Thallium-201 SPECT for Predicting Histological Types of Meningiomas

Seishi Jinnouchi, Hiroaki Hoshi, Takashi Ohnishi, Shigemi Futami, Shigeki Nagamachi, Katsushi Watanabe, Takashi Ueda and Shinichro Wakisaka

Department of Radiology and Neurosurgery, Miyazaki Medical College, Miyazaki, Japan

Early and delayed ^{201}Tl SPECT studies were performed on 13 patients with intracranial meningiomas, which were classified in three groups according to their histological types: meningothelial (n = 7); transitional and fibroblastic (n = 3); and malignant types (n = 3). The early uptake indices (UI, ratios of average counts/pixel in the lesion to those of the contralateral area on early images) were relatively high in all types: meningothelial meningiomas, 5.75 ± 2.16 (mean ± s.d.); transitional and fibroblastic meningiomas, 4.69 ± 0.54; and malignant meningiomas, 7.10 ± 3.72. There were no statistical differences in relation to histological type. The delayed uptake indices were 2.65 ± 0.89, 3.37 ± 1.02, and 5.16 ± 1.62, respectively. Statistically, the delayed UI of meningothelial meningiomas were lower than those of malignant types ($p < 0.05$). The retention indices (RI, ratios of delayed to early UI) were 0.48 ± 0.08, 0.79 ± 0.16, and 0.84 ± 0.16, respectively. The RI of the meningothelial type were also statistically lower than those of the other two groups ($p < 0.05$). There were no statistically significant differences between transitional plus fibroblastic types and malignant meningiomas. We conclude that ^{201}Tl exhibits early high accumulations in all types of meningiomas, but its retention rates probably differ according to histological types, and a high retention index is predictive of the malignant potential in a meningioma.

J Nucl Med 1993; 34:2091–2094

Thallium-201 is known to accumulate in a variety of tumors. The utility of ^{201}Tl in intracranial lesions lies in its capacity to distinguish residual or recurrent viable tumor from post-therapy changes such as radiation necrosis (*1–3*). Kim et al. (*4*) differentiated low-grade from high-grade gliomas using an index for comparing tumor uptakes normalized to the homologous contralateral hemisphere on SPECT images. Relatively high ^{201}Tl uptakes, however, do occur, not only in biologically malignant tumors, but in hypervascular tumors, such as meningiomas (*5,6*). Actual uptakes in brain tumors are related to combinations of factors, including regional blood flow, blood-brain barrier (BBB) permeability and cellular uptake (*7,8*). In meningiomas, any large accumulations of ^{201}Tl are thought mainly to be related to their rapid blood flow, but any correlations with factors such as histological differences have not yet been established. We therefore evaluated differences in thallium uptake and retention among different histological types of meningiomas by using data from a previous study (*6*), which revealed that high accumulation and long lasting retention of thallium in serial ^{201}Tl SPECT are indicative of a malignant brain tumor. In this study, we evaluated ^{201}Tl SPECT for its potential in predicting histological types of meningiomas.

MATERIALS AND METHODS

Patients

From March 1990 to November 1991, ^{201}Tl SPECT studies were performed on 13 patients with intracranial meningiomas. There were 5 males and 8 females (age range 41 to 77 yr, with a mean age of 62 yr) who were classified in three groups according to their histological types as meningothelial (n = 7), transitional and fibroblastic (n = 3) and malignant meningiomas (n = 3). Tumors ranged from 3 to 9 cm in maximum diameter on the MR images. Histological diagnoses were confirmed surgically and were histologically classified according to WHO methodology.

SPECT Imaging

Each patient received 148 MBq ^{201}Tl-chloride intravenously. Early and delayed SPECT images were initiated 15 min and 4 hr, respectively, after completion of the injections, using a circular detector array emission computed tomography system (Shimadzu SET-031, Kyoto, Japan). Data were acquired for 20 min in a minicomputer system ECLIPSE S-120 (Japan Data General, Tokyo, Japan) and were reconstructed in 12 transverse images using a 64 × 64 matrix (actual field 20 cm) with a Ramachandran-Butterworth filtered backprojection method. Corrections for attenuation and uniformity were made using the Sorenson method, a precorrection method that uses data obtained in a cylindrical pool phantom study (*9*). A high-resolution collimator was used with a slice thickness of 8 mm and a FWHM at the center of the field of 12.4 mm. The number of counts approximated 600,000.

Data Analysis

A round region of interest (ROI) 2.5 cm (5 matrix) in diameter was placed over the lesion on the slice showing the greatest activity in each early and delayed SPECT without any information about the histology of the lesion. An equal sized ROI (a symmetrical one if possible) was placed on the region presumed to be normal in the contralateral cerebral hemisphere. If a lesion was in the midline, an equal sized ROI was placed on the normal brain

Received Mar. 29, 1993; revision accepted Aug. 5, 1993.

For correspondence and reprints contact: Seishi Jinnouchi, MD, Department of Radiology, Miyazaki Medical College, 5200, Kihara, Kiyotake-cho, Miyazaki 889-16, Japan.

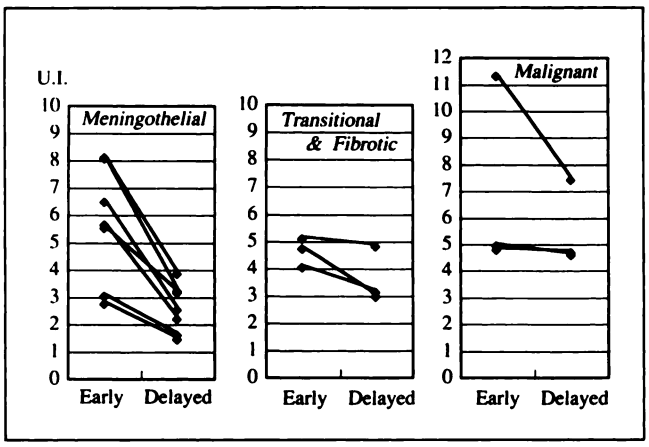

FIGURE 1. Early and delayed thallium uptake indices of all patients.

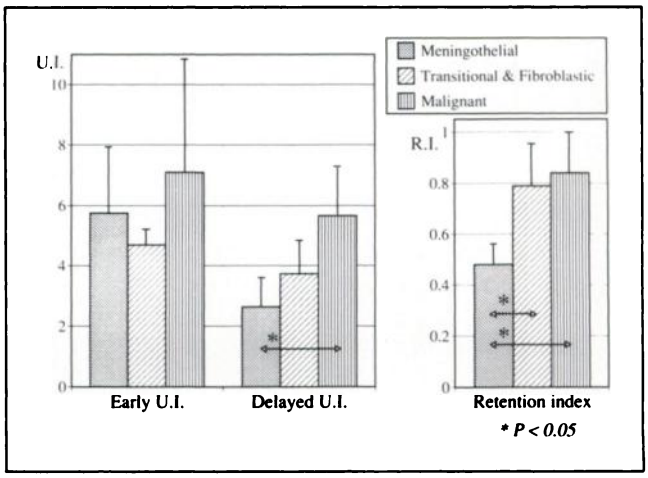

FIGURE 2. Mean uptake indices and retention indices of the three histological groups. Short bars above columns are standard deviations.

tissue near the lesion. Three parameters were calculated as follows:

1. Uptake index on early images (early UI) = the average counts/pixel of the lesion over the average counts/pixel of the contralateral area.
2. Uptake index on delayed images (delayed UI).
3. Retention index (RI) = delayed UI over early UI.

One-way analysis of variance and unpaired Student's t-test statistical methods were used. A p value < 0.05 was considered statistically significant.

RESULTS

For statistical analysis, an F-test with the data corrected for multiple comparisons was used. The early UI were relatively high in all types of meningiomas and the delayed UI of meningothelial types were relatively low (Fig. 1). The early UI (mean ± s.d.) were as follows: 5.75 ± 2.16 (meningothelial meningiomas, n = 7), 4.69 ± 0.54 (transitional and fibroblastic meningiomas, n = 3) and 7.10 ± 3.72 (malignant meningiomas, n = 3). There were no statistical differences in relation to histological type. The delayed UI were 2.65 ± 0.89, 3.37 ± 1.02 and 5.16 ± 1.62, respectively. The delayed UI of meningothelial meningiomas were lower statistically than those for malignant meningiomas. The retention indices were 0.48 ± 0.08, 0.79 ± 0.16 and 0.84 ± 0.16, respectively. The RI for meningothelial types were also statistically lower than those of the other two groups. There were no statistical differences between transitional plus fibroblastic types and malignant meningiomas (Fig. 2). Statistical analyses were made with an F-test and a post-hoc Bonferroni test of pairwise multiple comparisons, for which Bonferroni adjustments were made.

Case Examples

Case 1. Meningothelial meningioma (Fig. 3). A 52-yr-old woman presented with left hemiparesis. A Gd-DTPA T1-weighted MR image showed a 3.5-cm tumor in the right parietal region. A ^{201}Tl SPECT early image showed high uptake in the tumor, but a delayed image showed early washout. The early UI, the delayed UI and the RI were 5.74, 2.27 and 0.40, respectively.

Case 2. Transitional meningioma (Fig. 4). A 64-yr-old woman presented with bitemporal hemianopsia. A T1-weighted MR image with Gd-DTPA showed a 4-cm maximum diameter tumor in the suprasellar region. The ^{201}Tl SPECT early image showed high uptake in the tumor; the delayed image showed relative retention. The early, delayed UI and the RI were 4.10, 3.21 and 0.64, respectively.

Case 3. Malignant meningioma (Fig. 5). A 73-yr-old man presented with right hemiparesis. A Gd-DTPA T1-weighted MR image showed a 9-cm maximum diameter

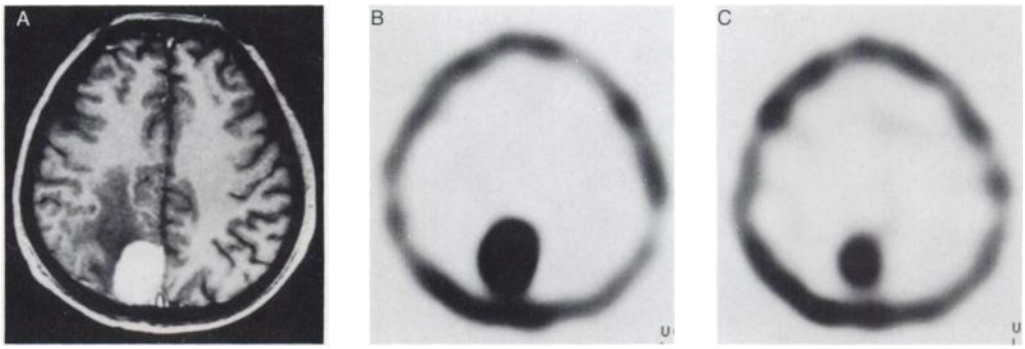

FIGURE 3. Meningothelial meningioma. (A) Postcontrast T1-weighted MR image shows a tumor in the right parietal region. Thallium-201 SPECT early image (B) shows high uptake in the tumor, but the delayed image (C) shows early clearance.

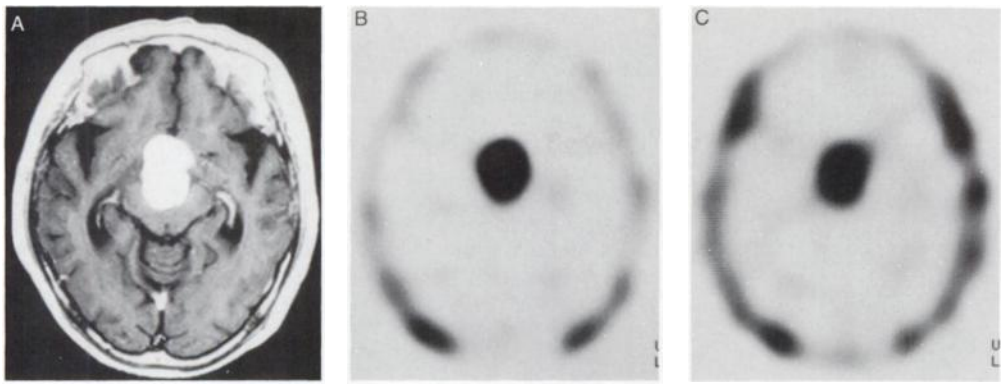

FIGURE 4. Transitional meningioma. (A) Postcontrast T1-weighted MR image shows a tumor in the suprasellar region. Thallium-201 SPECT early image (B) shows high uptake in the tumor, and the delayed image (C) shows relative retention.

tumor in the left parietal region. Early and delayed ^{201}Tl SPECT images showed the tumor to have high uptake and a high retention rate. The early, delayed UI and the RI were 5.04, 4.67 and 0.93, respectively.

DISCUSSION

Thallium-201 behaves biologically like potassium and is distributed in potassium-rich organs, such as the heart, kidney, gastrointestinal tract and the thyroid gland. Because of little uptake in the normal brain, intracranial lesions were well-defined with ^{201}Tl, producing good target-to-background contrast (*1,10*). Three possible factors relate to uptake in brain tumors; namely, regional blood flow, BBB permeability and cellular uptake (*7,8*). Kaplan et al. (*2*) demonstrated that ^{201}Tl scans accurately reflect viable tumor and not simply BBB permeable areas in a comparison of various scintigraphic images with autopsy data. They speculated that abnormal uptake is related to the presence of (Na^+-K^+)-ATPase pump activity on viable tumor cell membranes. Thallium scans more accurately represent post-therapy viable tumor burdens than do other imaging modalities such as CT (*1,2*).

Black et al. (*5*) reported that a ^{201}Tl index of less than 1.5 nearly excluded the probability of malignancy. The ^{201}Tl index they used was the rate of average counts in tumor to that in the homologous contralateral region only on early SPECT images. In our study, early thallium UIs were relatively high in all types of meningiomas and were higher than those reported by Black et al. (*5*), which were suspected of being malignant gliomas. The early high accumulations in meningiomas are related mainly to their increased blood flows. However, the delayed UIs in meningothelial meningiomas were lower than those of other types, and the retention indices were statistically lower than other types. These results indicate that ^{201}Tl exhibits earlier clearance in meningothelial gliomas than in other gliomas. In other words, a low retention index probably excludes the possibility of malignant meningioma.

Early uptake indices of ^{201}Tl in meningiomas reflect their blood flows, and their retention rates may reflect histological differences. Experimental evidence in other tumors suggests that the ionic movements of thallium and potassium are related to their active transport through an ATP cell membrane pump and that ^{201}Tl uptake is related to cell growth rates (*11,12*). These factors may also be related to differences in ^{201}Tl clearance in meningiomas according to histological types in the present study. In malignant meningiomas, the high RI reflects these increased factors (*6*).

These results are in agreement with those from previous studies of other tumors such as lung tumors (*13*) and thyroid tumors (*14*), in which ^{201}Tl uptake on delayed images suggested malignancy. In general, meningiomas are clinically benign; however, there are several variations of the malignant type. It is therefore important to predict the possibility of malignancy before planning therapy. From the present data, although it should be impossible to predict whether a lesion is malignant using ^{201}Tl SPECT, a high RI is indicative of the malignancy potential in a men-

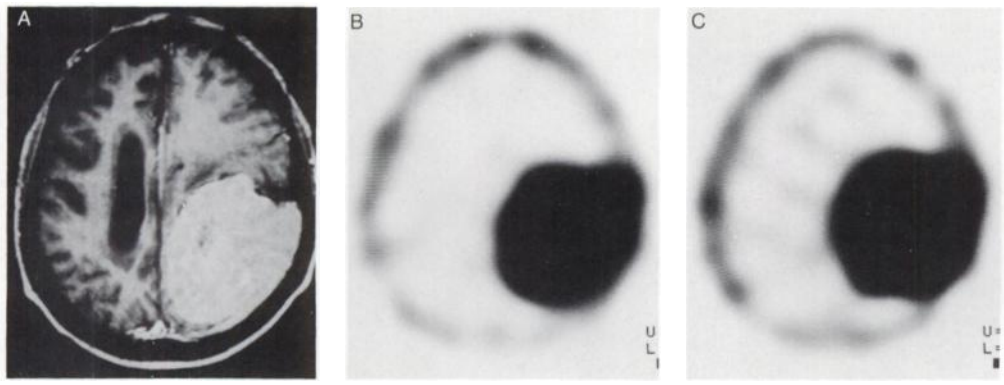

FIGURE 5. Malignant meningioma. (A) Postcontrast T1-weighted MR image shows a large tumor in the left parietal region. Thallium-201 SPECT early (B) and delayed images (C) show high uptake in the tumor. The retention rate is also high.

ingioma. This method would also be useful for detecting recurrent malignant meningiomas.

CONCLUSION

Thallium-201 exhibits early and relatively high accumulation in all types of meningiomas, but its retention rates probably differ according to histological types. By using a retention index for ^{201}Tl SPECT, we could predict the probable malignancy potential of a meningioma.

REFERENCES

1. Mountz JM, Stafford-Schuck K, McKeever PE, Taren J, Beierwaltes WH. Thallium-201 tumor/cardiac ratio estimation of residual astrocytoma. *J Neurosurg* 1988;68:705–709.
2. Kaplan WD, Takvorian T, Morris JH, Rumbaugh CL, Connolly BT, Atkins HL. Thallium-201 brain tumor imaging: a comparative study with pathologic correlation. *J Nucl Med* 1987;28:47–52.
3. Schwartz RB, Carvalho PA, Alexander E III, Loeffler JS, Folkerth R, Holman BL. Radiation necrosis vs high-grade recurrent glioma: differentiation by using dual-isotope SPECT with ^{201}Tl and ^{99m}Tc-HMPAO. *Am J Neuroradiol* 1991;12:1187–1192.
4. Kim KT, Black KL, Marciano D, et al. Thallium-201 SPECT imaging of brain tumors: methods and results. *J Nucl Med* 1990;31:965–969.
5. Black KL, Hawkins RA, Kim KT, et al. Use of thallium-201 SPECT to quantitate malignancy grade of gliomas. *J Neurosurg* 1989;71:342–346.
6. Ueda T, Kaji Y, Wakisaka S, et al. Time sequential single photon emission computed tomography studies in brain tumour using thallium-201. *Eur J Nucl Med* 1993;20:138–145.
7. Atkins HL, Budinger TF, Lebowitz E, et al. Thallium-201 for medical use. Part 3: human distribution and physical imaging properties. *J Nucl Med* 1977;18:133–140.
8. Mountz JM, Raymond-PA, McKeever-PE, et al. Specific localization of thallium-201 in human high-grade astrocytoma by microautoradiography. *Cancer Res* 1989;15:49:4053–4056.
9. Sorenson JA. Quantitative measurement of radioactivity in vivo by whole-body counting. In: Hine GJ, Sorenson JA, eds. *Instrumentation in nuclear medicine, volume 2*. New York: Academic Press; 1974:311–348.
10. Ancr D, Basset JY. Diagnosis of cerebral metastases by thallium-201. *Br J Radiol* 1980;53:443–453.
11. Elligsen JD, Thompson JE, Frey HE, Hruuv J. Correlation of (Na-K)ATPase activity with growth of normal and transformed cells. *Exp Cell Res* 1974;87:233–240.
12. Sehweil AM, McKillop JH, Milroy R, et al. Mechanism of ^{201}Tl uptake in tumours. *Eur J Nucl Med* 1989;15:376–379.
13. Tonami N, Shuke N, Yokoyama K, et al. Thallium-201 single photon emission computed tomography in the evaluation of suspected lung cancer. *J Nucl Med* 1989;30:997–1004.
14. el-Desouki-M. Thallium-201 thyroid imaging in differentiating benign from malignant thyroid nodules. *Clin Nucl Med* 1991;16:425–430.