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PRIMARY INTRAMEDULLARY TUMORS OF THE SPINAL CORD AND FILUM TERMINALE

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Primary Intramedullary Tumors of the Spinal Cord and Filum Terminale

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PREFACE

FOR MANY YEARS our predecessors and associates have been interested in tumors of the spinal cord. During the last 30 years various studies of the clinical and roentgen-ray diagnosis, the surgical management, and the pathologic investigations of various types of tumors of the spinal cord have been reported. We wish to express our thanks to our predecessors, particularly W. D. Shelden, H. W. Woltman, A. W. Adson, W. McK. Craig, and J. D. Camp for their efforts in accumulating this abundant material and thus making this study possible. The present review is the culmination of the work of many members of the staff of the Mayo Clinic.

In the earlier years, when the basis for this study was laid, there were few aids to the diagnosis of tumors of the spinal cord, and detailed neurologic examinations were the only method of arriving at an accurate localization of such neoplasms. The surgical treatment was hampered by the difficulty of controlling bleeding and the ever-present danger of infection. These hazards are still present, but are greatly diminished, whereas accurate localization is now greatly aided by myelography. Bleeding is more readily controlled by electrocoagulation, and infections are held in check by chemotherapeutic and antibiotic agents.

We hope this report will be of service to all who have the care of patients with tumors of the spinal cord; the work is directed especially to neurologists and neurosurgeons, and to pathologists who report on the tissue removed. We also hope it will be of interest and help to all students interested in neurologic diseases.

We wish to express our gratitude to Mr. Louis W. Nichols, Jr., of the Section of Photography of the Mayo Clinic, for the preparation of all the photomicrographs; to the Section of Medical Illustrations for the

preparation of the charts and tables; to the laboratory assistants in the Section of Pathologic Anatomy, and to Mrs. Beth Zimmermann for her secretarial assistance; and to Dr. James R. Eckman of the Section of Publications, for help, advice, and guidance in the preparation of the manuscript.

We finally express our thanks to the publishers for granting us the liberal use of illustrations. Without adequate illustrations, the usefulness of a volume of this type would be diminished. We are appreciative of their generosity in this respect.

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INTRODUCTION

It can be assumed safely that the existence and clinical importance of tumors of the spinal cord have been known for several hundred years. It was not until 1887, however, that the first intradural but extramedullary tumor of the spinal cord was removed successfully by Victor Horsley, after the diagnosis had been established by Gowers.[106] It was another 20 years, in 1907, before the first intramedullary tumor was successfully operated upon by Eiselsberg [Eiselsberg-Ranzi[77] (1913)]. These two surgeons can be credited for the increasing interest in this previously hopeless condition. Their efforts proved that lesions of the spinal cord can be removed successfully without too much or even no damage at all to the function of the spinal cord.

The simplification and perfection of lumbar puncture by Quincke[220] in 1891 and the adaptation of lumbar puncture to the study of the hydrodynamics of the cerebrospinal fluid by Queckenstedt[219] in 1916, as well as the advance in roentgenologic technics and interpretation, have proved to be of considerable value in the establishment of an earlier and more nearly accurate diagnosis. These measures are welcome addenda to the clinician who is faced with the difficult problem of evaluating the significance of the various symptoms, such as pain, disorders of sensation, and disturbance of motor and sphincter function. The results of early surgical intervention are usually encouraging, since

intervention may bring about total restoration of function. For the ultimate prognosis, however, the surgeon often is dependent upon the histologic nature of the removed tissue. To the histopathologist, the microscopic examination often is appealing, since he is faced with tumors of many sources of origin, such as bony structures, cartilage, ligaments, fat tissue, lymphoid tissue, spinal nerve roots, blood vessels, meninges, cord tissue, and congenital rests. It is, however, at this point that the interest of clinician and pathologist often is divergent. The former is predominantly interested in the prognosis for his patient, and the latter, preoccupied with the great variation in cytologic and histologic structures of the tumors, is not easily satisfied.

As Bailey[13] (1938) pointed out, there are two possible bases for the classification of gliomas: (1) a practical viewpoint tending to result in a classification useful to the clinician; and (2) an academic viewpoint tending to result in a classification more meaningful to the biologist. In this study an attempt will be made to find some correlation between both viewpoints. For such a study, certain criteria and limitations must be set. Our purpose was to study primary intramedullary tumors of the spinal cord. It appears worth while to give some explanation of our understanding of this concept.

The commonly accepted grouping of tumors of the spinal canal is on the basis of location of the lesion in respect to the various structures which compose the spinal column. In this way one recognizes the intraspinal but extradural, the intradural but extramedullary, and the intramedullary locations. The intramedullary lesions can be defined as "lesions located in the substance of the medulla spinalis." The lesions of the filum terminale often are considered apart. Harmeier[118] (1933) divided the filum terminale into an intradural part and an extradural part. He wrote that the intradural part appeared to be composed of elements similar to those found in the other segments of the medulla spinalis, although there was a difference in the proportion of the constituent cells. Especially noted was the fact that there were less neural and glial tissue and relatively more ependymal cells. A similar predominance of ependymal cells also is noted in the conus medullaris, and this predominance appears to be the result chiefly of the presence of the ventriculus terminalis [Kernohan[140] (1924)]. There is no doubt that the conus medullaris is a part of the medulla spinalis. Why should we hesitate to accept the notion of the downward continuation of the conus medullaris, which is the intradural part of the filum terminale, as the lower extension of the medulla spinalis?

It seems logical, therefore, to include tumors of the intradural part of the filum terminale in a study of intramedullary tumors of the spinal cord.

In respect to the word "primary," we wish to qualify it by noting that we are dealing only with tumors which originated in the substance of

the medulla spinalis and filum terminale. In most instances we had to base our opinion on the surgical reports or, in a small number of cases, on necropsy records. Those cases in which there was doubt regarding the original location of the tumor were not included in this study. It will also be understood that tumors originating from heterotopic glial tissue situated outside the medulla spinalis similarly were excluded.

The word "tumor" is used in the sense of "neoplasm."

INCIDENCE

Tumors of the spinal cord are considered to be rare. It is difficult to appraise accurately the frequency of occurrence of tumors of the spinal cord. When we began to evaluate the incidence, we found that this problem has been studied from different points of view by several authors.

One method of obtaining this information would be the study of a large group of postmortem examinations. This was done by Schlesinger[257] in 1898. He found 151 instances of intraspinal "tumors" in a series of 35,000 necropsies. Unfortunately, the word "tumor" at that time was used in relation to more disease entities—such as tuberculomas and gummas—than is true at present. In his series he found 20 intramedullary "tumors," but added that it was impossible to give exact figures concerning the frequency of occurrence of the gliomas, remarking, "There is no common opinion in regard to the meaning of the diagnosis glioma."

More information can be gathered from a study by Peers[212] (1936). In a series of 10,592 consecutive necropsies, 5150 examinations of the head were performed. There is no note as to whether the spinal cord was included routinely in the examinations. In these 5150 examinations 188 "tumors" of the central nervous system were encountered (this included 19 instances of tuberculosis and syphilis). There were 81 gliomas of the brain and four intramedullary neoplasms of the spinal cord (gliomas). Thus, we find that on this basis intramedullary tumors of the spinal cord represent 0.08 per cent of the total group of lesions found during examination (supposing that examination of the spinal cord was performed routinely), or 4.9 per cent of the 81 gliomas.

Flock[91] (1936–1937) found one glioblastoma of the spinal cord in 8172 postmortem examinations (0.01 per cent, or 1.3 per cent of 74 intracranial gliomas).

Courville,[55] according to Poser[217] (1956), found three intramedullary tumors in a series of 30,000 necropsies.

There is no doubt that a necropsy series, although it provides valuable information, cannot be regarded as completely representative of

the incidence of any type of disease, since it is a well-known fact that the number of times permission for necropsy is granted is dependent chiefly on the special interests which certain conditions evoke.

A second way of obtaining some insight into the incidence of intramedullary tumors of the spinal cord is to compare the number of tumors of the brain with the number of tumors of the spinal cord seen by neurosurgeons.

Eiselsberg and Ranzi[77] (1913) described two intramedullary tumors of the spinal cord, as well as 183 tumors of the brain (this includes also nongliomatous tumors). Elvidge, Penfield, and Cone[84] (1937) found 20 gliomas of the spinal cord in a series of 210 gliomas of the central nervous system. Gagel[100] (1938), in a paper describing 237 gliomas of a group of 560 tumors of the central nervous system, mentioned that 11 gliomas were located in the medulla spinalis. Wolf (1941), in Elsberg's[80] *Surgical Diseases of the Spinal Cord, Membranes and Nerve Roots* (1941), reported the finding of 22 intramedullary gliomas as compared to 704 gliomas of the brain. These tumors were among 253 primary and secondary intraspinal neoplasms found at 4426 necropsies and among 2717 surgical specimens. Broager[31] (1953), in his study of neurilemmomas, reported that in a 17-year period 2548 intracranial (no further details were given) and 271 intraspinal tumors were found. Among the latter were 43 intramedullary gliomas (and 44 spinal neurilemmomas and 86 spinal meningiomas).

Table 1 indicates that there is a remarkable degree of difference between the frequency of occurrence of tumors of the brain and that of intramedullary tumors of the spinal cord. The figures of Eiselsberg-Ranzi[77] and of Broager[31] are comparable, since they deal with the total group of tumors of the brain. It is evident from these studies—and the view is acceptable—that there are one to two intramedullary tumors of the spinal cord for every 100 intracranial tumors. The difference in percentages in the series of Elvidge-Penfield-Cone[84] (9.5 per cent), of Gagel[100] (4.6 per cent), and of Wolf[304] (3.1 per cent) is remarkable and unexplained. No doubt it will be agreed that surgical series have a limited value, since they are influenced not only by the operability of the lesion, but by the interest of the surgeon in the particular lesion, and by his skill.

A third method of determining the incidence of intramedullary tumors of the spinal cord and one which, by reason of its objectives, is the most nearly ideal, deals with the frequency of occurrence of these lesions in a closed group of population. This was the objective of a study by Kurland[160] (1958). He used the resident population of Rochester, Minnesota, on the reasonable assumption that most people living there are attended during their illnesses by physicians of the Mayo Clinic. In a period of 10 years 50 intracranial neoplasms and 12 intraspinal tumors were recorded in a population of 30,000. During the calendar

year 1954, 22 patients who had received the diagnosis of intracranial or intraspinal neoplasm were alive in this city. The number of these patients and age-adjusted rates pertaining to tumors in each site are shown in Table 2, which is taken from Kurland's paper.

The number of tumors of the spinal cord in the foregoing series is too small to be conclusive, so far as accurate determination of the incidence of intramedullary tumors of the spinal cord is concerned. Primary intraspinal neoplasms diagnosed in the 10-year period were classified as follows: three neurilemmomas, two meningiomas, and two ependymomas. One tumor was diagnosed on clinical and roentgenologic evidence only. There were four metastatic tumors inside the spinal cord. It thus can be expected that between 20 and 25 per cent of all primary spinal tumors are intramedullary in location.

Another and perhaps better approach to the relative incidence of intramedullary tumors of the spinal cord is study of published statistics from some of the larger series (Table 3). The available literature contains many, and some very interesting, incidental reports of cases, but they are not suitable as bases for evaluation of the frequency of occurrence of this type of tumor. Caution must be exercised in evaluating lesions in even the larger series, since the descriptions often are based on different criteria, with the result that, in some, metastatic gliomas and intramedullary vascular tumors are included with extramedullary vascular lesions. However, the difference between the two percentages for intramedullary tumors of the spinal cord shown in this table—10 in the series of Denk[68] and 23.4 in the series of Robineau[235]—is too extreme to be explained solely on this basis. We are unable to offer any explanation for this incongruence.

A few other facts can be found in Table 3. The generally recognized

Table 1. *Incidence, Based on the Literature, of Intramedullary Tumors of the Spinal Cord in Relation to That of Tumors of the Brain*

Reporter	Tumor, Site and Number		
	Brain	Intramedullary, Spinal Cord	Per Cent
Eiselsberg–Ranzi [77] (1913)	183	2	1
Broager [31] (1953)	2548	43 (gliomas)	1.6
Elvidge and associates [84] (1937)	210 (gliomas)	20 (gliomas)	9.5
Gagel [100] (1938)	237 (gliomas)	11 (gliomas)	4.6
Wolf [304] (1941)	704 (gliomas)	22 (gliomas)	3.1

Table 2. Prevalence of, and Age-Adjusted† Rates per 100,000 Population for, Neoplasms Affecting the Central Nervous System, by Site, Population of Rochester, Minnesota, 1954, Taken From Kurland[160] (1958)*

Neoplasm, Type	Patients, No.	Age-Adjusted Rate per 100,000 Population‡	
Primary brain—certain	8	24.7	= 46.0
Primary brain—probable	4	12.4	
Pituitary	3	8.9	
Intracranial metastasis	3	9.7	
Primary spinal cord	4	12.9	
All types	22	68.6	

*Prevalence: the number of patients living at any time during a specified year per unit of population; obtained by accepting all patients who were resident and alive in Rochester, Minnesota, at some time during 1954.

†Rate adjusted for age on the total population of the United States in 1950.

‡Ninety-five per cent confidence limits of the age-adjusted rates were computed.

Note: No patient for whom a diagnosis of intraspinal metastasis had been made was alive during 1954.

predominance of males appears to be present in all the series represented in which this information was given in the original paper. The ratio which evolves from all the series in the table is that 14 males are affected for every 10 females. A surprising observation arises when the several rates of incidence are compared on the basis of the segmental location of the tumors. Thus, the incidence of all tumors in the cervical segment of the spinal column is seen to vary, among the different publications, between 5.7 and 25.5 per cent, and the incidence of intramedullary tumors in that segment is seen to vary between 17.3 and 75.0 per cent. The same marked variation in incidence based on anatomic location is noted in the thoracic (50.0 to 68.6 per cent for all tumors, against 19.1 to 80.0 per cent for intramedullary tumors) and lumbosacral (5.7 to 25.0 per cent for all tumors, against 1.4 to 51.7 per cent for intramedullary

Table 3. Relative Incidence, Based on the Literature, of Intramedullary Tumors of the Spinal Cord in Relation to all Spinal Tumors, With Indications of Sex of Patients and Location of Lesions

Reporter	Total Spinal Tumors	Intramedullary		Sex		Cervical, Per Cent		Cervicodorsal, Per Cent	Thoracic, Per Cent		Dorsolumbar, Per Cent	Lumbosacral, Per Cent	
		No.	Per Cent	M	F	Total Group	Intramedullary		Total Group	Intramedullary		Total Group	Intramedullary
Denk[68](1932)	713	71	10.0	–	–	23.5	32.4	–	59.5	66.2	–	17.0	1.4
Eiselsberg[76](1931)	75	14	18.7	8	6	–	35.7	7.1	–	42.9	14.3	–	–
Jirasek[133](1932)	35	4	11.4	–	–	5.7	–	2.9	68.6	–	17.1	5.7	–
Robineau[235](1932)	64	15	23.4	8	7	15.6	20.0	–	62.5	80.0	3.2	18.7	–
Bunts[37](1935)	36	8	22.2	–	–	11.4	–	–	68.6	–	–	20.0	–
Foerster-Gagel[94](1935)	88	20	22.1	–	–	–	–	–	–	–	–	–	–
Ingebrigtsen-Leegaard[128](1939)	24	4	16.6	4	–	25.0	75.0	–	50.0	25.0	–	25.0	–
Elsberg[80](1941)	275	29	10.5	10	9	23.0	17.3	–	56.1	31.0	–	20.9	51.7
Woods-Pimenta[309](1944) lit.	–	–	–	72	54	–	29.0	9.5	–	51.5	2.5	–	7.5
Woods-Pimenta (1944)	–	–	–	18	17	–	25.7	11.4	–	28.6	11.4	–	22.9
Padberg-Davis[207](1952)	143	25	17.4	15	6	–	47.6	–	–	19.1	–	–	33.3
Henschen[121](1955) lit.	–	–	–	60	36	–	–	–	–	–	–	–	–
Henschen (1955)	–	–	–	–	–	–	34.3	–	–	47.4	–	–	18.3
Broager[31](1953)	271	43	16.0	–	–	18.3*	25.6	–	62.3*	34.9	–	19.4*	–
Ricard-Thiers-Bovet[228](1953)	206	26	12.5	–	–	25.5	–	–	56.0	–	–	18.5	–
Rogers[236](1955)	89	12	13.4	–	–	–	–	–	–	–	–	–	–

*Taken from 170 neurofibromas, meningiomas, and gliomas.

Table 4. *Incidence of Intramedullary Tumors of the Spinal Cord as Might Be Expected on the Basis of the Relative Length of the Segments Compared With the Incidence of Lesions in These Segments, Based on the Literature*

Area	Expected Percentile Incidence of Lesions According to		Literature
	Root Level	Vertebral Level	
Cervical	23	22.5	17.3 to 47.6
Thoracic	58	51.5	19.1 to 80.0
Lumbar	19	26.0	1.4 to 51.7

tumors) segments of the spinal column. What is surprising is the observation that, although in the total group of spinal tumors the lesions predominate in the thoracic segment (at least 50 per cent), this anatomic predominance is not so pronounced in the case of intramedullary tumors of the spinal cord. Surprising also is the high incidence of intramedullary tumors located in the cervical segment of the spinal column. It is again emphasized that care must be used in applying these statistics, especially since it is not certain whether or not tumors of the filum terminale are included in the several series.

According to Ravenel (cited by Elsberg[80]), the length of the cervical portion of the spinal cord is 10 cm.; of the thoracic, 26 cm.; and of the lumbar, 8.5 cm. On the basis of these data, 58 per cent of all tumors of the spinal cord could be expected to arise in the thoracic, 23 per cent in the cervical, and 19 per cent in the lumbar part of the cord. Approximately the same percentages (cervical, 22.5 per cent; thoracic, 51.5 per cent; and lumbar, 26 per cent) might be expected if the tumors were to be situated on the basis of the vertebral level of the spinal column, instead of the levels of the roots.

No definite opinions can be formed from comparison of these data (Table 4), but it is open to speculation whether the incidence of intramedullary tumors of the cervical portion of the spinal cord actually is relatively higher than would be expected.

Several studies have been made of intramedullary tumors among children.

Review of the relative rates of incidence of gliomas in different studies among children (Table 5) and a comparison of these with similar rates among persons of all age groups (Table 3) might provoke speculation whether the relative incidence of gliomas among children is slightly higher than it is among adult persons, but the series are too small to permit conclusions to be drawn in such a respect. According to some authors [Hamby[116] (1944); Pasztor-Paraicz-Szénásy,[211] (1961)], gliomas are

Table 5. Relative Incidence, Based on the Literature, of Intramedullary Tumors of the Spinal Cord Among Children

Reporter	Total Group	Total Children	Intramedullary Gliomas	
			No.	Per Cent
Stookey [273] (1928)	165	8	3	37.5
Ingraham [129] (1938)	–	15	1	6.6
Hamby [116] (1944)	–	214	44	17.1
Buchanan [34] (1950)	–	6	2	33.3
Anderson-Carson [5] (1953)	–	22	9	40.9
Grant-Austin [108] (1956)	409	30	6	20.0
Ford [95] (1960)	–	23	5	21.7
Rand and Rand [222] (1960)	–	64	20	31.2

the lesions which occur most frequently among intraspinal tumors in childhood. This view, however, is not generally accepted [Ingraham-Matson[131] (1954); Krayenbuhl-Lüthy[158] (1947)].

ANALYSIS OF MATERIAL

In the appendix of this volume we are presenting the details of 301 cases of intramedullary tumors of the spinal cord, and in the text proper we present reports of 42 cases from among these 301 cases.

Slightly less than 10 per cent of all tumors seen at the Mayo Clinic are those which arise in the central nervous system and its coverings. Details are available concerning 8784 verified neoplasms in this category. About 85 per cent of these were located in the cranial cavity. They have been classified according to the histologic types shown in Table 6. Of this total group, 1322 tumors, or 15.1 per cent of all the central nervous system tumors, were located in the spinal canal. Histologically, these tumors have been separated into seven groups (Table 7). The largest group of these consists of neurilemmomas (383 cases, or 29.0 per cent),

Table 6. *Primary Tumors of the Central Nervous System Encountered at Mayo Clinic*

Gliomas		
Astrocytomas (grades 1 to 4)		2725
Ependymomas		283
Oligodendrogliomas		335
Medulloblastomas		184
Gliomas, type (?)		113
Neurilemmomas (intracranial)		617
Tumors of mesenchymal tissue		
Blood vessels		363
Sarcomas		241
Lipomas		7
Meningiomas		1493
Tumors of developmental defects		
Dermoid, epidermoid		94
Craniopharyngioma		196
Tumors of the pineal body		55
Tumors of the pituitary body		756
Tumors in the spinal canal (For specifications see Table 7)		1322
	Total	8784

with a somewhat smaller number of meningiomas, and together they constitute more than half (721) of the 1322 intraspinal tumors.

The neurilemmomas were attached to the nerve roots, either intradurally or extradurally. Nearly two-thirds (62 per cent) were located intradurally, and this high percentage is partially explained by the fact that the dural attachment of the nerve root extends nearly to the dorsal root ganglion. Of the remaining, 6.2 per cent were both intradural and extradural, and 31.8 per cent were entirely extradural. Many of these latter were of a dumbbell shape, with the smaller portion within the spinal canal and the larger portion frequently being found in the thoracic cavity or, occasionally, in the retroperitoneal area or the abdominal cavity or, rarely, subcutaneously. The average age of the pa-