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Outcome predictors and complications in the management of intradural spinal tumours

Received: 4 May 2004
Revised: 21 October 2004
Accepted: 27 December 2004
Published online: 23 December 2005
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Abstract The results of the management of 115 patients with intradural spinal tumours are presented. Data was collected retrospectively from the case notes. Tumours were categorized as intramedullary or extramedullary for statistical analysis. Meningioma, schwannoma and ependymoma accounted for 70% of tumours. Complete macroscopic excision was achieved in 84% of extramedullary and 54% of intramedullary tumours. There were two post-operative deaths, one of which was secondary to methicillin-resistant staphylococcus aureus (MRSA) meningitis. Cerebrospinal fluid leak (10%) and meningitis (7%) were the commonest complications. Ninety-six percent of patients with extramedullary tumours improved or

remained unchanged on the Frankel scale. In the intramedullary group, 82% remained unchanged or improved after treatment. Pre-operative functional status was a predictor of good post-operative function for intra- and extramedullary tumours and for intramedullary tumours a good post-operative Frankel score predicted long-term survival.

Keywords Spine · Intradural tumour · Outcome · Complications

Introduction

Intradural spinal tumours account for only a small proportion of central nervous system tumours, with an incidence of 0.3 per 100,000 per year [26]. Despite their rarity, there is an extensive literature on the management of these tumours. Over the past 30 years, the approach towards management of these tumours has become more aggressive in an attempt to preserve or improve neurological function [5–7, 23], however, the role of adjuvant therapy remains unclear [6, 13, 24]. Surgical resection remains the treatment of choice for extramedullary tumours. Some authors contend that great effort should be made to follow and resect all extradural components in

order to reduce recurrence [8, 9, 12] though this is not a universal dictum [18].

This series represents patients in the 'MRI era' and assesses the functional outcome, complications of surgery and outcome predictors for intradural spinal tumours in a climate of increasingly aggressive management.

Materials and methods

Between January 1994 and December 2001, 115 patients underwent surgery for intradural spinal tumours at The Walton Centre for Neurology and Neurosurgery. Information was collected retrospectively from the case

records regarding clinical presentation, tumour location, operative procedures, histopathological diagnosis and post-operative complications. Functional outcome was assessed using the Frankel scale [11].

Univariate and logistic regression analysis was used to identify factors that could significantly affect the binary outcomes: death, and recurrent tumour. Death outcome analysis was performed in three ways to confirm any significant findings. Firstly, death was defined as being due to post-operative complications or disease progression and all other patients were classed as survivors (death from unrelated causes and lost to follow-up). Secondly, the analysis was repeated with patients who died of unrelated causes or lost to follow-up excluded from the analysis. Thirdly, death was defined as deaths from all causes with patients lost to follow-up excluded from the analysis. Multiple linear regression was used to investigate the post-operative Frankel grade recorded at the last clinical assessment. Correlation was used to identify and remove correlated explanatory variables before performing regression analysis. Stepwise regression was used to simplify any resulting models (Genestat 3.2, Lawes Agricultural Trust, 1995). The following explanatory variables were investigated initially: subject age (years), duration of symptoms (months), complete resection of tumour, tumour histology, use of adjuvant therapy, recurrent tumour (excluded when used as an outcome), pre-operative Frankel grade and post-operative Frankel grade (excluded when used as an outcome).

Results

Study population

There were 76 patients (48 female, 28 male) with extramedullary tumours with an age range of 12–87 years (mean 54 years). 16 tumours were cervical (21%), 35 thoracic (46%), 4 thoracolumbar (5%) and 21 lumbar (28%).

There were 39 patients (22 male, 17 female) with intramedullary tumours with an age range of 15–87 years (mean 44 years). 16 tumours were cervical (41%), 9 thoracic (23%), 6 thoracolumbar (15%), 7 lumbar (18%) and one craniocervical (3%).

Clinical presentation

In the extramedullary group, the duration of symptoms ranged from 1 month to 72 months (mean 17 months). One patient had recurrent haemangiopericytoma detected on routine follow-up MRI. In the intramedullary group, the duration of symptoms ranged from 1 month to 7 years (mean 20 months). The incidence of presenting symptoms and signs is shown in Table 1.

Table 1 Clinical symptoms and signs, on initial examination, of extramedullary and intramedullary spinal tumours

	Extramedullary tumours (<i>n</i> = 76) (percentage of cases)	Intramedullary tumours (<i>n</i> = 39) (percentage of cases)
Pain (local or radicular)	48 (63%)	19 (49%)
Sensory disturbance	30 (39%)	21 (54%)
Limb stiffness	15 (20%)	14 (36%)
Limb weakness	40 (53%)	16 (41%)
Sphincter disturbance	15 (20%)	4 (10%)
Weakness	42 (55%)	27 (69%)
Spasticity	22 (29%)	9 (23%)
Sensory disturbance	27 (36%)	14 (36%)

Four cases in this series had pre-existing pathology. Two cases of previously treated intramedullary spinal tumours (haemangioblastoma and astrocytoma) were detected on routine follow-up MRI. The first patient had a known intramedullary tumour (not biopsied) that was treated empirically with radiotherapy in 1986 and subsequently presented with a lesion increasing in size on MRI. The second patient was assigned a diagnosis of transverse myelitis in 1997 and she presented 4 years later with neurological deterioration and a change in the appearance of the lesion on MRI.

Operation

A posterior approach using a laminectomy was used for all tumours and care was taken to preserve as much bony anatomy as possible to prevent destabilization. Microsurgical techniques were employed as standard and instrumentation was not used. The operative aim in all cases was to attempt complete excision but this was not always achievable due to indistinct tumour margins, or when surgery would result in destabilization of the spinal column. 64 extramedullary tumours were macroscopically excised and 12 were debulked. Of the 39 intramedullary tumours, 21 were completely excised, 13 were debulked and 5 biopsied.

Complications

There were two post-operative deaths. One case of thoracic meningioma suffered a fatal myocardial infarction. One patient with complete macroscopic excision of a cervical ependymoma developed methicillin-resistant staphylococcus aureus (MRSA) meningitis resulting in brainstem infarction and death.

Twelve cases of post-operative dural cerebrospinal fluid (CSF) leak occurred and five went on to develop meningitis (one cultured MRSA). There were three cases of meningitis without dural CSF leak and MRSA was

isolated in one case. There were four wound infections and five wounds dehiscenced.

Pathology

Histological diagnosis was obtained in all cases and the frequency of distribution of tumour types is shown in Fig 1.

Adjuvant therapy

Patients with intramedullary tumours were treated with adjuvant radiotherapy if complete macroscopic resection was not achieved. Fourteen intramedullary tumours (eight ependymomas, five astrocytoma, one metastasis) received adjuvant radiotherapy. Two cases (one ependymoma and one astrocytoma) received chemotherapy after developing recurrent disease. One patient with recurrent haemangioblastoma received chemotherapy for disease progression at multiple levels.

Two extramedullary tumours received adjuvant therapy. One case of recurrent haemangiopericytoma that was initially resected in 1987 and recurred after 6 years was debulked and treated with radiotherapy.

One case of malignant nerve sheath tumour was debulked and received chemotherapy.

Tumour recurrence

Tumour recurrence implies that complete tumour excision was achieved at the initial operation. As this was not possible in all cases, tumours were considered to have recurred if there were new symptoms related to tumour growth or tumour re-growth on routine follow-up MRI. Table 2 lists the cases and further treatment.

Follow-up

Patients with extramedullary tumours were followed-up for a mean of 3 years and 9 months (range 4 months to 9 years 9 months). As a regional neurosurgical unit many patients have to travel up to 120 miles for their clinic appointments and patients who successfully undergo complete excision of meningioma, schwannoma or neurofibroma are frequently discharged from routine follow-up, but are given direct clinic access if they

Fig. 1 Pathological classification of **a** 76 extramedullary tumours and **b** 39 intramedullary tumours

Table 2 Tumour recurrences following initial surgery and subsequent therapy

Histology	Extent of tumour excision	Adjuvant therapy	Time to recurrence (months)	Further therapy	Outcome
Astrocytoma	Complete	No	33	Surgery, XRT	Survived
Astrocytoma	Biopsy	XRT	8	Palliation	Died 4 months after recurrence
Astrocytoma	Biopsy	XRT	12	Palliation	Died 6 months after recurrence
Ependymoma	Complete	No	23	Surgery, XRT	Survived
Ependymoma	Debulked	XRT	15	DXT	Died 5 months after recurrence
Haemangioblastoma	Complete	No	27	XRT	Survived
Malignant nerve sheath tumour	Debulked	DXT	3	Palliation	Died 3 months after recurrence
Schwannoma	Debulked	No	40	Surgery	Survived
Schwannoma	Complete	No	43	Surgery	Survived
Schwannoma	Complete	No	71	Surgery	Survived
Meningioma	Complete	No	48	Surgery	Survived
Meningioma	Debulked	No	26	Surgery	Survived

XRT radiotherapy, *DXT* chemotherapy

deteriorate neurologically. Mean follow-up in the intramedullary group was 4 years and 4 months (range 1–9 years 5 months).

There were 11 deaths in this series. Two patients died in the post-operative period as previously discussed and three patients died of unrelated causes at a mean of 15 months post-surgery.

Six patients died of disease progression. One case of malignant nerve sheath tumour with intra-abdominal extension died within months of biopsy, and one case of recurrent haemangioblastoma died from intracranial disease 33 months after surgery. Two patients with astrocytomas died from recurrent disease despite radiotherapy. One patient with a low-grade ependymoma developed recurrence and died 15 months after treatment. One patient with metastatic mesothelioma died within a month of biopsy and radiotherapy. Two patients were lost to follow-up.

Functional outcome

Functional outcome was assessed using the Frankel scale [11], which is an objective measure permitting comparison with pre-operative status. The post-operative functional status refers to the last recorded clinical examination in the case notes prior to either discharge, loss to follow-up or deterioration due to disease progression. The results are summarized in Fig 2.

In the extramedullary group, 49 patients (64%) remained unchanged; twenty (26%) improved by one grade; two (3%) improved by two grades and two patients (3%) improved by three grades to become ambulant. Two patients (3%) deteriorated by one grade but remained ambulant and one patient (1%) deteriorated

by three grades to complete paralysis as a consequence of MRSA meningitis. Thirteen patients with extramedullary tumours had no useful motor function pre-operatively and ten became ambulant after surgery.

Twenty-six patients (67%) with intramedullary tumours remained unchanged; six (15%) improved by one grade and seven (18%) deteriorated by one or more grades, though one patient remained ambulant.

Statistical analysis

Intramedullary and extramedullary tumours were analysed separately and the results are presented in Tables 3 and 4. In extramedullary tumours, statistical analysis did not show any consistent significant explanatory variables that influenced survival. For intramedullary tumours, a better post-operative Frankel grade (Odds Ratio 13.9; 95% Confidence Interval 1.2–158.8) favoured survival, whereas tumour recurrence (Odds ratio 2.9×10^{-3} ; 95% Confidence Interval 2×10^{-5} –0.4) and the use of adjuvant therapy (Odds Ratio 0.012; 95% Confidence Interval 1.6×10^{-4} –0.861) did not favour survival. No factor was identified predicting tumour recurrence in either intra- or extramedullary tumours. Post-operative Frankel grade was positively correlated with a good pre-operative Frankel grade for both intra- (Odds ratio 1.9; 95% confidence interval 1.3–2.7) and extramedullary tumours (Odds ratio 1.4; 95% confidence interval 1.2–1.7).

Discussion

It is now widely accepted that aggressive surgical excision is the primary treatment for intramedullary tumours to control disease and prevent neurological decline [5–7, 23].

Fig. 2 Functional outcome using the Frankel scale, (a) extramedullary tumours, (b) intramedullary tumours

		Postoperative Frankel grade				
		A	B	C	D	E
Preoperative Frankel grade	A				2	
	B				1	
	C			3	6	1
	D	1			34	14
	E				2	12

		Postoperative Frankel grade				
		A	B	C	D	E
Preoperative Frankel grade	A		1			
	B					
	C				2	
	D	1	1	4	22	3
	E				1	4

This applies especially to low grade astrocytomas and ependymomas [4, 10, 15]. McCormick presented a series of 23 ependymomas in which there were no deaths or recurrences [21] and Ohata et al. [22] had a series of 18 ependymomas with no recurrence and favourable outcome in 16 patients. Both advocate early aggressive microsurgical resection alone [21, 22] and the extent of excision has been shown to be statistically significant in determining disease recurrence in ependymomas [3], though this is not borne out in our study. In astrocytomas, the extent of resection and tumour location do not appear to influence long-term survival, however, tumour grade [4, 10, 15] and favourable post-operative neurological function [19] have been shown to be predictive factors. In our series, neither tumour histology nor extent of resection influenced survival, though a good post-operative Frankel score was associated with improved survival in the group as a whole.

The recurrence rate for the intramedullary tumours is low (15.4%) with a mean time to recurrence of 19.7 months and as might be expected recurrence did not favour survival. However, a note of caution is warranted regarding the length of follow-up (mean 52 months). Whilst we can draw conclusions regarding early tumour recurrence, long-term follow-up is required to determine the delayed recurrence rate in this group.

There are no prospective randomized trials of adjuvant radiotherapy in the current literature and its role remains controversial. Even in the absence a statistically significant improvement in survival several studies recommend radiotherapy for all ependymomas and astrocytomas that are not completely macroscopically excised [3, 16, 22]. In the current study, three patients who received adjuvant radiotherapy after subtotal resection for intramedullary tumours developed recurrence within 15 months of initial treatment and all three died within 6 months of recurrence. The initial histological analysis revealed low-grade tumours but it is possible that they may have undergone anaplastic transformation. We routinely treat all astrocytomas and ependymomas that are not completely excised with adjuvant radiotherapy, although the univariate and multivariate analysis did not identify radiotherapy as a predictor of increased survival. A large, well-structured multi-centred prospective trial is required to resolve this issue since modern radiotherapy treatment planning and imaging may allow more accurate target definition and respect for normal neural tissue.

There is no consensus on the management of recurrent astrocytomas and ependymomas. We adopt a realistic approach depending on the patient's clinical condition. Further surgery is unlikely to be of benefit in

Table 3 Explanatory factors for extra- and intramedullary lesions present after stepwise regression for the outcomes, survival and post-operative Frankel grade

	Odds ratio	95% confidence intervals
Extramedullary: survival		
Duration	27	1.5×10^{-8} – 4.6×10^{10}
Post-op Frankel grade	1.9×10^{10}	0 – 1.0×10^{76}
Extramedullary: post-op Frankel grade		
Pre-op Frankel grade	1.39	1.16–1.662
Intramedullary: survival		
Post-op Frankel grade	13.9	1.2–158.8
Adjuvant therapy	0.012	1.6×10^{-4} –0.861
Recurrence	2.9×10^{-3}	2×10^{-5} –0.433
Intramedullary: post-op Frankel grade		
Pre-op Frankel grade	1.868	1.29–2.71

cases where macroscopic excision of the tumour was not possible at the initial operation. Patients who had a complete macroscopic excision initially may benefit from radiotherapy. Recurrence beyond this stage can be treated with chemotherapy but the results are disappointing. Salvage chemotherapy with oral etoposide in a small cohort of patients with recurrent medically and surgically refractory ependymomas has been shown to have a modest activity in maintaining stable disease [2]. There is also anecdotal evidence of a grade II astrocytoma in a child responding to chemotherapy alone [1], but this result is not duplicated elsewhere in the literature and palliative care is often a more appropriate option.

The spinal roots giving rise to extramedullary tumours are frequently non-functional at the time of surgery and the risk of post-operative neurological deficit is,

therefore, small when these roots are sacrificed [17, 20]. Some authors advise an aggressive surgical approach [8, 9, 17, 20] but we adopt a different stance with the minimum bone removal to maintain spinal column stability and avoid the need for instrumentation, which makes post-operative MRI interpretation difficult. Only three patients deteriorated post-operatively, two remained ambulant, and one patient, who initially improved, developed MRSA meningitis leading to paralysis. Two meningioma and three schwannomas recurred, requiring a second operation, without deterioration in function. With meningiomas aggressive resection may not be required as the recurrence can be as low as 1.3% and further surgery does not pose any major difficulties [18]. Whilst benign tumours require long-term follow-up with MRI and further resection for recurrence, some of our patients with successfully

Table 4 Univariate analysis for the three outcomes; death (all causes), post-operative Frankel grade and recurrence for (a) extramedullary tumours, and (b) intramedullary tumours

Variable	Outcome					
	Death (all causes)		Post-operative Frankel grade		Recurrence	
	Odds ratio	<i>P</i> value	Odds ratio	<i>P</i> value	Odds ratio	<i>P</i> value
Extramedullary tumours						
Symptom duration	1.8	0.16	1.0	0.34	0.98	0.63
Complete resection	5.8	0.29	0.9	0.7	0.33	0.24
Recurrence	0.07	0.052	0.7	0.29	–	–
Adjuvant therapy	0.014	0.014	0.8	0.55	13.7	0.15
Pre-op Frankel grade	2.6	0.15	1.4	< 0.001	0.8	0.7
Post-op Frankel grade	4.2	0.04	–	–	0.6	0.33
Intramedullary tumours						
Symptom duration	0.99	0.59	1.0	0.99	0.99	0.7
Complete resection	7.7	0.06	1.1	0.7	0.58	0.4
Recurrence	0.05	0.006	1.4	0.4	–	–
Adjuvant therapy	0.09	0.02	1.1	0.8	2.5	0.24
Malignant	1.3	0.55	1.3	0.44	0.98	0.65
Pre-op Frankel grade	1.0	1.0	1.9	0.002	1.7	0.48
Post-op Frankel grade	1.8	0.24	–	–	1.7	0.36

excised meningiomas are discharged but given open access to the neurosurgical clinic if they deteriorate. The meningioma recurrence was 5.5% in our study with a mean time to recurrence of 3 years and 1 month, which is comparable to other published studies [25].

Unsurprisingly, the majority of complications were due to dural CSF leak and meningitis, the incidence of which ranges from 5–13% and 1–10%, respectively [5, 8, 9, 21, 23]. Watertight dural closure is not always possible, especially with extramedullary meningiomas when the dura may be resected as part of the attempt to achieve complete excision. We do not routinely use synthetic dural substitutes or glue. A good closure in layers with close attention to the risk of wound leaks and early intervention with either a CSF lumbar drain or additional sutures allows the wound to heal. Although our meningitis rate is comparable to other series, there were two serious consequences of MRSA meningitis resulting in paralysis and brainstem death. In a case of suspected meningitis, CSF is sent for urgent gram stain and culture. Antibiotics are commenced empirically and on the basis of the gram stain. Forty-eight hours culture is required to isolate organisms from the CSF sample, and in a case of MRSA meningitis it is likely that a patient might have been treated with antibiotics to which the organism is resistant. During this time the infecting organisms may have already caused irreversible neurological injury. The possibility of MRSA meningitis should be considered and balanced against the risks of starting more toxic antibiotics that are used for its treatment as MRSA is a growing problem in neurosurgical units [13].

Comparison of functional outcome between series is difficult as different scoring systems are used. The Frankel system has several advantages over newer more accurate spine scoring systems; it provides an objective and reproducible score of useful function, the score can be determined from case records, and it is universally recognized. The ability to walk independently is important for patient self-esteem. Treatment of intradural spinal tumours is a balance between disease control and preserving function. Only one patient in the extramedullary group who was ambulant prior to surgery lost useful function, whilst ninety-four percent of patients with pre-operative functional deficits achieved normal or near normal post-operative functional outcome. Of the intramedullary tumours only 11% of patients with

normal or near normal function pre-operatively lost function and this compares favourably to other large series [5, 21]. The loss of function in two patients can be attributed to loss of proprioception secondary to dorsal column damage and great care should be taken to avoid excessive manipulation during resection. It is particularly pleasing that two patients with intramedullary tumours actually gained useful function after surgery. Timely surgical resection can dramatically improve functional status even in patients who have complete loss of spinal cord function, however, in the majority of patients in this study (65%) the functional status remained unchanged.

Few attempts have been made to statistically analyse outcome predictors for intradural spinal tumours [14] and prove the anecdotal evidence that good post-operative function is determined by good pre-operative function. In this study, we have shown that irrespective of histological diagnosis, pre-operative functional status is the best predictor of functional outcome for both intra- and extra-medullary tumours.

Conclusions

The early recurrence rate for intramedullary tumours is low, however, the follow-up is too short to draw conclusions regarding delayed recurrence. With regards to the use of adjuvant therapy the numbers are too small to be able to draw any conclusion.

For benign extramedullary tumours, we advise a posterior laminectomy and macroscopic resection without being too aggressive towards the extramedullary component to prevent destabilization of the spinal column and the need for instrumentation. Long-term follow-up with MRI and further surgery for recurrence is advised as good functional outcome can be achieved.

Regression analysis demonstrated that for intramedullary tumours only, reduced survival was predicted by tumour recurrence and adjuvant therapy whereas, good post-operative Frankel scale predicted improved survival. There were no predictors for tumour recurrence in either group, though the length of follow-up may be too short to draw any meaningful conclusion. For intramedullary and extramedullary tumours, pre-operative functional status was the best predictor of functional outcome.

References

1. Bouffet E, Amat D, Devaux Y and Desuzinges C (1997) Chemotherapy for spinal cord astrocytoma. *Med Pediatr Oncol* 29(6):560–562
2. Chamberlain MC (2002) Salvage chemotherapy for recurrent spinal cord ependymoma. *Cancer* 95(5):997–1002
3. Chang UK, Choe WJ, Chung SK, Chung CK and Kim HJ (2002) Surgical outcome and prognostic factors of spinal intramedullary ependymomas in adults. *J Neurooncol* 57(2):133–139
4. Cooper PR (1989) Outcome after operative treatment of intramedullary spinal cord tumors in adults: intermediate and long-term results in 51 patients. *Neurosurgery* 25(6):855–859
5. Cooper PR and Epstein F (1985) Radical resection of intramedullary spinal cord tumors in adults. *J Neurosurg* 63:492–499
6. Cohen AR, Wisoff JH, Allen JC and Epstein F (1989) Malignant astrocytomas of the spinal cord. *J Neurosurg* 70:50–54
7. Cristante L and Herrmann H-D (1994) Surgical management of intramedullary spinal cord tumors: functional outcome and sources of morbidity. *Neurosurgery* 35(1):69–74
8. El-Mahdy W, Kane PJ, Powell MP and Crockard HA (1999) Spinal intradural tumours: part I—extramedullary. *Br J Neurosurg* 13(6):550–557
9. Kane PJ, El-Mahdy W, Singh A, Powell MP, Crockard HA (1999) Spinal intradural tumours: part II—intramedullary. *Br J Neurosurg* 13(6):558–563
10. Epstein FJ, Farmer JP and Freed D (1992) Adult intramedullary astrocytomas of the spinal cord. *Neurosurgery* 77(3):355–359
11. Frankel HL, Hancock DO, Hyslop G, Melzak J, Michaelis LS, Ungar GH, Vernon JDS and Walsh JJ (1969) The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia. *Paraplegia* 7:179–192
12. Gezen F, Kahraman S, Canakci Z and Beduk A (2000) Review of 36 cases of spinal cord meningioma. *Spine* 25(6):727–731
13. Ghanalingham KK, Elsaghier A, Kibbler C and Shieff C (2003) The impact of methicillin-resistant *Staphylococcus aureus* in a neurosurgical unit: a growing problem. *J Neurosurg* 98:8–13
14. Hanbali F, Fourny DR, Marmor E, Suki D, Rhines LD, Weinberg JS, McCutcheon IE, Suk I and Gokaslan ZL (2002) Spinal cord ependymoma: radical surgical resection and outcome (discussion 1172–1174). *Neurosurgery* 51(5):1162–1172
15. Houten JK and Cooper PR (2000) Spinal cord astrocytomas: presentation, management and outcome. *J Neurooncol* 47:219–224
16. Kim MS, Chung CK, Choe G, Kim IH and Kim HJ (2001) Intramedullary spinal cord astrocytoma in adults: postoperative outcome. *J Neurooncol* 52(1):85–94
17. Kim P, Ebersold MJ, Onofrio BM and Quast LM (1989) Surgery of spinal nerve schwannoma—risk of neurological deficit after resection of involved root. *J Neurosurg* 71:810–814
18. King AT, Sharr MM, Gullan RW and Bartlett, JR (1998) Spinal meningiomas: a 20-year review. *Br J Neurosurg* 12(6):521–526
19. Lee HK, Chang EL, Fuller GN, Aldape KD, Atkinson GJ, Levy LB, McCutcheon IE and Maor MH (2003) The prognostic value of neurologic function in astrocytic spinal cord glioma. *Neuro-oncol* 5(3):208–213
20. Levy WJ, Latchaw J, Hahn JF, Sawhny B, Bay J and Dohn DF (1986) Spinal neurofibromas: a report of 66 cases and a comparison with meningiomas. *Neurosurgery* 18(3):331–334
21. McCormick PC, Torress R, Post KD and Stein BM (1990) Intramedullary ependymoma of the spinal cord. *J Neurosurg* 72:523–532
22. Ohata K, Takami T, Gotou T, El-Bahy K, Morino M, Maeda M, Inoue Y and Hakuba A (1999) Surgical outcome of intramedullary spinal cord ependymoma (discussion 346–347). *Acta Neurochir (Wien)* 141(4):341–346
23. Samii M and Klekamp J (1994) Surgical results of 100 intramedullary tumors in relation to accompanying syringomyelia. *Neurosurgery* 35(5):865–873
24. Sandler HM, Papadopoulos SM, Thornton AF and Ross DA (1992) Spinal cord astrocytoma: results of therapy. *Neurosurgery* 30(4):490–493
25. Schick U, Marquardt G and Lorenz R (2001) Recurrence of benign spinal neoplasms. *Neurosurg Rev* 24(1):20–25
26. Cancer in South East England (2000) Thames cancer registry. Alpine