.9 months and 9.5 months, respectively. On the other hand, Jellema et al. (27) reported a slightly longer mean duration of symptoms of 12.3 months. These comparisons highlight variations in the duration of symptoms among different populations and healthcare settings, underscoring the importance of early diagnosis and timely management of spinal tumors.

In the context of the duration of neurological deficits following surgical treatment, our study observed that 43.6% (17 out of 39) of patients experienced deficits lasting <2 days. In addition, 23.1% (9 out of 39) of patients exhibited deficits lasting between 2 and 7 days, while 33.3% (13 out of 39) had deficits lasting between 8 and 14 days. Notably, van Tol et al. (28) reported a mean delay of 8 days for surgical treatment in the case of metastatic tumors, which aligns with our findings. Delays in surgical intervention may lead to poorer outcomes, due the compression effect (29).

Spinal tumors require surgical intervention, and the indication for surgery is the compressive effect and subsequent neurological deficiency. Specific guidelines are not defined, but surgical radical treatment is considered the treatment of choice by most authors (13). It is important to note that the majority of spinal intradural tumors are benign, and therefore have a good prognosis if timely and adequately treated with surgical intervention (30). Furthermore, delaying surgical intervention imposes additional financial burden on the healthcare system (31), which is unacceptable, especially in LIMICs.

In this study, all patients underwent surgical intervention, and a high percentage of gross total resection, indicating complete tumor removal, was achieved 87.2% cases. This high rate of successful complete excision in resource-limited conditions demonstrates the feasibility of such procedures. Laminectomy was performed in all patients to enhance tumor exposure. Hemilaminectomy can be performed for smaller tumors, but previous studies have shown no significant differences in final outcomes and occurrence of complications among patients when considering the selected surgical treatment modality (32). Of course, when choosing the surgical approach, the tumor size should be taken into consideration. For smaller-sized tumors, hemilaminectomy is the treatment of choice due to reduced intraoperative bleeding and shorter hospital stay in the post-operative period (33).

The prevalence of meningiomas among spinal tumors ranges from 25% to 46% (34), and the results of our study confirm this range. The second most prevalent are schwannomas, with a higher prevalence compared to the data reported by Jeon et al. (35). Ependymomas rank third in frequency at 7.7% two cases of primary melanoma were also confirmed through histopathological analysis, which is quite rare and occurs in 0.07% of CNS tumor cases (36). The incidence of non-neurenteric cysts ranges from 0.7% to 1.3% (37), which corresponds to the findings of our study. These results indicate that the prevalence of individual histopathological types of spinal tumors in the population of Bosnia and Herzegovina is almost equal to that reported in other studies worldwide.

Interesting data are related to post-operative complications, considering the limited working conditions. Out of 39 patients, one death occurred within the 6-month follow-up period, which pertains to the patient diagnosed

with primary melanoma (Supplement Table 1, No 17). The exceptional aggressiveness and spread of melanoma to the leptomeninges shorten the lifespan, with a median survival of 10 weeks (38). Post-operative pneumonia as a complication of the surgical procedure was observed in one case (2.6%), which is lower compared to the results of the study by Malik et al. (39), with an incidence of 22%. A possible reason for the low percentage of pneumonia prevalence in limited resource conditions in our institution is early patient mobilization because prolonged bed rest during hospitalization increases the risk of developing pneumonia (40). In addition to pneumonia, one case of cerebrospinal fluid leakage was evident as a post-operative complication of spinal tumor surgery. According to Li et al. (41), the presence of cerebrospinal fluid leakage as a complication occurs in 10.6% of cases, which is significantly higher compared to the results of our study. The limitation in the representativeness of the sample itself and the practice carried out in our institution, which involves autologous fat tissue grafting, should also be taken into account, in line with the recommendation of Arnautovic et al. (9).

The absence of other life-threatening complications, such as infections and deep vein thrombosis, is another significant confirmation that complications can be prevented in limited resources conditions. Thorough preparation of the operative field, according to the practices in our institution, involved cleaning the operative field with a cationic preparation, following iodine disinfection, the effect of which on intrahospital and resistant pathogens has been confirmed in multiple studies (42,43).

In terms of the extent of resection, our study found that 34 out of 39 patients (87.2%) underwent gross total tumor resection, which is higher compared to the findings of Arora et al. (44) in Northern India (51.35%). In addition, Antkowiak (45) reported complete tumor excision in 78.6% of patients in their study, while Bellut et al. (2) reported gross total resection in 73% of patients in Switzerland.

The McCormick scale has proven to be a valuable tool for monitoring the neurological status of patients with spinal tumors in previous research (46-48). Its notable advantage lies in its simplicity and ease of use, particularly in LIMICs settings where physicians may be time-constrained due to large number of patients to examine throughout the day. In the specific case of Bosnia and Herzegovina, it has been classified as a country with fewer than 5 neurosurgeons per million population according to the classification by Mukhopadhyay et al. (49).

Before surgery, the majority of patients fell into Grades IV and V, indicating severe neurological impairment by McCormick scale. However, after 3 months, there was a notable shift toward Grade I, indicating significant improvement in neurological function. This positive trend continued at the 6-month follow-up, with a significant proportion of patients remaining in Grade I. After a 6-month follow-up, 17 out of 39 patients had achieved complete neurological recovery, indicating the absence of any motor or sensory deficits. In addition, 16 out of 39 patients had a score of I, which suggests the absence of motor deficits but the presence of sensory impairments. This indicates that 84.6% of 39 patients had a full motoric recovery after 6 months. According to Endo et al. (50), 27.6% of patients with intramedullary tumors showed neurological improvement, as assessed by the McCormick scale, 6 months after surgery. However, the majority of patients remained neurologically unchanged compared to the pre-operative evaluation. Managing intramedullary tumors presents challenges even in developed countries, and their outcomes tend to be relatively consistent. Most intradural tumors are extramedullary, and these cases have shown significantly greater recovery rates. According to the study conducted by Patel et al. (51), 19 out of 31 patients with intradural extramedullary tumors demonstrated a notable improvement. Conversely, Arora and Kumar (44) reported a lower overall improvement rate of 39.9% in Northern India, which contrasts with our findings.

Advancements in the management of spinal tumors are constantly emerging, encompassing diagnosis, treatment, and post-operative care. These progressions have the potential to significantly enhance patient outcomes, especially in LIMICs with limited resources. The Bosnian model, exemplified in the realm of spinal tumor management, provides valuable perspectives on overcoming challenges and delivering effective care within resource-constrained environments.

Within the Bosnian context, the study outcomes demonstrated positive findings regarding neurological recovery. A considerable number of patients exhibited improvements in both motor and sensory deficits, leading to a noticeable advancement in their McCormick scale grades during the 3-month and 6-month follow-up periods. These results signify the potential for achieving favorable outcomes in spinal tumor management, even within settings with limited resources.

The experience gained from the Bosnian model highlights the importance of early diagnosis, thorough symptom assessment, and timely surgical intervention in resource-limited settings. Embracing technological advancements, ensuring timely access to specialized care, and employing a multidisciplinary approach are key strategies that can empower LIMICs settings to optimize the management of spinal tumors and ultimately enhance patient outcomes.

The limitations of this study include its retrospective, non-randomized design. It was conducted at a single center, limiting generalizability. The 6-month follow-up may not capture long-term outcomes and complications. While it demonstrates the feasibility of spinal tumor management in resource-limited settings, it raises questions about generalizability to healthcare systems with more resources.

CONCLUSION

This retrospective study provides valuable insights into the management of intradural spinal tumors within a resource-limited healthcare setting. The findings highlight the feasibility of achieving positive patient outcomes, particularly in cases of early diagnosis and timely surgical intervention. The study's emphasis on neurological recovery underscores the potential for significant improvements in both motor and sensory deficits. However, it is essential to acknowledge the limitations inherent in the study's retrospective design, single-center focus, and relatively small

sample size. Despite these constraints, the study demonstrates the Bosnian model's potential for delivering effective care in a resource-constrained environment.

DECLARATION OF INTEREST

Authors declare no conflict of interest.

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SUPPLEMENT TABLE

SUPPLEMENT TABLE 1. Individual case presentations with age, sex, location, topography, extent of resection, histopathological diagnosis, and neurological follow-up

No	A	Sex	Location	Topography	Extent of resection	HPD	Neurological follow-up*		
							Preop	3 m	6 m
1	49	M	Th12/L1	IE	Total	Schwannoma	I	W/O	W/O
2	68	F	Th2	IE	Total	Meningioma	V	III	I
3	45	F	TH8/9	IE	Total	Meningioma	II	I	W/O
4	57	F	Th4	IE	Total	Meningioma	II	I	W/O
5	69	F	Th10/11	IE	Subtotal	Schwannoma	III	II	I
6	60	F	C2	IE	Total	Meningioma	II	I	W/O
7	58	M	C1/C2	IE	Subtotal	Schwannoma	II	I	W/O
8	59	M	L2/L3	CE	Biopsy	Metastasis-NHL	V	IV	III
9	63	F	Th11/12	IE	Total	Meningioma	IV	II	I
10	21	F	Th11/L2	IE	Subtotal	Metastasis-Ewing sarcoma	V	IV	IV
11	35	M	Th9/11	CE	Total	Primary melanoma	IV	IV	IV
12	52	F	L2/L3	CE	Total	Schwannoma	III	I	W/O
13	68	F	Th12	IE	Total	Meningioma	III	I	W/O
14	72	F	L2/L3	CE	Total	Metastasis-Lung cancer	IV	II	I
15	45	F	L2	CE	Total	Neurenteric cyst	III	I	W/O
16	17	F	L4/L5	CE	Total	Meningioma	III	I	W/O
17	54	M	C5/C6	IE	Total	Primary melanoma	V	IV	W/O
18	79	F	L5/S2	CE	Total	Non-Hodgkin Lymphoma	IV	II	I
19	54	M	C5	IE	Total	Schwannoma	IV	II	I
20	62	F	C3-C5	CE	Total	Meningioma	IV	II	I
21	18	M	Th8/9	IE	Total	Schwannoma	III	II	I
22	53	M	Th8/9	IE	Total	Meningioma	III	I	W/O
23	55	M	L5	IE	Total	Schwannoma	V	III	I
24	61	M	Th4/5	IE	Total	Meningioma	IV	I	I
25	56	F	Th1/2	CE	Total	Meningioma	IV	III	II
26	47	F	L4/L5	IE	Total	Schwannoma	II	I	W/O
27	69	M	C1/C2	IE	Subtotal	Metastasis-Ovarian cancer	V	II	I
28	18	M	L1-S2	IE	Total	Lipoma	V	IV	II
29	54	F	Th4/5	I	Total	Meningioma	III	I	W/O
30	66	M	Th1-3	CE	Total	Ependymoma	IV	II	W/O
31	38	F	C6/C7	IE	Total	Meningioma	III	I	W/O
32	45	F	L2/L3	I	Total	Ependymoma	V	II	I
33	58	F	L2/L3	CE	Total	Schwannoma	III	I	W/O
34	61	F	Th1/th2	CE	Total	Meningioma	V	III	II
35	65	F	L1/L2	I	Total	Ependymoma	III	W/O	W/O
36	60	M	Th12	CE	Total	Metastasis-NHL	IV	I	I
37	55	M	L5	IE	Total	Schwannoma	V	III	I
38	55	M	L5	IE	Total	Schwannoma	V	III	I
39	61	M	Th4/5	IE	Total	Meningioma	IV	I	I

No: Number of patient, A: Age, C: Cervical, Th: Thoracal, L: Lumbar, S: Sacral, IE: Intradural extramedullary, I: Intramedullary, CE: Cauda equina, HPD: Histopathological diagnosis, NHL: Non-Hodgkin lymphoma, *Value of McCormick scale, Preop, McCormick scale value before surgery, 3 m: McCormick scale value after 3 months of surgery, 6 m: McCormick scale value after 6 months of surgery, W/O: Without neurological deficit