Review Article

Ependymoma of the spinal cord and cauda equina: a review

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Ependymoma of the spinal cord and cauda equina is an uncommon tumor. Because it is rare, studies include few patients, who generally represent a selected group, depending on the referral pattern and specialty of the physician. The relative roles of surgery and radiotherapy are controversial. The authors review the literature to analyze patterns of treatment failure and to outline the natural history of the disease with a view to defining the roles of radiotherapy and surgery in the management of this tumor.

Index terms: Cauda equina•Ependymoma•Spinal cord

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Ependymoma of the spinal cord and cauda equina is an uncommon tumor.[1–3] Because it is rare, reports in the literature include only a few cases, usually collected over decades, and generally represent a selected population. The relative roles of surgery and radiotherapy are controversial. Since these patients were treated over many years, differences in surgical and/or radiotherapy techniques exist. By analyzing the patterns of failure and defining the natural history of the disease, as well as by reviewing the effectiveness of modern microneurosurgery and state-of-the-art megavoltage radiotherapy, we try to define the roles of radiotherapy and surgery in the management of ependymoma of the spinal cord and cauda equina.

From a critical review of the literature,[2–24] the following observations can be made: Ependymoma of the spinal cord has a long, relatively benign natural history.[3,10,11,13,14,16,18,19,21] Complete resection is possible, and

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recurrences are rare after total excision.[2,3,5,6,13,20,22–24] When the tumor has not been totally excised, radiotherapy can prevent recurrences.[2–4,6,8,12,14,15,21,22,24]

Most authors recommend total surgical excision, if possible; there are others whose approach is biopsy only, followed by radiotherapy (RT). In our opinion, the treatment must be highly individualized, with one important dictum in mind, "do no harm." The patient and the family, the neurologist, the neurosurgeon, and the radiation oncologist should all be part of the decision-making process.[25]

Natural history and patterns of failure

Treatment of neoplasms can improve only if one analyzes the failures of current treatment[26] in the context of the natural history of the disease. Characteristically, the natural history of ependymoma of the spinal cord and cauda (cauda equina, filum terminale, and conus medullaris) is long.[2,9–11,13,14,16,18,21,26] There are anecdotal reports of patients surviving for as long as 25 years after decompressive laminectomy and biopsy.[27] Without treatment, spinal cord dysfunction and death can be expected in the majority,[12,20] although long-term follow-up information on sufficient numbers of untreated patients is lacking.[5,12] For example, Kopelson et al[10] reported on three patients who underwent subtotal or total resection alone; only one of the three was alive without disease at 74 months. In addition, the myxopapillary subtype, which is more common in the cauda region, is biologically more benign.[2,9,10,13,16]

Local failure is almost the only pattern of failure seen in the ependymoma of spinal cord cauda.[6,19] However, Wight et al[18] and Shaw et al[19] each reported a case in which a caudal ependymoma metastasized outside the central nervous system (CNS). In their review of the literature, Wight et al[18] found five cases of spinal ependymoma that had metastasized. In addition, these authors point to the long natural history of spinal ependymoma (survival 4–32 years in six cases of spinal ependymoma with metastasis) compared with survival of nine months to 13 years (nine months to two years in 11 of 15 patients) in metastasizing intracranial ependymoma.[18]

Spread within the cerebrospinal axis (CSA) is also rare, although a few cases have been documented.[5,8–10,17,19] Marks and Adler[9] reported a case with simultaneous recurrence in the spinal cord and ventricles. However, the possibility of "drop" metastasis from an intracranial occult primary tumor cannot be excluded. For this reason, a computed tomographic (CT) scan or magnetic resonance (MR) image of the head is mandatory in all patients with spinal cord ependymoma to exclude an intracranial lesion.[3,4] The estimated risk of spread within the central nervous system for ependymoma of spinal cord and cauda is about 7%.[8,10]

Garcia[6] reported that 37 patients with primary spinal cord tumors, including 18 ependymomas, were seen between 1954 and 1979 at Mallinckrodt Institute of Radiology. The cause of death in 82% (14 of 17 patients) whose treatment failed was persistent or recurrent tumor at the primary site. None showed evidence of seeding within the CNS. Interestingly, 13 of the 14 failures (in 26 patients) were caused by primary tumors in the spinal cord; only one was in the cauda group, totaling 11 patients. In three patients, the death was from unrelated causes.

At the same institute, Marks and Adler[9] compared the outcome for patients with ependymoma by site of origin. Local control was achieved in 88% of ependymomas arising from the cauda equina and 43% of ependymomas arising from spinal cord, versus 20% for supratentorial (ST) ependymomas and 50% for infratentorial (IT) ependymomas. Time to recurrence from the end of RT in 80% of the patients was 17 months for spinal cord and cauda ependymomas. However, the time to initial failure was much longer in two other series. In the report from Massachusetts General Hospital,[10] it was 3, 19, 75, and 82 months for four patients whose therapy failed. Similarly, Shaw et al[19] at the Mayo Clinic reported a time to recurrence of one and one half to 12 years among seven patients (median time to recurrence, four years). Among 22 patients who were treated with surgery and RT over 20 years (1963–1983), treatment failed in 32% (7 of 22). The majority (86%, 6 of 7) experienced local, in-field tumors. One patient had a recurrence in the fourth ventricle, with no local recurrence. This patient with grade II, cellular ependymoma had a normal CT scan of the brain at the time of initial diagnosis and was alive 38 months after diagnosis of recurrence and treatment with whole-brain RT. In fact, five of seven patients whose treatment failed were alive 38–181 months after this first recurrence, again emphasizing the long natural history of this disease. Three of these five patients were alive with disease at 97.5, 159.5, and 181 months after the

Table 1. Rate of complete resection (number of patients with complete resection/total patients [%])

Reference	Ependymoma			Astrocytoma
	Cauda (%)	Spinal cord (%)	Spinal cord + cauda (%)	
Garcia*[6]	47/95 (49)	54/107 (50)	101/202 (50)	6/107 (6)
Peschel et al[8]	1/4 (25)	1/5 (20)	2/9 (22.2)	—
Marks and Adler[9]	0/8 (0)	0/7 (0)	0/15 (0)	—
Cooper and Epstein[5]	—	—	12/14 (85.7)†	8/11 (72.7)
Fischer and Mansuy[11]	—	16/16 (100)	16/16 (100)	—
Shaw et al[19]	—	—	8/22 (36.3)	—
Garrido and Stein[20]	—	3/3 (100)	3/3 (100)	3/5 (60)‡
Fearnside and Adams[22]	13/30 (43.3)	—	13/30 (43.3)	—
Takata et al[23]	—	2/4 (50)	2/4 (50)	—
TOTAL	61/137 (44.5)	76/142 (53.5)	157/315 (49.8)	17/123 (13.8)

* Derived from Table 3, ref. 3, (Garcia DM). The author has compiled these from nine different series, including his own. The range for ependymoma varies from 0% to 100%; for astrocytoma, 0% to 19%.
† 6/14 had total resection; 6/14 had "99%" resection.
‡ 3/5 had total resection; the remaining two had 90% to 95% resection.

first recurrence. Only three of 22 patients have died: one of colon cancer; one of widespread distant (lungs, kidney, and skin) metastasis; and one of sepsis, unrelated to local recurrence.

Role of surgery

Surgery plays a crucial role in the management of ependymoma of spinal cord and cauda.[3,5,19] It is necessary to obtain a tissue diagnosis and to obtain immediate decompression, if possible, for total surgical resection of the tumor. In the past, it was common to perform a laminectomy and not a biopsy because of fear of neurological sequelae[6,16,28] and to administer postoperative RT. The rationale was that, since astrocytoma and ependymoma contribute about 90% of intradural intramedullary spinal cord tumors, both of which require RT, the risk of neurological sequelae was not justified. However, we strongly recommend at least a biopsy for two reasons: with the advancement of modern microsurgical techniques, the risks of sequelae are minimal with biopsy,[5,20] and the prognosis for astrocytoma is different from that for ependymoma.[4,6]

Is complete resection possible and desirable?

In a recent report, Cooper and Epstein,[5] from New York University Medical Center, showed that total resection is possible with modern microsurgical techniques in a majority of patients with ependymoma of spinal cord and cauda equina. They reported the results of surgical treatment alone in 29 adults with intramedullary spinal cord tumors. Fourteen had ependymoma, 11 astrocytoma, two lipoma, one intramedullary fibrosis, and one astrogliosis. Total removal was achieved in 16 and "99% removal" in seven; so, over a period of two and one half years, near total or total excision was possible in 21 of 29 (72.4%) consecutively treated patients. The authors point out that, because ependymomas are more defined from the surrounding cord, they can be resected more easily than astrocytomas. Also, tumors from the cauda equina can be excised more easily.[3–6] With a follow-up range of six to 36 months, there was stabilization or improvement in the neurological status of the lower extremity in 21 of 29 patients and of the upper extremity in 87%.[5] There were no deaths in the 30-day postoperative period, although six patients died during the six- to 36-month follow-up. None of those six patients died of ependymoma. However, as pointed out by the authors themselves, because of short follow-up, the long-term prognosis is not known.[5]

The percentage of tumors that could be totally resected varies from series to series,[5,6,8,9,11,19,20,22,23] probably representing the philosophy of the operating surgeon and the extent of neurological sequelae one is willing to accept as well as the surgical technical sophistication of the time. Garcia[6] reviewed nine series in the literature. These reports spanned more than 30 years, from 1951 to 1985. However, five of the eight series were reported after 1978; seven of the eight after 1963. The rate of complete excision ranged from 0% to 100%. The rate of complete resectability was better for ependymoma than for astrocytoma. We have added patients from eight more series to those reported by Garcia (*Table 1*). Total resection appears to be possible in about half of patients with epen-

Table 2. Results with surgery (total resection)

Reference	No. Patients	Follow-up Mean (yr)	Follow-up Range (yr)	Survival	Comment
Cooper and Epstein[5]	14	—	6 mo–3	No deaths due to tumor in this short follow-up	21 of 29 patients with intramedullary tumor (14 ependymoma) had stabilization/improvement in neurological functions
Fischer and Mansuy[11]	16	6.3	3–11	14/16 alive (10/14 > 10 yr)	12/14 resumed professional activities 8/14 no/mild sequelae 4/14 moderate sequelae 2/14 complete paraplegic (Both had this before surgery) No recurrence in all 13 pts with grade I/II lesions
Greenwood[13]	9	8.1	3–21	7/9 alive 3–21 yr 1/9 died on postop day 6 1/9 died 3 mo postop	6/7 surviving patients with postsurgical neurological status of >85% (80–100% normal gait)
Mørk and Løken[16]	51*	—	1–22	10-yr survival for intramedullary = 55% 10-yr survival for cauda group = 94%	No difference in survival between surgery vs. surgery + RT No details of RT given
Fischer and Mansuy[11]	3	0.9	8 mo–1	All 3 alive	
Shaw et al[19]	8	—	—	5-yr freedom from relapse = 88% 5-yr overall = 100%	3/8 treatment failures, 2 locally and 1 in ventricle IV No statistical difference between total vs. subtotal resection/biopsy only (P = .74) All patients received postop RT
Barone and Elvidge[2]	16	15.2	3–21	12 yr (mean)	Of 7 pts who died 3 died of intercurrent disease (1 postop death, 2 lost to follow-up at 1 yr NED)
Fearnside and Adams[22]	13	2.0	2 mo–27	—	Only 1 recurrence among 13 pts Among pts with incomplete resection, 5/16 had recurrences

NED = no evidence of disease.
* 50/51 survived >4 weeks after surgery; 34/50 treated with surgery alone, 16/50 treated with surgery + RT.

dymomas, arising either from spinal cord or cauda. Remarkably, our figures are very similar to Garcia's.[6]

The influence of the surgeon's philosophy and the importance of technical advances are reflected in Fischer and Mansuy's[11] report of 100% total resectability of spinal cord ependymoma among 16 patients. From 1967 to 1977 at University of Lyons, France, these authors performed complete excision in 10 males and six females ranging in age from nine to 51 years. The technical details of removal of the tumor through the posterior sulcus of the spinal cord without a myelotomy or lateral incision are well described. Fourteen of the 16 patients were alive three to 11 years after surgery. All 13 patients with grade I and II ependymoma were alive at the time of this report (*Table 2*). Ten of the 14 patients lived for more than 10 years. Twelve of the 14 patients went back to work. Takata et al[23] also stress the importance and success of microsurgical techniques.

An earlier study, published in 1963 by Greenwood,[13] also attests to the possibility of complete removal of the tumor with careful technique. Of nine ependymoma patients who underwent total resection, seven survived three to 21 years after surgery without any recurrence. Six of eight surviving patients were rated to have had a neurological status of more than 85% (80% to 100% reflected normal gait). The authors recommended that total excision should not be at-

tempted in infiltrating tumors and in those with unclear planes of cleavage. Greenwood[13] observed late worsening of neurological status in 30% of his patients two to seven years after surgery, which he attributed to late glial changes.

Garrido and Stein[20] have described the dorsal myelotomy microsurgical technique in the total removal of intramedullary tumors. Three of the 11 patients had ependymoma. Many of the patients had had previous decompressive laminectomy and RT. The three patients with ependymoma, all of whom had total removal, had short follow-ups of eight, 11, and 12 months, respectively. Two of the three ependymoma patients had stabilization and one had improvement in neurological function.

Barone and Elvidge[2] have also reported on total resection. From 1928 to 1964, 16 of 27 patients with ependymoma of spinal cord underwent total resection at Montreal Neurological Institute. Three of the 16 underwent postoperative RT. Nine of the 16 patients were alive three to 21 years after surgery (mean 15.2 years). Of the seven patients who died, two died of secondary malignancy, one in the postoperative period and one of chronic renal failure, and two were lost to follow-up at one year with no evidence of disease. The survival times between RT and no-RT groups were not different, although the number of patients is small and mean survival was used to compare results. In a smaller series of 13 patients who underwent gross total resection, only one had recurrence.[22] However, the mean follow-up was two years.

Table 2 summarizes results reported with total surgical resection. From these results, the following conclusions can be drawn: With total surgical resection alone, survival is satisfactory, although the parameters reported in the literature are not uniform. One notable exception is the study by Mørk and Løken[16] in which the 10-year survival for the spinal cord group was 55%. Stabilization or improvement of neurological status can be expected in the majority. Incomplete resection alone is inadequate treatment.[22] Although Shaw et al[19] did not find any difference between the groups that had total resection and subtotal resection or biopsy only ($P = .74$), it should be noted that all patients received postoperative RT.

One should recognize that the definition of "total" macroscopic resection is arbitrary.[3] The criteria for "total" removal are outlined well by Fischer and Tommasi[3] in their chapter on spinal ependymomas.[3] For instance, in a patient with minimal neurological deficit, extreme caution should be taken to avoid spinal cord damage, whereas more freedom can be taken in resection if complete flaccid paralysis is present. The extent of surgical resection must be highly individualized depending on the invasiveness of the tumor, presence of cleavage planes, experience of the surgeon, and intraoperative histology. Fischer and Tommasi stated, "However, the concept of 'removal at any cost,' which necessarily implies some spinal cord damage, remains just as reprehensible as it was and is rejected by all authors."[3]

Role of radiotherapy

Although some neurosurgeons question the usefulness of RT in ependymoma of spinal cord and cauda,[5,11,20] others attest to its benefits.[2,22] There is sufficient evidence in the literature of the ability of RT to achieve local control and prolong survival in patients in whom gross or microscopic residue has been left behind after surgery.[2–4,6,8–10,12,14,15,17] After total resection, additional RT is not required. However, extension of this observation to those patients in whom a biopsy or a less-than-total resection can be achieved is not justified. The risk of radiation myelopathy with external RT is very low and should not deter the neurosurgeon from recommending local external RT when it is indicated.

Table 3 details results of RT reported in the literature. The number of patients in each series is small, ranging from three to 23. There is no uniformity in reporting the survival statistics. However, a majority of patients have been followed for at least five years. The following conclusions can be drawn from *Table 3*: Administration of RT can lead to long-term survival in about 75% of these patients. Both long-term survival and local control are better for the cauda group than the spinal cord group. With appropriate doses and fractionation, risk of radiation-induced myelopathy is minimal with external RT. The risk is significant with the use of intrathecal radioactive gold administration, and this treatment is not recommended. Stabilization or improvement in neurological status can be expected in the majority of patients.

The curability of ependymoma with RT is well illustrated by three cases of infiltrating papillary ependymoma of cauda equina reported by Scott.[14] One patient had 50% removal and the other two had biopsy only. All three patients were alive 17–20 years later with "relatively minimal complaints and dysfunction." Scott recommends

Table 3. Radiotherapy (RT) results in ependymoma of spinal cord and cauda (RT administered after total/subtotal resection or biopsy)

Reference	No. Pts	Dose administered (Gy)		Follow-up	Survival	Comment
		Range	Mean			
Garcia[6]	18	30–55	—	92%, minimum 5 yr	10 yr survival cauda group = 75%	Results in group of 37 pts with various primary tumors of spinal cord and cauda
				73%, minimum 10 yr	Spinal cord group = 60%	Recurrent tumor was cause of death in 82% of those who died
						Radiation myelopathy was noted in 1 pt who received 30 Gy external RT + 5 mCi (185 MBq) Au-198*
						Retroperitoneal sarcoma developed in 1 pt
Peschel et al[8]	9	43.2–52.2	48.04	8 mo–8 yr	100% in 8 mo–8 yr	No local recurrences noted
						No radiation myelopathy seen
						In 3/9 pts, neurological status stabilized by RT
						In 6/9 pts, neurological status improved by RT
Marks and Adler[9]	15	1000–1600 RET	—	3–23 yr	5-yr cauda group = 83%	80% of recurrences within 17 mo
					5-yr spinal cord group = 57%	Local control spinal cord = 43%
						Local control cauda = 88%
						Radiation myelopathy with external RT = 4%
						Radiation myelopathy with external RT+ intrathecal Au-198 = 33%*
Kopelson et al[10]	12	26.88–55.0	—	3/21–15-6/12 yr	5 yr = 100%	Local failure:
					10 yr = 73%	1/1 subtotal resection only
						1/2 total resection only
						1/1 RT only
						1/8 subtotal resection + RT
						34/45 neurological deficits became normal, 8/45 improved after RT
Wood et al[12]	23	—	—	0.1–19.1 yr	12/16 followed >6 yr	Pts received 800–3,000 R (19/23,
				16/23 >6 yr	were alive	1,100–2,100 R) per series, 1–9 series per patient, over 0.3–15 yr; 5/23 received 1 series; 5/23, 6–9 series; 13/23, 2–5 series
Scott[14]	3	2,000–5,000		17–23 yr	All alive	Minimal sequelae noted in all 3 pts
						All 3 pts treated with conservative surgery + RT
Schwade et al[15]	12	28.54–50.4	47.85	2.5–17 yr (mean: 6.6 yr)	12/12 alive	11/12 received 44–50.4 Gy
				11/12 followed >3 yr		Excluding 1 pt who received 28.54 Gy, mean dose was 49.62 Gy
				5/12 followed >5 yr		
DeSousa et al[17]	7	—	—	Mean: 6 yr	5/6 who received RT alive	2/7 had total removal
						5/7 had subtotal removal
						6/7 received RT
Shaw et al[19]	22	36–57	50 (median)	—	5-yr FFR = 81%	7/22 failures (32%)
					Overall = 95% 10 yr	6/7 (86%) local
					5-yr FFR = 71%	1 CNS failure
					Overall = 95%	1 widespread metastasis
						3/8 received RT after total resection

FFR = freedom from recurrence.

* Note a high incidence associated with intrathecal radioactive gold administration. External RT alone has excellent tolerance.[5,12,15]

† Dose in cGy converted to nominal standard dose.

against radical surgical removal of infiltrating tumors in view of the effectiveness of RT. At least two other neurosurgical papers mirror this opinion,[2,22] although no details of RT are mentioned. In Barone and Elvidge's[2] data from Montreal Neurological Institute, the mean survival in the group with incomplete resection was 2.5 years without RT and 9.5 years with RT. In a report from the Radcliffe Infirmary, Oxford, England, 11 of 16 patients who had incomplete resection plus RT had no recurrence, with a mean follow-up of 57 months.[22]

Dose recommendations

Doses prescribed by radiation oncologists often reflect a compromise between the tumor control dose and normal tissue tolerance dose for a given tumor and its anatomical location.[29] The choice of dose is not easy, since both curability with RT and normal tissue tolerance dose curves are sigmoid. The chances of both a cure and complications can increase 5–95% within a range of a few Grays. The optimal dose for the ependymoma of the spinal cord and cauda is further complicated by two factors: the wide range of doses reported in the literature and the possible complication of radiation myelopathy.

Fortunately, there are at least two recent reports in which relatively uniform doses were used with excellent results and without significant morbidity.[8,15,19] At Yale University School of Medicine, Peschel et al[8] administered 43.2–52.2 Gy (mean 48.04 Gy) in nine patients. Seven of the nine had only subtotal resection. All nine were alive eight months to eight years after RT. Neurological status improved significantly in three of nine patients. No radiation myelopathy was noted. The authors recommended 45–50 Gy with 1.8–2 Gy per fraction. Schwade et al[15] recommend similar doses. Eleven of their 12 patients received 44.0–50.4 Gy; one patient received 28.54 Gy. All 12 patients were alive with follow-ups of 2.5–17 years. Four of 12 patients had biopsy only, seven had subtotal resection, and one had total resection.

In a more recent report from the Mayo Clinic,[19] the dose ranged from 36 Gy to 57 Gy (median 50 Gy). The median dose per fraction was 2.0 Gy. When <50 Gy was administered, treatment failed in 35% (six of 17 patients), whereas treatment failed in 20% (one of five patients) with a dose of >50 Gy. Treatment failed in all three patients who received a split course. The authors recommended slightly higher doses: 50 Gy to the tumor plus a margin of two vertebral bodies followed by a 5-Gy boost to the gross tumor. Nineteen of 22 (86%) patients were still alive (follow-up 2.5–19.5 years). Neurological status remained stable or improved in all except one patient in whom the worsening was due to local recurrence.

At least 40 Gy is required to achieve satisfactory results. For instance, in Garcia's series with 18 patients,[6] with <40 Gy, 77% died of recurrent tumor, whereas, after >40 Gy, 83% were alive for 4.1–28.9 years. Kopelson et al[10] observed a similar dose response, and they recommend 40–45 Gy with 1.8–2.0 Gy/fraction.[10]

The tolerance of the spinal cord with tumor appears to be no different from normal spinal cord.[30] Although Maras et al[28] noted "vascular lesions" in three of 15 patients with gliomas of spinal cord, the doses used are slightly higher than those generally recommended (mean dose 5492 ± 494 cGy). In the analysis by Kopelson,[30] none of the 19 patients with glioma developed evidence of radiation myelopathy after receiving curative doses of RT. Kopelson recommends a dose of 40–45 Gy.

In summary, the tumor should be totally removed, if possible. If this is achieved, no further treatment appears to be necessary. *Table 1* shows that only 50% of tumors can be totally resected. However, in two recent series,[5,11] this was achieved in 90–100% of a small series of patients (total of 30 patients from both series).

If total removal is not possible, postoperative RT should be administered. In view of the low incidence of CSF spread, local field irradiation of the tumor with a margin of one to two vertebral bodies above and below should suffice.[4,10,19] A dose of 45 Gy to above-said volume is recommended, preferably at 1.8 Gy/fraction. Using the shrinking-field technique, an additional 5 Gy can be administered to a smaller volume if gross tumor has been left behind during surgery. Craniospinal axis irradiation can be considered with poorly differentiated tumors[8,19] and when CSF cytologic findings are positive.[3,10]

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References

1. Sloof JL, Kernohan JW, MacCarthy CS. Primary intramedullary tumors of the spinal cord and filum terminale. New

York, WB Saunders, 1984.
2. Barone BM, Elvidge AR. Ependymomas: a clinical survey. J Neurosurg 1970; **33**:428–438.
3. Fischer G, Tommasi M. Spinal ependymomas. [In] Vinken PJ, Bruyn GW, eds. Tumours of the Spine and Spinal Cord, part 2. New York, American Elsevier, pp 353–387.
4. Kornblith PL, Walker MD, Cassady JR. Neoplasms of the central nervous system. [In] DeVita VT Jr., Helman S, Rosenberg SA, eds. Cancer: Principles and Practice of Oncology, 2nd ed. Philadelphia, JB Lippincott, pp 1437–1510.
5. Cooper PR, Epstein F. Radical resection of intramedullary spinal cord tumors in adults: recent experience in 29 patients. J Neurosurg 1985; **63**:492–499.
6. Garcia DM. Primary spinal cord tumors treated with surgery and postoperative irradiation. Int J Radiat Oncol Biol Phys 1985; **11**:1933–1939.
7. Read G. The treatment of ependymoma of the brain or spinal canal by radiotherapy: a report of 79 cases. Clin Radiol 1984; **35**:163–166.
8. Peschel RE, Kapp DS, Cardinale F, Manuelidis EE. Ependymomas of the spinal cord. Int J Radiat Oncol Biol Phys 1983; **9**:1093–1096.
9. Marks JE, Adler SJ. A comparative study of ependymomas by site of origin. Int J Radiat Oncol Biol Phys 1982; **8**:37–43.
10. Kopelson G, Linggood RM, Kleinman GM, Doucette J, Wang CC. Management of intramedullary spinal cord tumors. Radiology 1980; **135**:473–479.
11. Fischer G, Mansuy L. Total removal of intramedullary ependymomas: follow-up study of 16 cases. Surg Neurol 1980; **14**:243–249.
12. Wood EH, Berne AS, Taveras JM. The value of radiation therapy in the management of intrinsic tumors of the spinal cord. Radiology 1954; **63**:11–22.
13. Greenwood J Jr. Intramedullary tumors of spinal cord: a follow-up study after total surgical removal. J Neurosurg 1963; **20**:665–668.
14. Scott M. Infiltrating ependymomas of the cauda equina: treatment by conservative surgery plus radiotherapy. J Neurosurg 1974; **41**:446–448.
15. Schwade JG, Wara WM, Sheline GE, Sorgen S, Wilson CB. Management of primary spinal cord tumors. Int J Radiat Oncol Biol Phys 1978; **4**:389–393.
16. Mørk SJ, Løken AC. Ependymoma: a follow-up study of 101 cases. Cancer 1977; **40**:907–915.
17. DeSousa AL, Kalsbeck JE, Mealey J Jr, Campbell RL, Hockey A. Intraspinal tumors in children: a review of 81 cases. J Neurosurg 1979; **51**:437–445.
18. Wight DGD, Holley KJ, Finbow JAH. Metastasizing ependymoma of the cauda equina. J Clin Pathol 1973; **26**:929–935.
19. Shaw EG, Evans RG, Scheithauer BW, Ilstrup DM, Earle JD. Radiotherapeutic management of adult intraspinal ependymomas. Int J Radiat Oncol Biol Phys 1986; **12**:323–327.
20. Garrido E, Stein BM. Microsurgical removal of intramedullary spinal cord tumors. Surg Neurol 1977; **7**:215–219.
21. Cameron MM. Surgical management of multiple neuraxial ependymomas: case report. Eur Neurol 1976; **14**:365–369.
22. Fearnside MR, Adams CBT. Tumours of the cauda equina. J Neurol Neurosurg Psychiatry 1978; **41**:24–31.
23. Takata K, Takeuchi RN, Hamawaki J, Yonezawa T, Naruse A, Ikata T. Diagnosis and treatment of intramedurally ependymoma in the cervical region. Tokushima J Exp Med 1977; **24**:113–119.
24. Guidetti B. Intramedullary tumours of the spinal cord. Acta Neurochir 1967; **17**:7–23.
25. Radiation Oncology in Integrated Cancer Management: Report of the Intersociety Council for Radiation Oncology, November 1986.
26. Cox JD. Failure analysis in diagnostic and treatment strategies in cancer management. Cancer Treat Symp 1983; **2**:1–3.
27. Baker GS, Greenwood JC. Discussion. [In] Greenwood JC, Intramedullary Tumors of Spinal Cord. J Neurosurg 1963; **20**:668.
28. Marsa GW, Goffinet DR, Rubinstein LJ, Bagshaw MA. Megavoltage irradiation in the treatment of gliomas of the brain and spinal cord. Cancer 1975; **36**:1681–1689.
29. Rubin P, Keller B, Quick R. The range of prescribed tumor lethal doses (PTLD) in the treatment of different human tumors. [In] Friedman M, ed. The Biological and Clinical Basis of Radiosensitivity. Springfield, Charles C. Thomas, 1974, pp 435–484.
30. Kopelson G. Radiation tolerance of the spinal cord previously-damaged by tumor and operation: long term neurological improvement and time-dose-volume relationships after irradiation of intraspinal gliomas. Int J Radiat Oncol Biol Phys 1982; **8**:925–929.