J Neurosurg 84:726–732, 1996

Value of postoperative surveillance imaging in the management of children with some common brain tumors

PAUL STEINBOK, M.B.B.S., F.R.C.S.(C), STEPHEN HENTSCHEL, B.SC., D. DOUGLAS COCHRANE, M.D., F.R.C.S.(C), AND JOHN R. W. KESTLE, M.D., M.SC., F.R.C.S.(C)

Division of Neurosurgery, Department of Surgery, University of British Columbia, and Division of Neurosurgery, British Columbia's Children's Hospital, Vancouver, British Columbia, Canada; and Centre for Evaluation Sciences, British Columbia Research Institute for Child and Family Health, Vancouver, British Columbia, Canada

The rationale for obtaining surveillance computerized tomography (CT) scans or magnetic resonance (MR) images in pediatric patients with brain tumors is that early detection of recurrence may result in timely treatment and better outcome. The purpose of this study was to investigate the value of surveillance cranial images in a variety of common pediatric brain tumors managed at a tertiary care pediatric hospital.

A retrospective chart review was performed of children with astrocytoma of the cerebral hemisphere, cerebellum, optic chiasm/hypothalamus, or thalamus; cerebellar or supratentorial high-grade glioma; supratentorial ganglioglioma; posterior fossa or supratentorial primitive neuroectodermal tumor (PNET); and posterior fossa ependymoma. Data were analyzed to determine the frequency with which recurrences were identified on a surveillance image and how the type of image at which recurrence was identified related to outcome.

In 159 children, 17 of 44 recurrences were diagnosed by surveillance imaging. The percentage of recurrences identified by surveillance imaging was 64% for ependymoma, 50% for supratentorial PNET, 43% for optic/hypothalamic astrocytoma, and less than 30% for other tumors. The rate of diagnosis of recurrence per surveillance image varied from 0% to 11.8% for different tumor types. Only for ependymomas did there appear to be an improved outcome when recurrence was identified prior to symptoms.

Our results indicate that, using the protocols outlined in this study, surveillance imaging was not valuable in identifying recurrence of cerebellar astrocytoma or supratentorial ganglioglioma during the study period, but was probably worthwhile in identifying recurrence of posterior fossa ependymoma and optic/hypothalamic astrocytoma and, possibly, medulloblastoma. Surveillance protocols could be made more effective by individualizing them for each type of tumor, based on current data on the patterns of recurrence.

KEY WORDS • **brain neoplasm** • **computerized tomography scanning** • **magnetic resonance imaging** • **surveillance** • **children**

A STANDARD part of the management of pediatric brain tumors includes serial follow-up computerized tomography (CT) and/or magnetic resonance (MR) imaging of the brain. The purpose of using these imaging techniques is 1) to document the response to treatment; 2) to provide a baseline against which to judge future imaging, so that diagnosis of recurrence or complications of treatment can be facilitated; 3) to look for evidence of recurrence when new symptoms or signs are present; and 4) for surveillance to detect asymptomatic tumor recurrence. Scheduling protocols for follow-up imaging, particularly those performed for surveillance (surveillance images), have been proposed; these protocols have been based loosely on the biological characteristics of the different varieties of pediatric brain tumors, taking into account the rate of tumor growth and the patterns of local and metastatic recurrence.[2,3]

The rationale for using surveillance imaging is that it may identify tumor recurrence before symptoms are present and that such early detection may translate into a better outcome for the patient. Whether surveillance images, obtained according to existing protocols, do diagnose asymptomatic recurrences and improve outcome in practice has been studied only for the medulloblastoma/primitive neuroectodermal tumor (PNET), and the results have been inconclusive.[1,4] The potential benefits of such images have to be balanced against their cost; the risk to the child, who may require sedation; and the negative psychological impact that may be experienced in some families, created by the anxiety associated with an upcoming imaging session. In addition, if early identification of recurrence by surveillance imaging does not improve outcome, such early identification may simply prolong the period of suffering for the patient and family.

The purpose of the current study was to determine, for a variety of common types of pediatric brain tumors managed at a tertiary care pediatric hospital, the frequency with which recurrences were identified by surveillance imaging, and whether identification of recurrence by a surveillance image, as opposed to one obtained to investigate symptoms, resulted in an improved outcome.

Clinical Material and Methods

Patient Population

The study was performed at British Columbia's Children's Hospital (BCCH), the only tertiary care pediatric hospital in the province of British Columbia. During the time covered by the study, BCCH was an active member of the Children's Cancer Group (CCG) and participated in a number of CCG protocols for the management of pediatric brain tumors.

The database of the Division of Neurosurgery at BCCH was searched to identify children (under 18 years of age) who had been diagnosed and coded as having a brain tumor and had been followed by the Division of Neurosurgery at BCCH between July 1982 and June 1994. The database included patients who had been treated initially at another hospital, in addition to those treated primarily at BCCH. From this population, patients were selected who met the following criteria: 1) patient had a histologically proven diagnosis of low-grade astrocytoma of the cerebral hemisphere, cerebellum, optic chiasm/hypothalamus, or thalamus; cerebellar or supratentorial high-grade glioma; supratentorial ganglioglioma; posterior fossa or supratentorial PNET; or posterior fossa ependymoma; 2) patient survived more than 1 month after surgery for biopsy or resection of tumor; and 3) patient's clinical records contained adequate information. Patients with tumors primarily involving the brainstem (midbrain, pons, or medulla oblongata) were excluded, as were those with intraventricular giant-cell astrocytomas associated with tuberous sclerosis and with optic gliomas involving the optic nerve anterior to the chiasm.

The records of patients selected were reviewed to obtain information regarding the tumor's histological characteristics, tumor location, extent of resection, adjuvant therapy, clinical status during the follow-up period, date of recurrence, and the dates and results of any contrast-enhanced CT scan or MR image of the head obtained to assess tumor size. Spinal MR images were not reviewed.

The extent of tumor resection was based on the surgeon's operative report and the radiologist's report of the immediate postoperative image.

Definition of Terms

Recurrence was defined as 1) a new area of contrast enhancement on the CT scan or MR image at the site of the original tumor, 2) radiographic evidence of metastatic disease that had not been identified previously, or 3) an increase in the size of the primary tumor on CT scans or MR images. When the increase in tumor size was minimal and equivocal, recurrence was said to have occurred only if the patient also had clinical findings consistent with recurrence. If the patient had no new symptoms, a diagnosis of recurrence was not made until subsequent imaging showed further increase in the tumor size.

Based on the information provided in the clinical records and in the radiologist's reports, CT and MR images were divided into categories. They were termed: 1) "postoperative" if the imaging was done in the early postoperative period to determine the amount of residual tumor after surgical intervention; 2) "surveillance" if the imaging was performed for surveillance in the absence of symptoms suggestive of tumor recurrence; 3) "nonsurveillance," which included "symptomatic" images, if the imaging was performed because of the presence of symptoms that created concern about possible recurrence; and "asymptomatic" if the imaging was done to determine whether there had been a response to a therapeutic intervention, to provide a baseline evaluation following a therapeutic intervention, or to confirm an equivocal finding on a previous scan; and 4) "query" if the reason for the imaging was unclear.

When there was no evidence of residual tumor on the postoperative image, but an additional image was obtained at the completion of postoperative adjuvant therapy (radiotherapy or chemotherapy), the second image was categorized as a "surveillance" image. It was rationalized that because the postoperative image had shown no residual tumor, that image provided an adequate baseline; thus there was no need to obtain another image after adjuvant therapy to determine response to the therapy or to clarify a new baseline because it was impossible for the tumor to become smaller. If the radiologist's report of the "postoperative" image indicated that it was unclear whether contrast enhancement represented residual tumor or enhancement in the resection margin, for the purpose of categorizing future images, the image was considered to show residual tumor. In this instance an additional image scheduled after adjuvant treatment could be categorized as a "nonsurveillance" image designed to search for a therapeutic response or to establish a new baseline.

For each image, it was determined whether the image caused a change in the management of the patient. Such a change in management was said to have occurred if the image altered previous treatment plans with respect to chemotherapy, radiotherapy, or surgery.

An attempt was made to identify all CT and MR images obtained to assess the tumor leading up to the time when tumor recurrence was identified. Images obtained after the diagnosis of tumor recurrence were ignored for the purposes of this study. Images were included in the study if they were performed at BCCH or if a report was available for imaging performed outside of BCCH. For a minority of patients, there may have been some imaging performed elsewhere for which no record of the radiologist's report was available in the clinical charts that were reviewed.

Patterns of Practice

During the period of the study, surveillance images were obtained in all children having brain tumors. Except in cases of patients who were enrolled in a CCG study protocol, there was no standardized protocol establishing when the imaging should be performed. However, all treating physicians were consistent in their approach to the timing of follow-up imaging. For patients with high-grade gliomas, PNETs, and ependymomas, images were usually

TABLE 1

*Presence of residual tumor on postoperative CT or MR image in 159 pediatric patients with brain tumor**

Type of Brain Tumor (no. of cases)	Residual Tumor on Postop Imaging		
	No	Yes	Unclear
supratentorial ganglioglioma (18)	14	3	1
cerebellar astrocytoma (45)	37	4	4
cerebral low-grade astrocytoma (10)	7	2	1
optic/hypothalamic low-grade astrocytoma (11)	0	10	1
thalamic low-grade astrocytoma (5)	1	1	3
cerebellar high-grade glioma (4)	2	1	1
supratentorial high-grade glioma (9)	3	4	2
medulloblastoma/PNET (32)	23	2	7
supratentorial PNET (6)	3	1	2
fourth ventricular ependymoma (19)	13	3	3
totals	103	31	25

* Abbreviations: CT = computerized tomography; MR = magnetic resonance; PNET = primitive neuroectodermal tumor.

obtained at 3 months, 6 months, and 1 year postoperatively, yearly thereafter. For patients with low-grade astrocytomas and gangliogliomas, images were usually obtained at 3 months and 1 year postoperatively, yearly thereafter for 5 years, and then every 3 to 5 years.

Statistical Analysis

The data were entered into a commercially available computer software spreadsheet (Excel; Microsoft Corp., Redmond, WA) and analyzed to determine the number and type of CT scans and MR images that were obtained, the frequency with which surveillance images resulted in a change in management, the frequency with which recurrences were identified on a surveillance image, and how the type of image at which recurrence was identified related to outcome after recurrence.

Results

Population of Brain Tumors Identified

A search of the pediatric neurosurgery database at BCCH identified 327 patients with brain tumors, of which 171 fit the criteria based on histopathological findings and location. Of these, 12 patients were excluded: three who died within 1 month postoperatively (two cases of medulloblastoma and one of cerebral PNET), and nine for whom the records contained inadequate information (three cases of cerebellar astrocytoma, two of medulloblastoma, two of optic chiasm/hypothalamic astrocytoma, one case each of cerebral astrocytoma and cerebral glioblastoma). This left 159 patients in the valid study group, composed of 71 patients with low-grade astrocytoma, the most common of which was a cerebellar astrocytoma (45 cases), 32 patients with medulloblastoma/PNET, six with supratentorial PNET, 19 with posterior fossa ependymoma, 18 with supratentorial ganglioglioma, and 13 patients with high-grade glioma (Table 1).

The duration of the follow-up period after surgical biopsy or resection for the patients who were alive at their last follow-up examination ranged from 2 months to 175 months, with an average of 67 months and a median of 57 months. Deaths occurred from 3 to 100 months after surgery, with an average time of 34 months and a median of 22 months.

Imaging Studies

Early postoperative CT or MR imaging was obtained in all patients to provide an assessment of the amount of residual tumor after surgical intervention. These images were used to determine whether there was a radiographically identifiable residual tumor, information important in categorizing further follow-up images. Because these "postoperative" images did not have the potential to identify a recurrence, they were excluded from further analyses. In 103 of the 159 cases, no residual tumor was seen on the postoperative image; in 31 cases there was definite residual tumor; and in the remaining 25 patients it was not clear whether enhancement in the resection margin repre-

TABLE 2

*Reasons for obtaining follow-up CT and/or MR images in 159 pediatric patients with brain tumor**

Type of Brain Tumor	Total Images	CT Scans	MR Images	Reason for Imaging			
					Nonsurveillance		
				Surveillance	Symptomatic	Asymptomatic	Query
supratentorial ganglioglioma	52	49	3	51	1	0	0
cerebellar astrocytoma	214	194	20	192	14	4	4
cerebral low-grade astrocytoma	49	46	3	36	6	3	4
optic/hypothalamic low-grade astrocytoma	48	43	5	27	7	12	2
thalamic low-grade astrocytoma	22	22	0	19	1	2	0
cerebellar high-grade glioma	38	33	5	28	2	8	0
supratentorial high-grade glioma	37	25	12	17	4	14	2
medulloblastoma/PNET	197	163	34	150	23	14	10
supratentorial PNET	25	25	0	17	5	3	0
fourth ventricular ependymoma	113	89	24	81	12	17	3
totals	795	689	106	618	75	77	25

* Postoperative imaging is not included in this tabulation. Abbreviations: CT = computerized tomography; MR = magnetic resonance; PNET = primitive neuroectodermal tumor.

TABLE 3

Diagnosis of tumor recurrence in 159 pediatric patients with brain tumor

Type of Tumor*	Type of Image From Which Recurrence Was Diagnosed	
	Surveillance (no. of cases)	Symptomatic† (no. of cases)
low-grade tumors (89 cases)	5	10
high-grade tumors (70 cases)	12	17
total	17	27

* Ependymomas are included in the high-grade group.

† All nonsurveillance images at which recurrence was diagnosed were obtained to investigate symptoms.

sented residual tumor (Table 1). For the purpose of categorizing further follow-up images the latter two groups were both considered to have residual tumor, forming a total of 56 patients in whom follow-up imaging could be performed to identify a response to adjuvant treatment and/or provide a new baseline.

Excluding the postoperative images, there were 795 follow-up images (689 CT and 106 MR) in the 159 patients. Of these images, 618 were surveillance, 152 were nonsurveillance, and 25 were obtained for reasons that were not clear. The details of the type of images according to the different categories of brain tumor are tabulated in Table 2.

Identification of Recurrence and Outcome

In the 89 patients with low-grade tumors (that is, ganglioglioma and astrocytoma), there were 15 tumor recurrences, of which 10 were identified on nonsurveillance images obtained to investigate symptoms and five on surveillance images (Table 3). The recurrences in the low-grade tumors were all at the site of the primary tumor, except for one case of a child with a cerebral astrocytoma, who experienced recurrence with symptomatic spinal subarachnoid disease and who was also found to have intraventricular ependymal metastases.

In the 70 cases of high-grade tumors (ependymomas included in this category) there were 29 recurrences, of which 17 were diagnosed on nonsurveillance images obtained to investigate symptoms and 12 on surveillance images (Table 3). Four of seven recurrences in patients with medulloblastoma/PNET were extracranial metastases: two of the symptomatic and one of the asymptomatic recurrences were metastatic spinal disease, and one symptomatic recurrence was an extraspinal bone metastasis. All recurrences of ependymoma were at the site of the primary tumor, except in the case of one patient in whom third ventricular and spinal intradural metastases were identified on a surveillance image. For the other malignant tumors, all recurrences were at the primary intracranial site.

The way in which recurrences were identified, the time from the original tumor operation to recurrence, the outcome after diagnosis of recurrence, and the time from the original tumor operation to death are detailed in Table 4 for each of the tumor categories in the study.

Time From Surgery to Diagnosis of Recurrence, Last Follow-Up Examination, or Death

The relationships between the time from surgical resection or biopsy to the time of diagnosis of recurrence, the time from surgery to the time of death or last follow-up examination if alive, and the type of imaging in which recurrence was identified were examined, based on the information provided in Table 4. For most tumor categories, the small number of recurrences and the pattern of diagnosis of recurrence did not permit a meaningful analysis. In cases of optic/hypothalamic astrocytoma, recurrences tended to be diagnosed earlier after surgery when they were diagnosed by a surveillance image than by one scheduled in response to symptoms. In the case of medulloblastoma and fourth ventricular ependymoma, there was no difference in the time from surgery to diagnosis of recurrence whether the diagnosis was made on the basis of a surveillance or a nonsurveillance symptomatic image.

Changes in Patient Management After Imaging

An alteration in care with respect to chemotherapy, radiotherapy, or surgery occurred in response to findings on 38 of the 795 follow-up images (excluding postoperative images). Of 618 surveillance images, 18 precipitated a change in management; these included 17 in which a recurrence was diagnosed and one in which a suspected recurrence of a cerebral low-grade astrocytoma led to a reoperation at which no recurrence was present. An additional patient was identified as having a recurrence on a surveillance image, but it had been decided previously not to treat that patient should the tumor recur.

Rates of Diagnosis of Recurrences per Surveillance Image

The rates of diagnosis of recurrence per surveillance image varied according to tumor type (Table 5). For low-grade tumors, 27 surveillance images obtained to investigate recurrence of optic hypothalamic astrocytoma diagnosed three recurrences for a rate per image of 11.1%, whereas the rates of diagnosis per image for supratentorial ganglioglioma, cerebellar astrocytoma, cerebral astrocytoma, and thalamic astrocytoma ranged from 0% to 2%. Among the more common high-grade tumors, medulloblastoma had a rate of diagnosis per surveillance image of 1.3% of 150 images, and fourth ventricular ependymoma 8.6% of 81 images.

Discussion

The rationale for posttreatment surveillance imaging of patients with brain tumors is that the identification of asymptomatic recurrences with smaller tumor bulk will result in improved outcome with treatment of the recurrence. Surveillance imaging for pediatric brain tumors has been standard practice, and apparently reasonable surveillance strategies have been developed based on the rate of growth of the primary tumor and the pattern of metastatic disease.[2,3] Whether these strategies result in a significant rate of identification of asymptomatic recurrences or, more importantly, in an improved outcome for the patient has only recently been addressed.[1,4]

TABLE 4

*Diagnosis of tumor recurrence and duration from operation to recurrence, last follow-up examination, or death**

Type of Tumor (no. of cases)	No. of Recurrences	Mos From OR to Recurrence Average (range)	Patients Who Are Alive: No. of Cases	Patients Who Are Alive: Mos Postrecurrence Average (range)	Patients Who Are Alive: Mos Post-OR Average (range)	Patients Who Died: No. of Cases	Patients Who Died: Mos Postrecurrence Average (range)	Patients Who Died: Mos Post-OR Average (range)
supratentorial ganglioglioma (18)								
diagnosed on surveillance image	1	26	1	12	38	0	—	—
diagnosed by image for symptoms	0	—	0	—	—	0	—	—
cerebellar astrocytoma (45)								
diagnosed on surveillance image	1	7	1	63	70	0	—	—
diagnosed by image for symptoms	1	140	1	142	282	0	—	—
cerebral low-grade astrocytoma (10)								
diagnosed on surveillance image	0	—	0	—	—	0	—	—
diagnosed by image for symptoms	4	21 (12–32)	3	35 (10–70)	57 (34–102)	1	1	18
optic/hypothalamic low-grade astrocytoma (11)								
diagnosed on surveillance image	3	6 (2–11)	3	52 (4–96)	58 (6–106)	0	—	—
diagnosed by image for symptoms	4	26 (9–37)	2	22 (5–40)	54 (32–76)	2	30 (14–46)	49 (22–76)
thalamic low-grade astrocytoma (5)								
diagnosed on surveillance image	0	—	0	—	—	0	—	—
diagnosed by image for symptoms	1	2	0	—	—	1	1	3
cerebellar high-grade glioma (4)								
diagnosed on surveillance image	0	—	0	—	—	0	—	—
diagnosed by image for symptoms	2	55 (13–98)	0	—	—	2	4 (2–5)	59 (18–100)
supratentorial high-grade glioma (9)								
diagnosed on surveillance image	1	14	1	15	30	0	—	—
diagnosed by image for symptoms	4	10 (3–16)	0	—	—	4	8 (5–11)	18 (9–28)
medulloblastoma/PNET (32)								
diagnosed on surveillance image	2	12 (5–20)	2	63 (9–118)	75 (28–123)	0	—	—
diagnosed by image for symptoms	5	14 (5–25)	1	84	102	4	2 (0–5)	15 (8–26)
supratentorial PNET (6)								
diagnosed on surveillance image	2	38 (21–55)	1	50	105	1	12	35
diagnosed by image for symptoms	2	6 (5–6)	0	—	—	2	4 (3–6)	10 (8–12)
fourth ventricular ependymoma (19)								
diagnosed on surveillance image	7	33 (4–52)	3	42 (7–62)	74 (51–111)	4	33 (19–70)	66 (45–99)
diagnosed by image for symptoms	4	35 (21–57)	0	—	—	4	20 (5–35)	55 (31–87)

* Abbreviations: OR = initial surgical resection or biopsy for tumor; PNET = primitive neuroectodermal tumor; — = not applicable.

Rates of Identification of Asymptomatic Recurrences

In this series of 159 children with a variety of brain tumors, 17 (39%) of 44 recurrences were diagnosed on the basis of a surveillance image, whereas the majority of recurrences were identified from findings on an image obtained in response to a change in symptoms. The percentage of recurrences that were asymptomatic at diagnosis was not homogeneous among the different categories of tumors. The fourth ventricular ependymoma stood out as the single tumor in which the majority of recurrences (64%) were diagnosed using a surveillance image. In the supratentorial PNET and optic/hypothalamic low-grade astrocytoma, approximately half of the recurrences were picked up on surveillance imaging; in the remainder of the tumors, 23% were diagnosed while the patients were asymptomatic. There have been three previous studies that addressed the frequency with which asymptomatic recurrences of pediatric brain tumors were identified. In 1993, Elterman and Bruce[1] reported that 13 (62%) of 21 recurrences of medulloblastoma were asymptomatic at detection. On the other hand, in the 1994 study by Torres and colleagues[4] four asymptomatic recurrent medulloblastomas (17%) were detected among 23 recurrences; this was similar to our series in which two (29%) of seven recurrent medulloblastomas were asymptomatic at diagnosis. In a study of cerebellar astrocytomas undertaken by Sutton and associates (LN Sutton, personal communication, 1995), 11 asymptomatic recurrences were identified among 17 recurrences in 93 patients.

Relationship Between Identification of Asymptomatic Recurrence and Outcome

There was a suggestion of improved outcome with asymptomatic diagnosis of recurrence in patients with malignant tumors. This was most apparent in the cases of fourth ventricular ependymomas in which all four patients with symptomatic recurrences died, but three of seven with asymptomatic recurrences survived until the most recent follow-up examination. It should be noted, however, that the follow-up period in these cases was relatively short. For the low-grade tumors, a possible outcome advantage was seen only in patients with optic/hypothalamic tumors. Tumor recurrences were rare in patients with the most benign tumors, namely cerebellar astrocytomas (two recurrences in 45 cases) and supratentorial gangliogliomas (one recurrence in 18 cases), and all three patients were alive after treatment of their recurrence. Although two of the recurrences were asymptomatic, the outcome may have been the same if treatment, namely repeat resection, was withheld until the recurrence caused symptoms.

TABLE 5

Diagnosis of asymptomatic tumor recurrence by surveillance imaging in 159 pediatric patients with brain tumor

Type of Tumor	No. of Surveillance Images	No. of Asymptomatic Tumor Recurrences Identified	Rate of Diagnosis* (%)
supratentorial ganglioglioma	51	1	2.0
cerebellar astrocytoma	192	1	0.5
cerebral low-grade astrocytoma	36	0	0.0
optic/hypothalamic low-grade astrocytoma	27	3	11.1
thalamic low-grade astrocytoma	19	0	0.0
cerebellar high-grade glioma	28	0	0.0
supratentorial high-grade glioma	17	1	5.9
medulloblastoma/PNET†	150	2	1.3
supratentorial PNET	17	2	11.8
fourth ventricular ependymoma	81	7	8.6
totals	618	17	2.8

* The rate of diagnosis indicates the percentage of surveillance images that resulted in a diagnosis of recurrence.

† PNET = primitive neuroectodermal tumor.

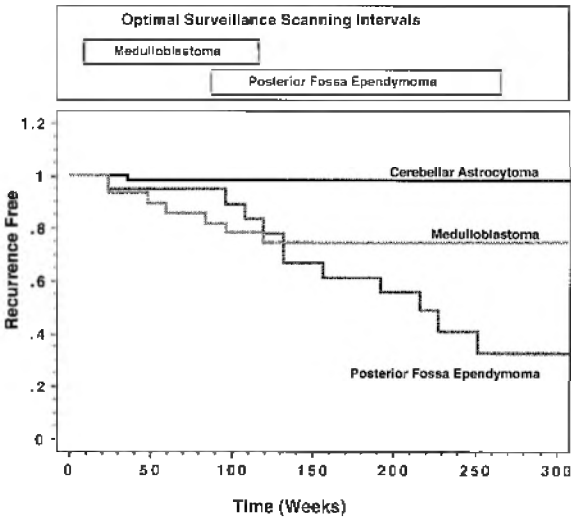

FIG. 1. Graph of Kaplan–Meier plots illustrating the time to recurrence for cerebellar astrocytoma, fourth ventricular ependymoma, and medulloblastoma/primitive neuroectodermal tumor. The postresection time periods during which surveillance images have the highest chance of detecting recurrence are shown for ependymomas and medulloblastomas.

Possible Negative Consequences of Surveillance Imaging

The benefits of diagnosis of asymptomatic recurrences must be weighed against the possible negative consequences of multiple surveillance images that are required. There may be morbidity associated with the sedation of a young child and anxiety to the patient and/or family associated with each imaging appointment, which is a reminder of the potential for recurrence of tumor. Imaging can be costly, and where there is a high demand for services, surveillance imaging may compete for scarce imaging time. In the 159 patients in this series, 618 surveillance images were documented, from these 17 asymptomatic recurrences were diagnosed, for a 2.8% rate of diagnosis of recurrence per image. The rate of diagnosis of recurrence per surveillance image varied according to tumor type, from 0% to 11.8% (Table 5).

Optimizing Surveillance Imaging Regimens

One possible explanation for the low rate of diagnosis of asymptomatic recurrences by surveillance imaging in this and other series may be that the timing of surveillance imaging was not optimal for detecting recurrence. The surveillance regimens that were used during the period of the study were either those specified by a CCG protocol for those children entered into a CCG study, or a nonstandardized, although fairly consistent, protocol based on the perceived malignancy of the tumor. These surveillance regimens may seem reasonable, but like other surveillance recommendations,[2] they are not based on specific data concerning the pattern and time to recurrence, and, as such, the yield per surveillance image may not have been optimal. To optimize the identification of asymptomatic recurrence, one might tailor the timing of surveillance imaging according to the actual patterns of recurrence of the individual tumor. Life table analysis of the time to recurrence for the three most common types of tumor in this study shows a striking difference in the pattern of the time to recurrence between cerebellar astrocytoma, medulloblastoma/PNET, and ependymoma (Fig. 1). A rational scheme for the timing of surveillance imaging could be designed according to tumor-specific patterns of recurrence accounting for the time to recurrence and the subsequent rate of recurrence, as follows: for cerebellar astrocytomas, no surveillance imaging; for medulloblastoma/PNETs, multiple (perhaps every 3 months) surveillance imaging in the first 2 1/2 years and none thereafter; and for fourth ventricular ependymomas, no surveillance imaging until 18 months after resection, followed by multiple imaging (every 4–6 months) for the next 3 1/2 years, and no imaging thereafter.

In addition to the timing of surveillance imaging, we also need to determine whether it is appropriate to investigate only the brain, or whether we should also examine the spine to identify metastatic disease. This should be based on the expected rate of spinal metastasis for any tumor type. In the current study, recurrence as spinal metastatic disease occurred significantly only in medulloblastoma/PNET, and thus we suggest that surveillance might reasonably include spinal MR imaging for medulloblastoma/PNET, but not for the other types of tumors studied.

Conclusions

We conclude that the value of surveillance imaging after treatment of pediatric brain tumors varies according to the type of tumor. Our data indicate that a surveillance imaging protocol such as the one described in this study is not required in cases of supratentorial ganglioglioma or cerebellar astrocytoma during follow-up intervals equivalent to those specified in this study, namely an average of 37 months for ganglioglioma and 82 months for cerebellar astrocytoma. Recurrence is unusual if the tumor has been resected completely, and therefore the rate of diagnosis of an asymptomatic recurrence per surveillance im-

age is very low. It may be argued that if there is residual disease, surveillance imaging may be appropriate because the risk of recurrence is increased (LN Sutton, personal communication, 1995). However, if the tumor recurs, it is probable that a favorable outcome will be achieved with resection of the recurrence, regardless of the tumor size, and thus early detection of recurrences when the patient is asymptomatic may not necessarily improve outcome.

We would recommend that surveillance imaging be performed in children with fourth ventricular ependymomas, because the majority of recurrences were identified on surveillance images, and outcome seemed to be better when the recurrence was identified prior to symptoms. Until further data are available we would also advocate surveillance imaging for patients with optic/hypothalamic astrocytomas because almost half of the recurrences were asymptomatic at diagnosis, and for medulloblastoma because the patients who were asymptomatic at detection of recurrence may have had a more favorable outcome.

Our conclusions about the value of surveillance imaging are based on the regimens for surveillance used in our institution during the period of the study, and on data spanning a 12-year period, during which the majority of images obtained were CT scans. In retrospect, these surveillance imaging regimens were probably not optimal. By individualizing surveillance protocols for each type of brain tumor, based on up-to-date data concerning the patterns of recurrence, it should be possible to increase the cost effectiveness of surveillance imaging, which might lead to different conclusions. It is also possible that MR imaging might detect recurrences earlier, and that as more effective therapies for recurrent disease become available, better outcomes may occur in patients whose recurrences are identified at an early stage. Our conclusions with respect to cerebellar astrocytomas and cerebral ganglioglioma will probably not be affected by such developments; however, for the other tumors it is important that there are ongoing prospective studies of the value of surveillance strategies, with reevaluation as technological and therapeutic advances occur.

References

1. Elterman RD, Bruce DA: The continued surveillance for recurrent medulloblastoma/primitive neuro-ectodermal tumor. **Pediatr Neurosurg 19:**322, 1993 (Abstract)
2. Kramer ED, Vezina LG, Packer RJ, et al: Staging and surveillance of children with central nervous system neoplasms: recommendations of the neurology and tumor imaging committees of the children's cancer group. **Pediatr Neurosurg 20:** 254–263, 1994
3. Kun LE, D'Souza B, Tefft M: The value of surveillance testing in childhood brain tumors. **Cancer 56:**1818–1823, 1985
4. Torres CF, Rebsamen S, Silber JH, et al: Surveillance scanning of children with medulloblastoma. **N Engl J Med 330:** 892–895, 1994

Manuscript received October 4, 1995.
Accepted in final form January 18, 1996.
Stephen Hentschel was supported by a Summer Student Research Award in Medicine from the Medical Research Council of Canada.
Address reprint requests to: Paul Steinbok, M.B.B.S., F.R.C.S.(C), Division of Neurosurgery, Room A325, British Columbia's Children's Hospital, 4480 Oak Street, Vancouver, British Columbia, V6H 3V4 Canada.