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Glycolytic Rate (PET) and Contrast Enhancement (CT) in Human Cerebral Gliomas

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A comparison of the glycolytic rate as determined by positron emission tomography (PET) with ^{18}F-deoxyglucose (FDG) and cerebral contrast computed tomography (CT) was carried out in 72 cases of cerebral glioma. FDG–PET is more accurate than contrast CT in predicting tumor grade.

It is well known that a positive correlation exists between the degree of malignancy and glycolysis in a variety of tumors [1, 2], including cerebral gliomas [3, 4]. Positron emission tomography (PET) scanning with ^{18}F-deoxyglucose (FDG) is a technique that permits measurement of regional cerebral glucose metabolism. In an ongoing study we have used this method to evaluate a large number of patients with suspected or proven cerebral gliomas. Our main goal has been that of tissue characterization or grading of the primary cerebral tumors. We have found a statistically significant positive correlation between glycolysis and tumor grade. In addition we have made an attempt to compare the PET scans with the computed tomographic (CT) findings to determine whether additional information could be derived from PET that might be used in the clinical management of these patients [5]. In the present report we emphasize a comparison of the tumoral glycolytic rate as studied by FDG–PET with the contrast medium enhancement observed by computed tomography. Enhancement is considered a diagnostic criterion having a positive correlation with the tumor grade [6, 7].

Materials and Methods

Our series consisted of 72 patients with suspected or proven cerebral gliomas. A number of cases were studied with FDG-PET more than once. When multiple studies were available the one closest in time to the verification or the most recent was selected for the purpose of this review. PET scans were obtained with either the ECAT II [8] or the Neuro-PET scanner [9]. Six to nine tomographic sections were obtained 40–120 min after intravenous administration of FDG. Detailed methodology of the technique including our own modifications is reported elsewhere [5].

Lesions showing increased isotope concentration on the PET images by comparison with a corresponding region of the contralateral hemisphere were characterized as hypermetabolic. Conversely, if the isotope concentration in the lesion was low, this was characterized as hypometabolic. The increased or decreased metabolic activity of the lesion was confirmed and quantitatively evaluated by calculating the rate of glucose utilization of the tumor as compared with that of an identical region in the contralateral hemisphere. The rate of glucose utilization was expressed in the number of milligrams consumed by 100 g of tissue/min.

Each of these patients had received at least one CT examination at the time of the PET scan. In our review of the CT scans various findings were noted including the density of the mass prior to the injection of contrast medium, the presence of calcification, and the occurrence of contrast enhancement.

Surgery was performed in most of our patients and the diagnosis was established histologically in 51 cases. In the remaining 21 the diagnosis was made using multiple clinical and CT criteria.

Results

Five groups of patients were distinguished. In each patient in group 1 (25 cases), CT showed an enhancing mass, often with an area of central necrosis. The enhancing part of the mass was isodense with respect to the normal brain parenchyma on the preinfusion scan. In two cases small calcific deposits were present in the tumor region. On PET scan each of the masses was shown to be hypermetabolic. All the lesions in this group were verified as high-grade gliomas (grade III or IV).

Findings for the patients in groups 2–5 are summarized in table 1. In each patient in group 2 (28 cases) there was a hypodense mass on CT that failed to show enhancement after intravenous administration of contrast medium. In 11 of these cases the mass was partially calcified. On the PET scan these tumors were shown to be hypometabolic and considered to be low-grade gliomas. This diagnosis was confirmed by biopsy in eight cases. In the other 20 patients, who are neurologically stable and who have shown no change in the size of the tumor over a period ranging from several months to eight years, the grade diagnosis was reached on the basis of clinical and neuroradiologic criteria.

In group 3 there were seven cases. In three the mass did not enhance on CT, which suggested a low-grade tumor. However, the PET scan in these cases showed that the tumor was hypermetabolic. This finding is strongly indicative of a high-grade glioma, and subsequent surgery confirmed this diagnosis. In the other four cases the tumor enhanced on CT but it was hypometabolic on PET. One of these was proven to be grade II glioma and the other three

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TABLE 1: **Summary of Findings in Cerebral Glioma Groups 2–5**

Group No.: Case No.	CT Attenuation ↓ ↑ =	CT Enhancement (+) (−)	PET–FDG ↓ ↑	Mode of Diagnosis	Histologic Grade
2:					
1	↓	−	↓	Biopsy	I
2	↓ (Ca++)	−	↓	Clinical	I or II
3	↓	−	↓	Clinical	I or II
4	↑ (Ca++)	−	↓	Clinical	I or II
5	↓	−	↓	Clinical	I or II
6	↓ (Ca++)	−	↓	Biopsy	II
7	↓	−	↓	Clinical	I or II
8	↓ (Ca++)	−	↓	Biopsy	I
9	↑ (Ca++)	−	↓	Clinical	I or II
10	↓ (Ca++)	−	↓	Clinical	I or II
11	↓ (Ca++)	−	↓	Clinical	I or II
12	↓	−	↓	Clinical	I or II
13	↓	−	↓	Clinical	I or II
14	↓	−	↓	Biopsy	II
15	↓	−	↓	Clinical	I or II
16	↓	−	↓	Biopsy	II
17	↓	−	↓	Clinical	I or II
18	↓	−	↓	Biopsy	II
19	↓	−	↓	Clinical	I or II
20	↓ (Ca++)	−	↓	Biopsy	I
21	↓	−	↓	Biopsy	II
22	↓	−	↓	Clinical	I or II
23	↑ (Ca++)	−	↓	Clinical	I or II
24	↓ (Ca++)	−	↓	Clinical	I or II
25	↓	−	↓	Clinical	I or II
26	↓	−	↓	Clinical	I or II
27	=	−	↓	Clinical	I or II
28	↓ (Ca++)	−	↓	Clinical	I or II
3:					
1	↓	−	↑	Biopsy	III
2	↓ (Ca++)	−	↑	Biopsy	III
3	=	−	↑	Biopsy	IV
4	=	+	↓	Biopsy	II
5	=	+	↓	Biopsy	Radiation necrosis
6	=	+	↓	Biopsy	Radiation necrosis
7	=	+	↓	Clinical	Radiation necrosis
4:					
1*	=	+	↓	Biopsy	III
2*	=	+	↓	Biopsy	III
3*	=	+	↓	Biopsy	IV
4*	=	+	↓	Biopsy	IV
5	=	+	↓	Biopsy	III
6	= (Ca++)	+	↓	Biopsy	III
7	↓	−	↑	Biopsy	II
5:					
1	=	+	↑	Biopsy	II
2	=	+	↑	Biopsy	II
3	=	+	↑	Biopsy	II
4	↓	−	↓	Biopsy	IV
5	↓	−	↓	Biopsy	III

Note.—↓ = diminished; ↑ = increased; = equals unaltered. (CA++) = calcification present.
* These cases had thin rim of tumor tissue and FDG values were artificially lowered by 1.7 cm scanner resolution.

were found to be postradiation necrosis. Thus PET was more accurate than CT in the characterization of all seven cases in this group.

Group 4 consisted of seven cases. In six of these the tumor demonstrated enhancement on the CT scan. These lesions were hypometabolic on PET, suggesting a low-grade glioma. Subsequent biopsy, however, revealed the tumor to be high-grade glioma. In the fourth case of this group the tumor was hypodense in both the pre- and postinfusion CT scan, and it was judged to be hypermetabolic on the PET scan. This lesion was a biopsy-proven grade II glioma. Thus, in the seven cases of this group, CT correlated better than PET with the histologic findings.

Group 5 consisted of five cases. In these patients neither CT nor PET findings agreed with the histologic diagnosis.

Discussion

The positive correlation between tumor grade and rate of glycolysis is reconfirmed in the present study. Although both CT and PET

were shown to be useful methods to predict the histologic grade of the tumor, PET was superior to CT in 10% of the cases studied. The failure of PET to identify the tumor grade correctly in seven case may be more apparent than real, for in most of these cases the tumor consisted of a thin rim of hypermetabolic (hot), that is, viable tissue surrounding a large hypometabolic (cold) necrotic center. In most cases, edema was also present at the periphery of the rim. Thus, because of partial volume effect, there was gross underestimation of the real metabolic rate in these lesions. Finally, the failure of both CT and PET to correlate well with the histology in group 5 may be related to the fact that the histologic examination could not be relied upon, since it was obtained long before these scans were performed.

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