Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/pjnns

Original research article

Surgical treatment of intramedullary ependymomas

Marek Prokopienko, Przemysław Kunert *, *Anna Podgórska, Andrzej Marchel*

Department of Neurosurgery, Medical University of Warsaw, Warsaw, Poland

ARTICLE INFO

Article history:
Received 11 November 2016
Accepted 30 June 2017
Available online 8 July 2017

Keywords:
Intramedullary ependymoma
Surgery
Outcome
Intraoperative monitoring

ABSTRACT

Object: The aims of this study were to present the results of surgery for intramedullary ependymomas (IEs), analyze complication and recurrence rates, and analyze factors that might influence outcome.

Methods: The charts of 29 consecutive patients (women – 8, men – 21; mean age – 38 years; range: 18–72) operated for IE were retrospectively analyzed. Mean follow-up was 9 years. Eighteen tumors (62%) were located in the cervical or cervicothoracic spine, and average tumor length was four spinal levels. Twenty patients (69%) presented with neurological deficit.

Results: Gross total resections (GTRs) comprised 87% of cases, subtotal resections (STRs) 10%, and partial resections 3%. The neurological outcome on postoperative day 1 was as follows: modified McCormick scale (mMS) grade I – 6%, grade II – 21%, grade III – 21%, grade IV – 31%, and grade V – 21%; at follow-up, outcomes were mMS grade I – 42%, grade II – 34%, grade III – 10%, and grade V – 14% of patients. Compared to the preoperative period, 69% of patients deteriorated postoperatively; however, 62% improved or remained without deficit in follow-up, and deterioration persisted in 24%. The functional results were significantly worse when the intraoperative monitoring potentials dropped below 50% ($p = 0.005$) and if the tumor involved >3 spinal levels ($p = 0.039$). Fourteen postoperative complications in 10 patients (34%) included respiratory failure (14%), pneumonia (7%), urinary infection (10%), bed sores (10%), and CSF leak (7%). Two tumors progressed after STR, with progression-free survival times of 5 and 14 years. No recurrence was observed after GTR.

Conclusions: Total tumor resection is the treatment of choice in cases of IEs: no tumor re-growth occurred after total resection, 86% of patients were independent at follow-up, and the 10-year survival rate was 79%.

* *Corresponding author at*: Department of Neurosurgery, Medical University of Warsaw, Banacha Street 1a, 02-097 Warsaw, Poland.
E-mail addresses: mpro76@tlen.pl (M. Prokopienko), przemyslaw.kunert@wum.edu.pl (P. Kunert).

Abbreviations: CNS, central nervous system; IOM, intraoperative monitoring; DTI, diffusion tensor imaging; SEPs, somatosensory evoked potentials; MEPs, motor evoked potentials; TES, transcranial electrical stimulation; GTR, gross total resection; STR, subtotal resection; mMS, modified McCormick scale.

http://dx.doi.org/10.1016/j.pjnns.2017.06.008
0028-3843/

1. Objective

Ependymomas constitute from 4% to 6% of all central nervous system (CNS) tumors and about 15% of intramedullary masses [1–3]. The peak of their appearance is between the third and sixth decades of life. These tumors are usually slow growing and benign [4] but tend to compress adjacent structures rather than infiltrate cord parenchyma, resulting in associated symptoms. In order of decreasing frequency, presentation may include neck or back pain, sensory deficits, motor weakness, and bowel and bladder dysfunction [5]. The aim of this study was to evaluate the short- and long-term results of surgery for intramedullary ependymomas, with an effort to identify factors related with functional outcome.

2. Methods

The charts of 29 consecutive patients operated on for intramedullary ependymomas during the last 16 years were retrospectively analyzed. Histopathological confirmation of the ependymoma was the only inclusion criterion. Ependymomas of filum terminale were not analyzed in this series.

2.1. Clinical evaluation

Patients were evaluated and compared at four time points: before treatment, on postoperative day one, on the day of discharge (early outcome), and at a follow-up examination (late outcome). Follow-up data were obtained from medical charts, telephone interviews with the patients, and interviews during individual visits. Patients were assessed with a modified McCormick scale (mMS; Table 1) [6], and grades I and II were considered a satisfactory result. The follow-up period ranged from 2.5 to 16 years (average 9 years), and the follow-up data were obtained in all cases.

2.2. Imaging evaluation

All patients underwent contrast-enhanced MRI before surgery and in follow-up. MR imaging was extended with diffusion tensor imaging in four patients from the last 4 years of the analyzed series. The length of the tumor (vertebral levels), presence of syringomyelia, and location in different spinal segments were assessed.

2.3. Neurophysiological monitoring

Intraoperative neurophysiological monitoring (IOM) was routinely used during the last 19 procedures (65%). The sensory tract was assessed by somatosensory evoked potentials (SEPs) elicited by medial nerve and tibial nerve stimulation bilaterally. If IOM was based only on cortical SEP, a 50% drop in amplitude was considered a significant change.

In patients with sensory and motor tract monitoring, the corticospinal tracts were assessed by motor evoked potentials (MEPs) and D-wave elicited by transcranial electrical stimulation. MEPs were recorded from thenar, tibialis anterior, and/or abductor hallucis muscles bilaterally. For muscle MEPS, present/absent criteria were used, and for D-wave, the amplitude decrement was assessed. The surgery was performed as a stop-and-go procedure based on the IOM findings. In cases of significant change in neurophysiological parameters, the dissection was temporarily stopped until the acceptable values returned again.

2.4. Neuroprotection

Methylprednisolone (Solu-Medrol™, Pfizer Europe) infusion was routinely started before surgery. The infusion protocol involved 15 min of a bolus of 30 mg/kg, and at least 23 h of continuous infusion at 5.4 mg/kg/h. Continuous infusion was performed for 23 h in 13 cases. Infusion time averaged 60 h. In six cases of significant neurological deficit progression after surgery, the infusion time exceeded 120 h. There were no complications related to steroid administration in our series.

2.5. Surgery

All tumors were removed through a posterior approach. Sixteen (55%) located in the thoracic spine and at the atlanto-occipital junction were operated on with the patient in the prone position. Thirteen patients (45%) with tumors in the cervical spine and at the cervico-thoracic junction were placed for surgery in a sitting position. The laminectomies were extended using a suboccipital craniotomy with widening of the foramen magnum in two patients. A midline dural incision was made over the dorsal surface of the spinal cord, followed by lateral dural sutures. The arachnoid and pia mater were incised at the midline in all cases. In five cases, several skip incisions were made to spare crossing vessels over the midline. The tumor was microsurgically detached from

Table 1 – Comparison of neurological status in different stages of treatment.

Grade of modified McCormick scale	Before surgery Number (%)	Postop. day 1 Number (%)	At discharge Number (%)	Follow-up Number (%)
I – Intact neurologically, normal ambulation, minimal dysesthesia	9 (31)	2 (6)	3 (10)	12 (42)
II – Mild motor or sensory deficit, functional independence	6 (21)	6 (21)	9 (31)	10 (34)
III – Moderate deficit, limitation of function, independent w/external aid	13 (45)	6 (21)	8 (28)	3 (10)
IV – Severe motor or sensory deficit, limited function, dependent	0 (0)	9 (31)	5 (17)	0 (0)
V – Paraplegia or quadriplegia, even w/flickering movement	1 (3)	6 (21)	4 (14)	4 (14)
	29 (100)	29 (100)	29 (100)	29 (100)

surrounding tissue, shrunk by using bipolar coagulation at low power, debulked in 17 cases (62%), and removed. In eight patients (28%), a cavitron ultrasonic surgical aspirator was used. In the more recent years of the analyzed period, the use of bipolar coagulation was minimized, and the tumor was dissected in a one-piece fashion without shrinking and debulking. The dura was closed in watertight fashion, and the muscles were sutured in a multilayer approach. Laminoplasty was not applied. One patient with massive intratumoral hemorrhage needed two procedures for gross total tumor removal. At the first operation, the intratumoral hematoma was evacuated with partial tumor removal. Two days later, complete tumor removal was successfully achieved.

2.6. Extent of resection of the tumor

The extent of resection was categorized as total, subtotal, or partial. Gross total resection (GTR) was defined as removal of 100% of visible tumor tissue with no evidence of the tumor remnant in postoperative MRI. Subtotal resection (STR) meant that more than 90% of visible tumor mass was removed.

2.7. Rehabilitation

Rehabilitation was initiated at postoperative day 1. Initially rehabilitation was performed within the bed limits. On day 2, patients were mobilized and assisted with walking if possible.

2.8. Statistical analysis

Fisher's exact or chi-square test was used to evaluate significance. A p-value <0.05 was taken as statistically significant.

3. Results

3.1. Patients, tumors, and symptoms

There were 8 women (28%) and 21 men (72%) included in this study (ratio 2.6:1). Age ranged from 18 to 72 years (mean, 38 years). The mean age of patients with anaplastic ependymoma averaged 37 years; among those with low-grade ependymoma, the average was 38 years.

The location of the tumors was as follows: cervical spine, 9 (31%); cervicothoracic spine, 9 (31%); spinal cone, 8 (28%); and thoracic spine, 3 (10%). The tumor length ranged from one to eight spinal levels (average four levels). In nine (31%) cases, only one spinal level was occupied. Intramedullary syrinx coexisted in four (14%) cases.

Twenty patients (69%) presented with neurological deficit. Among them were nine patients (31%) with progressive paraparesis, four (14%) with progressive tetraparesis, five (17%) with single limb weakness progression, one (3%) with sensory deficit only, and one (3%) with Brown-Sequard syndrome. Pain was the main cause of diagnosis in seven patients (24%). In two cases (7%), the tumor was asymptomatic. Ambulatory status was classified as grade I in 9 patients (31%), grade II in 6 (21%), grade III in 13 (45%), and grade V in 1 (3%) according to the preoperative mMS (Table 1).

3.2. Extent of resection

GTR was accomplished in 25 (87%) patients, STR in 3 (10%), and partial resection in one (3%). Decisions about subtotal resections were made intraoperatively. In all three cases, strong adherence to the spinal cord was the major cause of leaving small tumor remnants. The decision about partial resection in one case was made before treatment and was connected with an atypical appearance of the intramedullary tumor on MRI. The extent of the resection was confirmed in the postoperative MRI scans.

3.3. Neuromonitoring

Significant changes in intraoperative monitoring records occurred in eight cases (seven in SEPs and one in SEPs and MEPs). They returned to normal or mildly decreased values after approximately 15–60 min in five cases. In three patients, they worsened irreversibly.

3.4. Neurological status evaluation on postoperative day one

On postoperative day 1, the neurological status was as follows: mMS grade I in two (6%), mMS grade II in six (21%), mMS grade III in six (21%), mMS grade IV in nine (31%), and mMS grade V in six (21%) patients (Table 1). Immediately after surgery, compared to the preoperative status, one patient (3%) improved, and in six (21%) patients, the deficit remained stable. New neurological deficit appeared in eight patients (28%), and in twelve (41%), the preoperative deficit increased (Table 2). Dorsal column dysfunction appeared or increased temporarily in seven cases (24%). All eight patients with a significant decline in intraoperative SEP and/or MEP values deteriorated after surgery, including severe deterioration (mMS grades I and V) in all three patients with an irreversible decrease in responses.

3.5. Intensive care unit

Twelve patients (41%) with cervical or cervicothoracic tumors were admitted to the intensive care unit (ICU) and discharged to the neurosurgical ward when cardiorespiratory condition was stable. The mean stay in ICU was 15 days (range: 3–474 days). Prolonged respiratory failure occurred in four patients (44% of patients with cervical ependymomas).

3.6. Neurological status at discharge

Hospital stay ranged from 8 to 490 days (mean, 40 days; median, 23 days). At discharge, the neurological condition was as follows: mMS grade I in three (10%), grade II in nine (31%), grade III in eight (28%), grade IV in five (17%), and grade V in four (14%) patients (Table 1). Fifteen patients (48%) improved or maintained their good neurological status compared to the first day after surgery, and in fourteen (52%), the deficit remained unchanged (Table 2). However, compared to the preoperative period, preexisting neurological deficit deteriorated in eight (28%) and a new deficit appeared in seven patients (24%). Four patients (14%) improved or maintained their good neurological status. Preoperative deficit unchanged in 10 patients (34%) until discharge.

Table 2 – Evolution of neurological condition in different time periods.

Neurological status change	From pre-op. period to post-op. day 1	From post-op. day 1 to discharge	From discharge to last follow-up	From pre-op. period to last follow-up
Stable, no deficit	2 (7%)	2 (7%)	2 (7%)	6 (21%)
Improvement	1 (3%)	13 (45%)	19 (66%)	12 (41%)
Stable deficit	6 (21%)	14 (48%)	8 (27%)	4 (14%)
Deterioration	20 (69%)	0	0	7 (24%)
	29 (100%)	29 (100%)	29 (100%)	29 (100%)

Pre-op.: preoperative, post-op.: postoperative.

3.7. *Histopathology*

Histopathological examination demonstrated WHO grade II ependymoma in 26 (90%) cases and WHO grade III ependymoma in 3 (10%). The 2016 WHO Classification of Tumors of the Central Nervous System was not used in the current study because the histopathological diagnosis had been established in all cases before its introduction.

3.8. *Radiotherapy*

Seven (27%) patients were referred to regional oncology centers. Radiotherapy was initiated in three patients with anaplastic tumors and in four after partial or subtotal resection of WHO grade II ependymoma. No side effects of radiation treatment were observed.

3.9. *Neurological status evaluation at follow-up*

All patients were reached at follow-up, which averaged 9 years (range: 1–16 years). Neurological status was as follows: mMS grade I in 12 (42%), mMS grade II in 10 (34%), mMS grade III in 3 (10%), and mMs grade V in 4 (14%) patients (Table 1).

Six patients died, four (14%) from a severe postoperative neurological condition and two (7%) for reasons not related to the intramedullary tumor. The 3-, 5-, and 10-year survival rates were 82%, 79%, and 79%, respectively. The Kaplan–Meier survival curve is presented in Fig. 1.

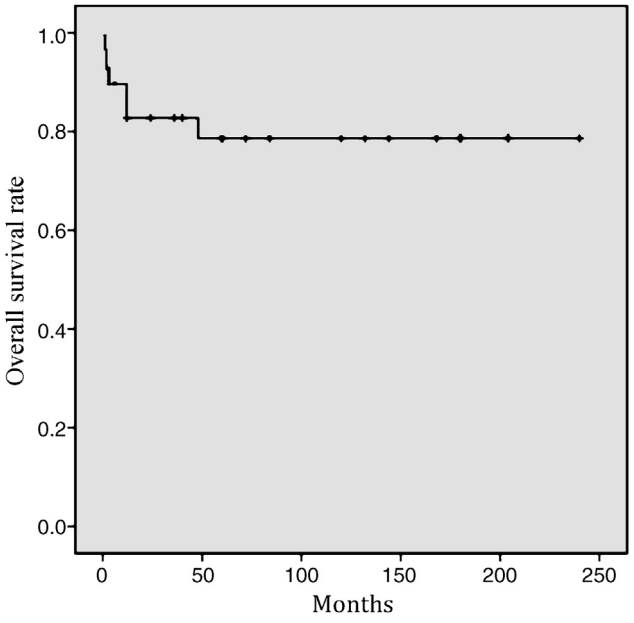

Fig. 1 – The Kaplan–Meier survival plot, patients after surgery for intramedullary ependymomas.

Compared to the preoperative status, an improvement or stable mMS grade I was noted in 18 patients (62%), stable deficit in 4 (14%), and deterioration in 7 (24%; Table 2). Improvement was noted in 23 (80%) patients compared to postoperative day one. Only in four cases (14%) did the postoperative deficit remain unchanged.

Among nine patients without neurological deficit before treatment, five patients (56%) finally reached mMS grade I, three patients (33%) had grade II, and one patient (11%) grade III (satisfactory outcome in 89%; Table 3). Among 20 patients presenting with deficit, 7 patients (35%) reached mMS grade I, 7 (35%) grade II, 2 (10%) grade III, and 4 (20%) grade V (satisfactory outcome, 70%; p = NS).

Among four patients with intraoperative potentials lost, the severe postoperative deficit remained in two cases, and two patients improved to mMS grade II in follow-up.

3.10. *Factors that might influence the outcome*

The analysis of factors that might influence the long-term outcome and the risk of permanent deterioration after tumor excision are presented in Tables 3 and 4. Nonsignificantly better outcomes compared to the opposite subgroups were associated with the following factors: age <40 years, female sex, good preoperative neurological status, and intramedullary syrinx. We found that the functional results were significantly worse when the IOM potentials dropped below 50% ($p = 0.005$) or if the tumor involved more than three spinal levels ($p = 0.039$; Table 3). Seven out of nine patients (78%) with tumors occupying only one spinal level achieved mMS grade I during follow-up. Improvement or a good stable (mMS grade I) condition during follow-up, compared to preoperative status, was noted in 11 out of 14 patients (79%) with tumors at ≤3 spinal levels, and only in 7 (46%) out of 15 with larger tumors ($p = 0.08$; Table 4).

3.11. *Postoperative complications and tumor recurrence*

Fourteen postoperative complications in 10 patients (34%) included respiratory failure in four cases (14%), pneumonia in two (7%), urinary infection in three (10%), bed sores in three (10%), and a cerebrospinal fluid leak in two (7%). The cerebrospinal fluid leak was treated successfully with wound compression and acetazolamide.

Two tumors progressed after STR in follow-up, and the progression-free survival was 5 and 14 years in these patients.

Table 3 – Analysis of factors that might influence the long-term outcome of surgical tumor excision.

Factor	Follow-up (McCormick classification)		*p* value (Fisher's exact or chi-square test)
	Grades I–II	Grades III–V	
Age < 40	14 (82%)	3 (18%)	NS
Age ≥ 40	8 (67%)	4 (33%)	
Female sex	7 (87.5%)	1 (12.5%)	NS
Male sex	15 (71%)	6 (29%)	
Preoperative deficit /–/	8 (89%)	1 (11%)	NS
Preoperative deficit /+/	14 (70%)	6 (30%)	
mMS grades I–II preop.	13 (87%)	2 (13%)	NS
mMS grades III–V preop.	9 (64%)	5 (36%)	
Spinal levels ≤3	13 (93%)	1 (7%)	$p = 0.039$
Spinal levels >3	9 (60%)	6 (40%)	
Syrinx /+/	4 (100%)	0 (0%)	NS
Syrinx /–/	18 (72%)	7 (28%)	
IOM potentials stable	11 (100%)	0 (0%)	$p = 0.005$
IOM potentials drop < 50%	3 (37.5%)	5 (62.5%)	
IOM not used	7 (70%)	3 (30%)	NS
IOM used	14 (74%)	5 (26%)	

NS: no significant difference between subgroups.

Table 4 – Analysis of factors that might influence the risk of long-term postoperative deterioration in relation to preoperative condition.

Factor	Evolution of neurological condition in follow-up			*p* value (Fisher exact test)
	Improvement or stable mMS grade I	Stable deficit	Deterioration	
Age <40 years	13 (72%)	2 (11%)	3 (17%)	NS
Age ≥40 years	5 (46%)	2 (18%)	4 (36%)	
Female sex	6 (75%)	0 (0%)	2 (25%)	NS
Male sex	12 (57%)	4 (19%)	5 (24%)	
Any preoperative deficit /–/	5 (56%)	0 (0%)	4 (44%)	NS
Any preoperative deficit /+/	13 (65%)	4 (20%)	3 (15%)	
mMS grades I–II preop.	8 (54%)	2 (13%)	5 (33%)	NS
mMS grades III–V preop.	10 (72%)	2 (14%)	2 (14%)	
Spinal levels ≤3	11 (79%)	0 (0%)	3 (21%)	$p = 0.08$
Spinal levels >3	7 (46%)	4 (27%)	4 (27%)	
Syrinx /+/	4 (100%)	0 (0%)	0 (0%)	NS
Syrinx /–/	14 (56%)	4 (16%)	7 (28%)	
IOM potentials stable	8 (73%)	2 (18%)	1 (9%)	NS
IOM potentials drop <50%	3 (37.5%)	2 (25%)	3 (37.5%)	
IOM not used	5 (50%)	1 (10%)	4 (40%)	NS
IOM used	11 (58%)	4 (36%)	4 (36%)	

After revision surgery, no residual tumor was demonstrated in either of these patients on follow-up MRI. No other recurrences were observed.

4. Discussion

4.1. *Patients, tumors, and symptoms*

In the analyzed series, the intramedullary ependymomas were diagnosed predominantly in males (72%) and in the cervical or cervicothoracic spine (62%). In other series, the percentage of males ranged from 43% to 82%, and the cervical location of the tumor ranged from 61% to 66% [7–9]. Intramedullary ependymomas involved only one spinal segment in 31% of cases in our series whereas Alkhani et al. [8] noted a small tumor size in the majority of patients. Neurological deficit was the main cause of diagnosis in 69% of our patients, similar to the findings of Kane et al. [10], who observed preoperative deficits in 72% of patients. The percentage of totally resected tumors in this study (87%) is close to the value Klekamp [11] reported, which was 86% of totally resected ependymomas.

4.2. *Timing of surgery*

Two major groups were used for the analysis: patients with preoperative neurological deficit and those who were neurologically intact. Satisfactory outcome was noted in 8 patients (89%) without preoperative deficit and in 14 patients (70%) presenting with neurological deficit in our series. Although the difference was not significant, our strategy is based on the belief that the early treatment of oligo- and asymptomatic

tumors enables preservation of more spinal cord functions in follow-up. Some authors still choose a watch-and-wait strategy in cases of asymptomatic intramedullary tumors [12–14], but our results encouraged us to start treatment as early as possible. Similar observations in recent literature confirm that the best outcomes are achieved in patients with good preoperative status [15–22]. Preoperative neurological deficit reflects the damage to the spinal cord caused by the tumor, and the operative procedure increases this damage. Therefore, waiting for more symptoms leads to increasing irreversible spinal cord damage before surgery and worsens the overall outcome. Brotchi et al. [15] and Halvorsen et al. [16] in large series of treated ependymomas found good neurological status to be the main prognostic factor determining favorable postoperative outcome. Brotchi et al. [15] additionally recommended that patients with intramedullary tumors should be operated when they are still able to walk. Alkhani et al. [8] emphasized early diagnosis and referral to specialized surgical centers as factors improving the outcome. Preoperative neurological status was the only statistically significant factor in their series. They found that all patients who originally presented with mMS grade I continued with the same grade 6 months postoperatively. Patients who presented with mMS grades III and IV remained the same in long-term observation after the procedure. The importance of surgery carried out immediately after diagnosis is underlined also by Epstein et al. [20]. Unfavorable operative treatment results were reported for 14% of patients in good preoperative status and 67% of patients in poor neurological condition in their series.

4.3. *Factors influencing the outcome*

The functional results were not significantly different depending on age, sex, the use of IOM, preoperative neurological deficit, and syrinx presence. In contrast, a larger size of the tumor (>3 spinal levels) and a drop in IOM potentials of 50% or more were associated with significantly worse outcomes in this study. Eroes et al. [21] also found a statistically significant difference between groups with an advantage of smaller ependymomas. They noted the best results in patients with tumors of less than five levels. In the material of Li et al. [7], good operative treatment results were achieved in 23% of patients with smaller tumors (up to 5 cm) and 44% patients with larger tumors. It is understandable that the smaller the tumor size, the smaller the operative injury to the spinal cord. However, Alkhani et al. [8] did not find that tumor size was a prognostically valuable feature, emphasizing good preoperative status as the only important factor resulting in a satisfactory outcome. In our series, the patients who were neurologically intact at presentation had slightly better results compared to those with deficits before surgery (mMS grades I and II: 89% vs. 70%, p = NS). On the other hand, it should be mentioned that a minor postoperative deficit persisted during follow-up in 44% of patients who had no deficit before the treatment (Table 4).

A significant drop in IOM values was associated with significantly worse results in our series. Currently, intraoperative neuromonitoring is the essential tool for intramedullary surgery assurance and should be obligatory. Patients with intramedullary neoplasms should be treated in specialized centers equipped with IOM devices and by clinicians who have adequate surgical experience [11]. All monitored potentials should be carefully analyzed during the whole resection, and their changes should affect surgeon behavior. Dorsal column mapping was not used in analyzed group. As this technique has proven to be safe and effective method for identifying functional midline of the spinal cord, it may reduce injury to the posterior columns [23].

Nonsignificantly better results have been found in younger patients. Klekamp recognized young age as predictive for better functional outcome in his series [11], noting unfavorable results in 24% of younger patients (≤60 years) and in 44% of older patients. These observations can be explained by a worse initial condition and worse rehabilitation results in older patients. However, most authors do not share this opinion [16,19,21].

4.4. *Extent of resection*

Our rate of non-total resections (13%) is very similar to that of Klekamp's series [11] and seems to be a good result. The percentage of non-total resections in other series ranged from 18% to 35% [7,8,10,12,16]. Strong adherence to the surrounding spinal cord and IOM recording decreases forced us to leave small pieces of the tumor in three cases. The atypical MR appearance of the tumor was the cause of partial resection in one case. Among these four, revision surgery was needed in two patients. No recurrence was noted after GTR. Our results allow us to conclude that the surgical priority is the maximal safe resection, which in the case of ependymoma usually means a total resection.

An attitude of watchful waiting with the residual tumor after primary surgery is supported by Halvorsen et al. in their study [16]. They found spontaneous regression of the tumor remnant after non-total resections in 37% of cases. Radiation therapy used in patients after partial and subtotal resection also could have resulted in good control of the growth of non-radically removed tumors. It has been well established that an early start of adjuvant treatment after non-total resection prolongs progression-free survival [24,25]. Radiation therapy is not recommended after total resection of benign ependymoma, which is considered as the gold standard in its operative treatment [12–28].

Beyond the benign ependymoma remnants, the high-grade forms, even if totally removed, require radiation therapy, although recently published studies suggest that it is not associated with a lower overall recurrence rate [29,30]. We did not refer our patients for chemotherapy, which has only a modest effect on ependymomas [30]. Ten percent of anaplastic ependymomas in our series is a rather small number compared to 30% in the series of Li et al. [7] and Klekamp [11].

4.5. *Functional results of surgery and their evolution*

Because the results of surgery in our series are satisfactory in 76% of the patients and 87% were independent in everyday life, the overall outcome seems to be positive. Comparably to Klekamp [11], we found that the majority of patients demonstrated deterioration immediately after surgery; however, early rehabilitation brought functional improvement.

4.6. *Postoperative complications*

The incidence of postoperative complications in the analyzed series was relatively high (34%). Respiratory failure was related to the cervical location of the tumor. Infectious complications occurred mainly in bedridden patients with severe postoperative deficit. In the series of Klekamp, a lower rate (17%) of complications probably was related to the better neurological status of patients immediately after surgery [11].

5. Conclusions

Complete tumor resection plays a key role in intramedullary ependymoma treatment because no tumor regrowth occurred after total resection, 86% of patients were independent in follow-up, and the 10-year survival rate was 79%. The functional results were significantly worse when the IOM potentials dropped below 50% or if the tumor involved more than three spinal levels.

Conflict of interest

None declared.

Acknowledgement and financial support

None declared.

REFERENCES

[1] Chamberlain MC. Ependymomas. Curr Neurol Neurosci Rep 2003;3:193–9.
[2] Gilbert MR, Ruda R, Soffietti R. Ependymomas in adults. Curr Neurol Neurosci Rep 2010;10:240–7.
[3] Tseng JH, Tseng MY. Survival analysis of 459 adult patients with primary spinal cancer in England and Wales: a population-based study. Surg Neurol 2007;67:53–8.
[4] Mork SJ, Loken AC. Ependymomas: a follow-up study of 101 cases. Cancer 1977;40:907–15.
[5] Nagasawa DT, Zachary A, Smith ZA, Cremer N, Fong Ch, Lu DC, et al. Complications associated with the treatment for spinal Ependymomas. Neurosurg Focus 2011;31(4):E13.
[6] Manzano G, Green BA, Vanni S, Levi AD. Contemporary management of adult intramedullary spinal tumors—pathology and neurological outcomes related to surgical resection. Spinal Cord 2008;46(8):540–6.
[7] Li TY, Chu JS, Xu YL, Yang J, Wang J, Huang YH, et al. Surgical strategies and outcomes of spinal ependymomas of different lengths: analysis of 210 patients: clinical article. J Neurosurg Spine 2014;21(August (2)):249–59. http://dx.doi.org/10.3171/2014.3.SPINE13481. Epub 2014 May 16
[8] Alkhani A, Blooshi M, Hassounah M. Outcome of surgery for intramedullary spinal ependymoma. Ann Saudi Med 2008;28(March–April (2)):109–13.
[9] McCormick PC, Torres R, Post KDMD, Stein B. Intramedullary ependymoma of the spinal cord. J Neurosurg 1990;72(April (4)):523–32.
[10] Kane PJ, el-Mahdy W, Singh A, Powell MP, Crockard HA. Spinal intradural tumours – Part II: intramedullary. Br J Neurosurg 1999;13:558–63.
[11] Klekamp J. Spinal ependymomas. Part 1: intramedullary ependymomas. Neurosurg Focus 2015;39(August (2)):E6.
[12] Cristante L, Herrmann H. Surgical management of intramedullary hemangioblastoma of the spinal cord. Acta Neurochir (Wien) 1999;141:333–40.
[13] Harrop JS, Ganju A, Groff M, Bilsky M. Primary intramedullary tumors of the spinal cord. Spine 2009;34 (October (22S)):S69–77.
[14] Scott R. Plotkin i wsp. J Neurosur Spine 2011;April (14) (4):543–7.
[15] Brotchi J, Fischer G. Spinal cord ependymomas. Neurosurg Focus 1998;4(May (5)):e2.
[16] Halvorsen CM, Kolstad F, Hald J, Johannesen TB, Krossnes BK, Langmoen IA, et al. Long-term outcome after resection of intraspinal ependymomas: report of 86 consecutive cases. Neurosurgery 2010;67(December (6)):1622–31.
[17] Sun J, Wang Z, Li Z, Liu B. Microsurgical treatment and functional outcomes of multi-segment intramedullary spinal cord tumors. J Clin Neurosci 2009;16:666–71.
[18] Boström A, von Lehe M, Hartmann W, Pietsch T, Feuss M, Boström JP, et al. Surgery for spinal cord ependymomas: outcome and prognostic factors. Neurosurgery 2011;68 (February (2)):302–8.
[19] Tuncay K, Mehdi S, 2 Tunc O, Bilgehan S, Ali Cetin S, Ali Fahir O. Clinical analysis of 21 cases of spinal cord ependymoma: positive clinical results of gross total resection. J Korean Neurosurg Soc 2010;47:102–6.
[20] Epstein FJ, Farmer JP, Freed D. Adult intramedullary spinal cord ependymomas: the result of surgery in 38 patients. J Neurosurg 1993;79:204–9.
[21] Eroes CA, Zausinger S, Kreth FW, Goldbrunner R, Tonn JC. Intramedullary low grade astrocytoma and ependymoma. Surgical results and predicting factors for clinical outcome. Acta Neurochir (Wien) 2010;152(April (4)):611–8. Epub 2010 Feb 1.
[22] Samii M, Klekamp J. Surgical results of 100 intramedullary tumors in relation to accompanying syringomyelia. Neurosurgery 1994;35(November (5)):865–73. discussion 873.
[23] Yanni DS, Ulkatan S, Deletis V, Barrenechea IJ, Sen C, Perin NI. Utility of neurophysiological monitoring using dorsal column mapping in intramedullary spinal cord surgery. J Neurosurg Spine 2010;12(June (6)):623–8. http://dx.doi.org/10.3171/2010.1.SPINE09112
[24] Lin Y-H, Huang C-I, Wong T-T, Chen M-H, Shiau C-Y, Wang L-W, et al. Treatment of spinal cord ependymomas by surgery with or without postoperative radiotherapy. J Neuro-Oncol 2005;71:205–10.
[25] Shaw EG, Evans RG, Scheithauer BW, Ilstrup DM, Earle JD. Radiotherapeutic management of adult intraspinal ependymomas. Int J Radiat Oncol Biol Phys 1986;12:323–7.
[26] Chang UK, Choe WJ, Chung SK, Chung CK, Kim HJ. Surgical outcome and prognostic factors of spinal intramedullary ependymomas in adults. J Neurooncol 2002;57:133–9.
[27] Quigley DG, Farooqi ĆN, Timothy JD, Gordon P, Findlay N, Pillay R, et al. Outcome predictors in the management of spinal cord ependymoma. Eur Spine J 2007;16:399–404. http://dx.doi.org/10.1007/s00586-006-0168-y
[28] Geraghty T, Engelhar HH, Mehta AI. Intramedullary spinal cord tumors: a review of current and future treatment strategies. Neurosurgical Focus 2015;39(August (2)):E14.
[29] Feldman WB, Clark AJ, Safaee M, Ames CP, Parsa AT. Tumor control after surgery for spinal myxopapillary ependymomas: distinct outcomes in adults versus children: a systematic review. J Neurosurg Spine 2013;19:471–6.
[30] Tobin MK, Geraghty JR BS, Engelhard H, Linninger AA, Mehta AI. Intramedullary spinal cord tumors: a review of current and future treatment strategies. Neurosurg Focus 2015;39(2):E14.