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The Utility of MR in Planning the Radiation Therapy of Oligodendroglioma

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Newer methods of radiation therapy for treating oligodendroglioma after surgical resection have produced promising results using high doses of radiation. However, these doses are close to those that cause necrosis of normal brain, making the accurate spatial localization of tissue at risk for containing tumor cells more important. Because MR imaging is superior to CT in detecting some types of intracranial disease, nine patients with oligodendroglioma were studied with both MR and CT. Results were compared with surgical findings. In six cases, MR identified some tumor volume found during surgery that was not detected by CT. In addition, the interface between abnormality (tumor plus edema) and normality was depicted much more clearly by MR than by CT in most cases. Such superior depiction of the margins of abnormality is important for radiation therapy planning because of the known tendency of oligodendroglioma to infiltrate adjacent edema, making all areas of abnormality potential tumor-bearing tissue. Finally, MR showed normal brain tissue in areas considered suspicious by CT, because they were not well seen on CT in several patients. In these cases of low-grade oligodendroglioma, MR was believed to be superior to CT in providing information needed for radiation therapy planning because of its ability to distinguish tumor and adjacent edema (considered tissue at risk for containing microscopic tumor) from contiguous normal brain.

Radiation therapy for oligodendroglioma after surgery may result in improved survival rates compared with surgery alone [1, 2]. However, radiation doses close to those resulting in necrosis of normal brain are required for long-term control of oligodendroglioma [1, 3, 4]. Such high doses require accurate localization of radiation to a volume that contains all bulk tumor as well as tissue potentially infiltrated with tumor and that contains as little normal brain as possible.

Oligodendroglioma is known to have a propensity for microscopically infiltrating adjacent edematous brain tissue [5]. For this reason, all areas identified by an imaging method as abnormal, including edema, are potential tumor-bearing regions. Accurate localization of this potential tumor-bearing tissue for planning radiation therapy for oligodendroglioma is a difficult problem because margins of abnormality (consisting of tumor plus edema) may be poorly demarcated from normal brain on CT studies [6]. Such poor definition of borders on CT introduces uncertainty into the radiation therapy planning process and may result in inclusion of some volume of normal-appearing brain in the treatment fields inadvertently or deliberately to ensure that all tissue at risk is treated.

MR imaging has been shown to be better than CT in detecting some types of intracranial disease [7, 8]. This superior detectability and demarcation of abnormality seemed particularly evident with the lower grades of glioma. For this reason, we studied nine consecutive cases of oligodendroglioma imaged with both CT and MR. Imaging results were correlated with surgical findings, and the utility of information provided by CT for planning the radiation therapy for this tumor was compared with that provided by MR.

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Subjects and Methods

CT was performed on a GE 9800 or a Picker 1200 scanner with and/or without contrast enhancement. Technical factors included 120 kVp, variable mA, head calibration size, 2 sec scan time, and contiguous 10-mm-thick slices. MR studies were performed on a Picker 0.15 T resistive system. Spin-echo sequences weighted for T2 were performed in all studies, and a 60 msec echo time (TE) and 1000, 1500, or 2000 msec repetition time (TR) were used. In addition, T1-weighted spin-echo sequences (TE 40/TR 600) were performed in eight studies. Slice thickness was 10 mm with 2 mm between slices; studies were performed multislice, single echo. Transverse, sagittal, and coronal images were obtained on all patients.

Temporally matched (within 72 hr) pairs of CT and MR studies were reviewed by five of the authors. Potential tumor volume as defined by areas of abnormality (representing tumor plus edema) was determined for each test. Pairs of CT and MR studies were compared for regions of abnormality detected by one method and not the other. The same pairs were also compared for relative definition (clarity) of borders between areas of abnormality and normal-appearing brain (Figs. 1 and 2). Definitions of three sets of borders (the craniocaudal, the anteroposterior, and the right and left lateral) of each region of abnormality were subjectively scored by consensus among the five reviewers: 0 = borders not defined, 1 = borders poorly defined, 2 = borders moderately well defined, 3 = borders well defined. Thus, there were three scores for each region of abnormality on each study. In addition to temporally matched CT and MR studies, CT studies that were not temporally matchable to an MR study were also reviewed and scored. This was done to increase the size of the CT sample and to look for consistency in the scores between matched and unmatched CT studies.

Eight of the patients had subtotal surgical resection of tumor before radiation therapy; one patient had four biopsies in the region of tumor and no resection. Pathologic specimens and slides were reviewed by a neuropathologist. Pathologic diagnosis was low-grade oligodendroglioma in seven cases and predominant low-grade oligodendroglioma with some scattered elements of low-grade astrocytoma in two cases. The patients consisted of six women and three men, ranging in age from 25–52 years.

Confirmation of tumor extent was based first on written surgical reports of tumor location, tumor volume resected, and tumor volume left behind after resection. Second, operative findings were compared with tumor location on CT and MR studies by the operating surgeon in conference with radiologists and radiation therapists within several days of surgery in each case. Regions of discrepancy between the imaging techniques were reviewed by the surgeon in light of findings at surgery, including histologic findings along the margins of excised tumor, results of biopsies of residual suspect regions after as much tumor bulk as possible had been resected, and visual inspection of the operative cavity before closing.

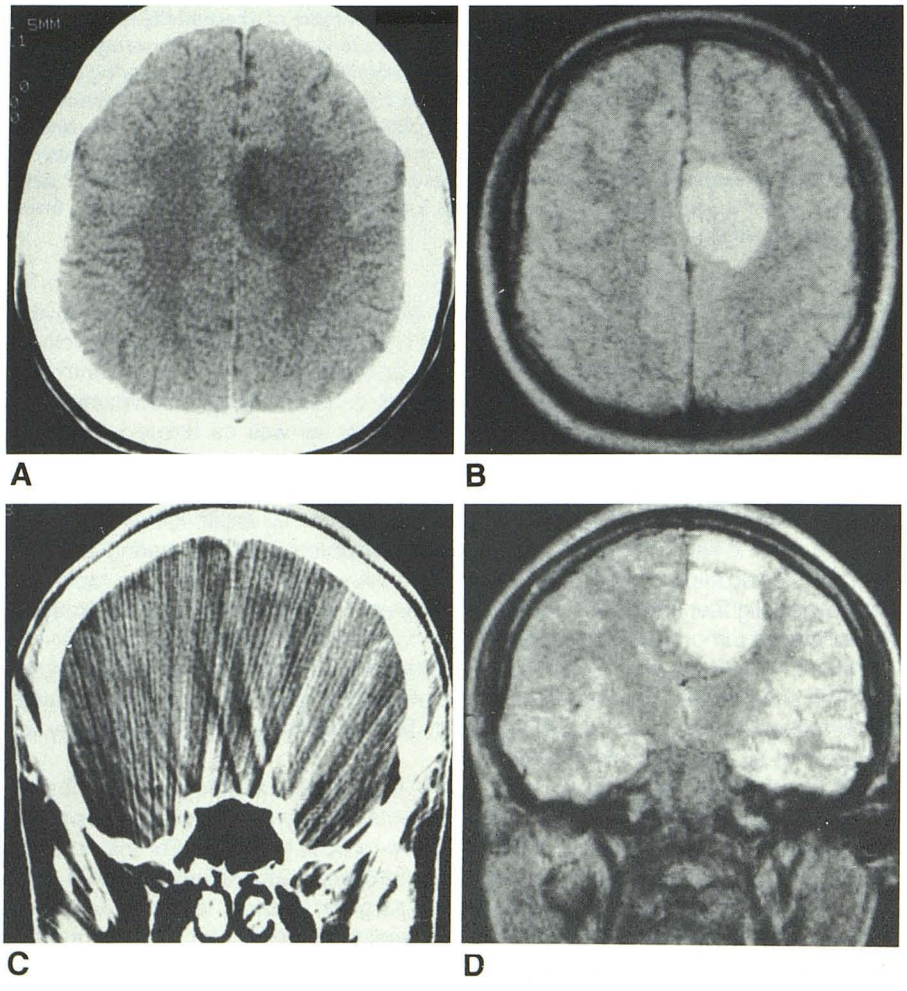

Fig. 1.—*A*, CT of oligodendroglioma. Poor definition of lateral border of lesion.
***B*, MR. Borders are well defined.**
***C*, Coronal CT. Artifact from dental amalgam obscures most information.**
***D*, Coronal MR. Craniocaudad extent of lesion is well defined.**

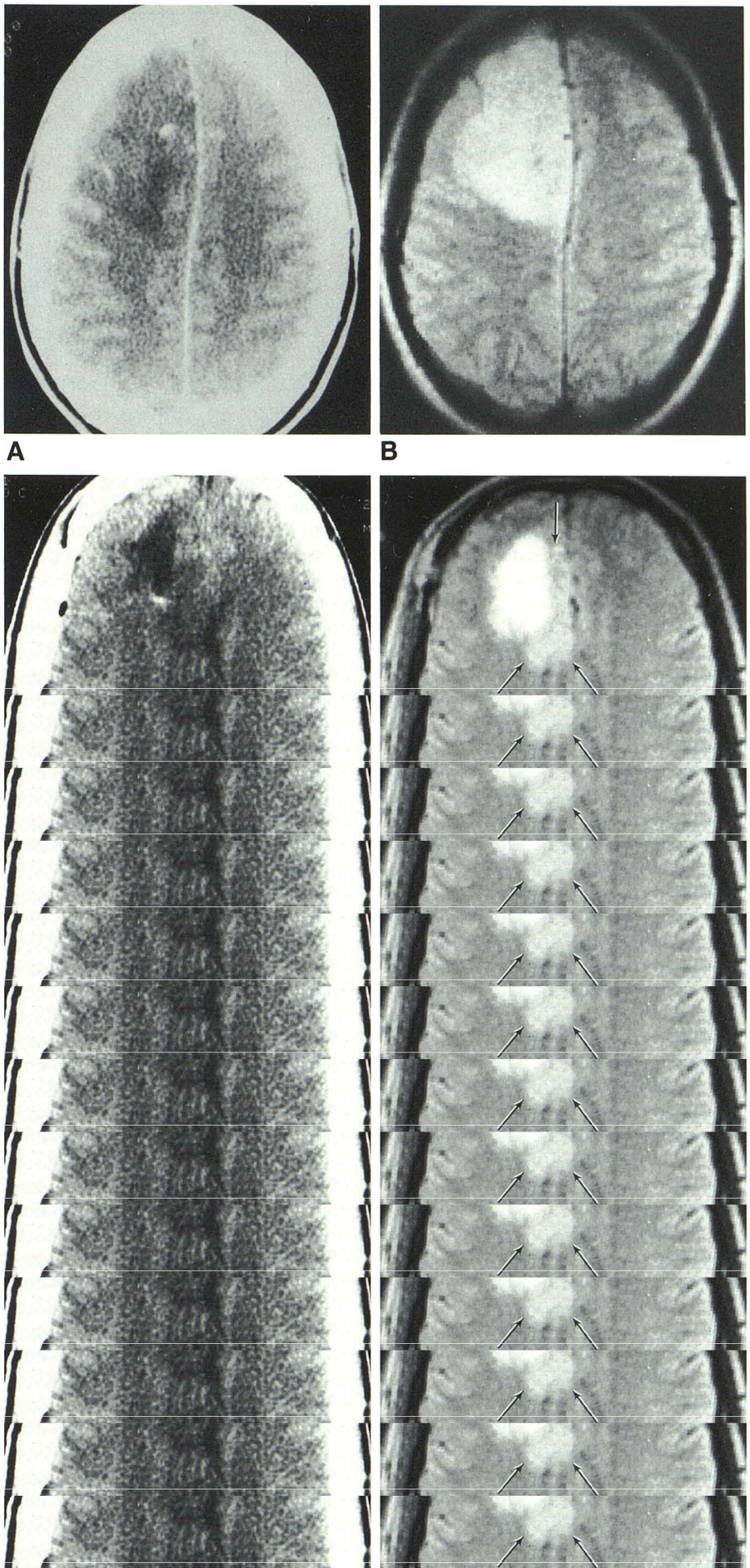

Fig. 2.—*A*, Preoperative CT of oligodendroglioma. Calcification identified but borders poorly defined.

***B*, Preoperative MR. Border definition is better than on CT.**

***C*, Postoperative CT after subtotal resection. Surgical defect seen, but borders of abnormality difficult to identify.**

***D*, Postoperative MR. Operatively confirmed residual tumor identified (*arrows*).**

TABLE 1: **Subjective Scores Assigned to Lesion Borders in Oligodendroglioma**

Score	No. of Lesion Borders by Score			
	CT Studies		MR Studies Matched to CT	Total
	Unmatched	Matched to MR		
0	5	8	0	13
1	33	21	1	55
2	4	2	9	15
3	0	2	23	25
Total	42	33	33	108

Note.—0 = borders not defined; 1 = borders poorly defined; 2 = borders moderately defined; 3 = borders well defined.

temporally matched MR studies, indicating some degree of consistency between these two groups. In general, there were more CT scores than MR scores in the lower two categories, and more MR scores than CT scores in the higher two categories, indicating that border definition between abnormality and normality was generally better with MR than with CT. In particular, significantly more MR studies had scores of 3 (n = 23) than did CT studies (n = 2). When individual lesion-border scores were compared on temporally matched CT and MR studies, CT had better border definition in none, MR had better border definition in 29, and the border definition was equal in four.

In each of the nine patients, MR was the primary method used for planning radiation therapy for one or more of five reasons. First, MR identified some operatively and histologically confirmed volume of tissue containing oligodendroglioma that was not seen by CT in six patients (Figs. 2C and 2D). This tumor volume seen only by MR often was a tongue or knob projecting away from the main tumor mass. It was appreciated on MR because of that technique's superior ability to evaluate the posterior fossa (two cases), the superior soft-tissue contrast of MR (four cases), the better definition provided by MR because of the multiple planes of image display (two cases), or various combinations of these reasons. Second, MR showed clearly superior border definition between abnormality and normal-appearing brain in six patients. Third, MR showed abnormality in two cases that was not seen on CT nor was it histologically confirmed to be tumor, but it was presumed to be tumor on the basis of MR and operative appearance (the tissue in question was not biopsied but was observed by the surgeon). Fourth, MR showed abnormality not surgically confirmed but presumed to be edema at risk for microscopic infiltration from adjacent tumor and not seen on CT in four cases. Fifth, superior border definition on MR allowed exclusion of normal-appearing tissue from the radiation field that otherwise would have been treated because of poor definition on CT in three patients (one in the posterior fossa, two involving tumor adjacent to but not crossing the falx) (Fig. 3).

Radiation therapists changed their therapy plans as a result of this MR information. These changes included making the field larger and shifting the field position in three patients; making the field larger, shifting the field position, and adding additional fields in two patients; making the field smaller and adding additional fields in two patients; and adding additional fields only or shifting the fields only in one patient each.

Discussion

Oligodendroglioma is a relatively rare, usually slow-growing low-grade glioma that has a tendency to infiltrate microscopically adjacent edematous brain [9, 10]. The treatment of choice for oligodendroglioma is radical excision of all tumor [1, 10, 11]. However, complete surgical excision of all tumor cells often is not possible because of microscopic infiltration of tumor into surrounding edematous brain tissue [9].

The role of postoperative radiation therapy for the treatment of residual tumor mass or residual microscopic tumor in edematous brain has been controversial [1, 2, 11]. Reports of series, including some patients treated with a low-dose orthovoltage technique, have shown no improved survival from the addition of postoperative radiation therapy [11]. By contrast, series with patients treated by megavoltage technique to high doses of 5000–6000 rad (50–60 Gy) report improved long-term survival with postoperative radiation [1, 2, 12, 13]. For example, Chin et al. [1] reported a 5-year survival of 100% in 24 patients treated in this fashion.

Newer high-dose treatment techniques require precise localization of tissue at risk for containing tumor cells because therapeutic doses of 5000–6000 rad (50–60 Gy) are close to those that may cause necrosis of normal brain, 5500–6000 rad (55–60 Gy) [2, 4]. The chance of radionecrosis of normal brain is related to the size of the volume of normal brain treated as well as to the dose [4]. This potential morbidity makes it important to exclude as much normal brain as possible from the treatment volume, while the tendency of oligodendroglioma to infiltrate adjacent edema makes it important to treat all areas of detectable abnormality, because these areas are potential tumor-bearing tissue.

If an imaging technique can depict the border between abnormality (tumor plus edema) and normal brain with a well-defined margin, the task of localizing radiation therapy to the abnormal region is easier and may be more precise. Separating tumor from edema is less important to the radiation therapist than separating normal brain from adjacent detectable abnormality (tumor *plus* edema), since potentially all areas of contiguous abnormality around oligodendroglioma are microscopically infiltrated with tumor.

CT has been shown to be quite sensitive to the presence of oligodendroglioma [6]. However, because of the characteristic low-grade histology of oligodendroglioma, CT often does poorly in defining the interface between tumor-associated abnormality and normal brain structures [14, 15]. MR is known to have soft-tissue contrast superior to that of CT in cerebral tissues [16]. MR's superior detection capability over CT has been demonstrated previously with the plaques of multiple sclerosis [7, 8, 17] as well as with other types of disease. The multiplanar display format of MR can also be helpful in displaying clearly all margins of abnormality, which may result in an improved understanding of the relationships

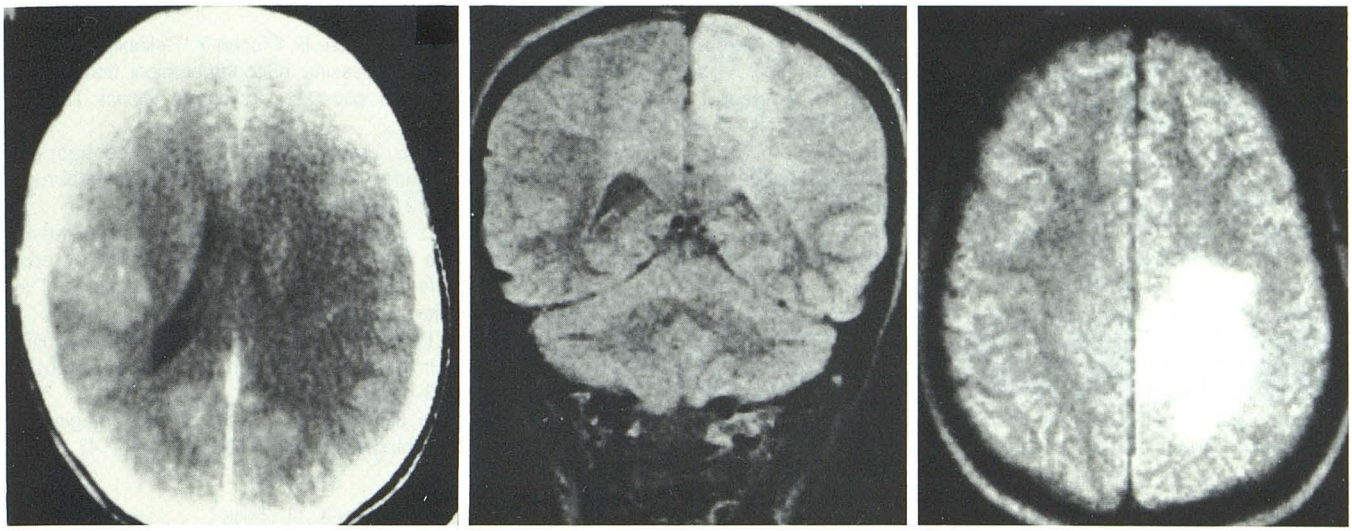

Fig. 3.—*A*, CT shows poorly defined area of low attenuation. Whether tumor crosses midline is uncertain. *B*, MR clearly shows tumor does not cross midline (confirmed at surgery). *C*, Axial MR.

between tumor and surrounding normal tissue [18]. In particular, we noted that margins of abnormality associated with tumors of low-grade histology were defined much better with MR than with CT, especially oligodendroglioma. The discrepancy between imaging techniques may not be as great for higher-grade gliomas, but that remains to be documented. While MR studies provided superior border definition in many cases, no MR findings were considered specific for oligodendroglioma. The amount of associated edema was not unique for low-grade tumor nor were the intensity differences with surrounding brain. In the future, the use of contrast material such as gadolinium may improve the specificity of MR for tumor grade.

In all nine cases in our report, both CT and MR detected regions of abnormality. However, MR subjectively provided better border definition between abnormality and normal-appearing brain tissue. When compared with surgical results, MR found some tumor volume not detected by CT in six of nine cases. In addition, MR found edema at risk for tumor infiltration that was missed by CT in four cases, and it showed normal-appearing brain tissue that was not well defined by CT and thus considered suspicious on the basis of CT findings alone. For various combinations of these reasons, MR was the primary technique used for identifying potential tumor-bearing tissue and separating it from normal brain for therapy-planning purposes in all of these cases. MR studies resulted in changes in therapy portal size, location, and number of fields. MR information was believed to be particularly helpful in designing the smaller therapy portals for the final boost dose.

This report does not attempt to assess improvement in response or cure rates for oligodendroglioma resulting from the use of MR. It does attempt to compare the value of information available from MR with that available from CT for purposes of planning radiation therapy and for verifying as much as possible the validity of that information on the basis of surgical findings in these low-grade tumors. It should be cautioned that gliomas of histologically higher grades may produce different results. However, our limited series suggests that, in cases of low-grade oligodendroglioma, MR may provide more useful information than CT and may become a necessary procedure for planning the postoperative radiation therapy of this tumor.

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