USE OF THE DELAYED BRAIN SCAN IN DIFFERENTIATING CALVARIAL FROM CEREBRAL LESIONS

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A series of 92 sequential positive brain scans on 69 patients was reviewed. Each patient was scanned early following injection of radionuclide and again approximately 3 hr after injection. The change in relative radioactivity in the lesion compared with the "rim" radioactivity was useful in revealing whether the lesion was intracerebral or calvarial. In more than 80% of the calvarial lesions, the radioactivity tended to decrease between early and delayed views whereas more than 90% of the intracranial lesions tended to increase in relative radioactivity on the delayed view. Exceptions to this general pattern were noted in both categories of lesions. The combination of early and delayed scans gives information regarding the location of brain lesions which is not obtained from either study alone. The technique represents an additional parameter to be considered in the determination of the location of a lesion on brain scan even though it does not achieve complete specificity.

Both calvarial and intracranial lesions may produce abnormal brain scan images (*1–3*). Combined isotopic techniques have been used in attempts to differentiate brain and bone lesions but with mixed results (*4,5*). To date, no reports have been published describing the changes in calvarial lesions at different intervals between injection of the radionuclide scanning agent and actual scanning. We have observed that on delayed views relative radioactivity in calvarial lesions, normal blood pools, and certain intracranial blood-pool lesions (such as arterial venous malformations) tends to diminish compared with the peripheral or so-called rim radioactivity. It appears that the combination of early and delayed views is useful in distinguishing between calvarial and intracranial lesions.

MATERIALS AND METHODS

We have reviewed 92 sequential positive brain scans on 69 patients. (Two of these patients had 5 scans each; 1 patient, 4 scans; 2 patients, 3 scans; 8 patients, 2 scans; and 56 patients, 1 scan.) A total of 100 lesions were found in these 92 scans, all of which were performed with a gamma camera. Twelve mCi of ^{99m}Tc-pertechnetate were administered intravenously following premedication with 1 gm of perchlorate. Initial views were started within 10 min and completed within 30–40 min of the time of isotope injection. Delayed views were taken on all patients 3–4 hr following the completion of initial views.

The relative activity in the lesion was compared with the radioactivity in the periphery or "rim," which represents primarily the extracellular fluid space of the skull and scalp with a minor vascular component.

RESULTS

Thirty-four of the 100 lesions studied were calvarial and the remaining 66 were intracranial. Twenty primary brain tumors were documented by pathology. The remaining lesions were confirmed at pathology or surgery with the following exceptions: 5 of 8 skull metastases were documented by skull x-ray; 9 of 18 brain metastases were documented clinically and 1 by angiography; 15 cerebral vascular accidents were documented clinically; 4 of 10 brain abscesses were confirmed by angiography; and 6 of 10 by their clinical course and by followup studies. A skull fracture and a case of Paget's disease of the skull were documented by x-ray and one case of meningitis was documented clinically.

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TABLE 1. INTRACRANIAL LESIONS

Lesions	No. of lesions	Delay increased	Delay decreased	Delay same
Primary tumor	20			
Glioblastoma	4	4	—	—
Craniopharyngioma	2	1	1	—
Acoustic neuroma	3	1	1	1
Ependymoma	2	1	—	1
Meningioma	4	4	—	—
AVM	3	—	3	—
Hemangio-endothelioma	2	2	—	—
Metastatic tumor	18	18	—	—
CVA	15	15	—	—
Abscess	10	8	—	2
Epidermoid	1	—	—	1
Meningitis & encephalitis	1	1	—	—
Contusion	1	1	—	—
Total	66	56	5	5

TABLE 2. CALVARIAL LESIONS

Lesion	No. of lesions	Delay increased	Delay decreased	Delay same
Surgical skull lesion	21	1	15	5
Metastatic tumor	8	2	6	—
Orbital hemangioma	1	—	—	1
Fracture	1	—	—	1
Neurofibroma of orbit	1	—	1	—
Paget's disease of skull	1	1	—	—
Eosinophilic granuloma	1	—	—	1
	34	4	22	8

TABLE 3. ACTIVITY OF LESIONS ON DELAYED SCAN

Lesion activity on delay	No. of lesions	Intracranial	Calvarial
Decrease	27	5/27 = 18.5%	22/27 = 81.5%
Increase	59	55/59 = 93%	4/59 = 7%
Unchanged	14	6/14 = 43%	8/14 = 57%

Tables 1 and 2 give the pathological description of the lesions included in the study and list the behavior of the lesions on the delayed as compared with the early views. The change in relative radioactivity in the 66 intracranial lesions is shown in Table 1. Fifty-five of the lesions showed increased radioactivity on the delayed scan whereas five had decreased radioactivity and six remained unchanged. Three of the five lesions which showed decreased radioactivity on the delayed scan were arteriovenous malformations. The remaining two cases were an acoustic neuroma and a cranipharyngioma.

The change in relative radioactivity in the 34 calvarial lesions is shown in Table 2. Twenty-two of the lesions showed decreased radioactivity on the delayed scan; four had increased radioactivity, and eight were unchanged. The five lesions with increased radioactivity on the delayed scan included two cases of metastatic neoplasm, a surgical bone flap, and a case of Paget's disease of the skull.

Table 3 shows the behavior of the 100 lesions on the delayed view and relates this to the location of the lesions. If a lesion faded on the delayed scan, it was calvarial in 82% of cases. If a lesion showed increased activity, it was intracranial in 93% of cases. Lesions that showed no change in relative activity were almost equally divided between intra- and extracranial sites.

DISCUSSION

Illustrative examples of typical early and delayed-view brain scan findings with intracranial and calvarial lesions as well as a dramatic exception to this pattern are seen in Figs. 1–4.

Technetium-99m-pertechnetate is the most popularly used scanning agent for the detection of intracranial abnormalities (*6*). However, this compound like most others which have been used in brain scanning does not localize in cerebral lesions to the exclusion of other tissues. Since ^{99m}Tc-pertechnetate also accumulates in lesions of the calvarium, differen-

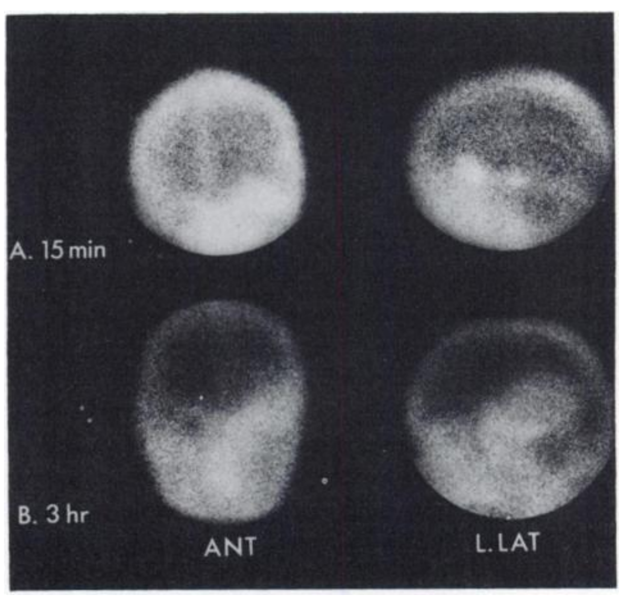

FIG. 1. Typical intracranial lesion: hemangioepithelioma of left temporal lobe. (A) Early view shows vascular portion of tumor. (B) On delayed view anterior activity has faded and uptake is seen in posterior cystic portion of tumor.

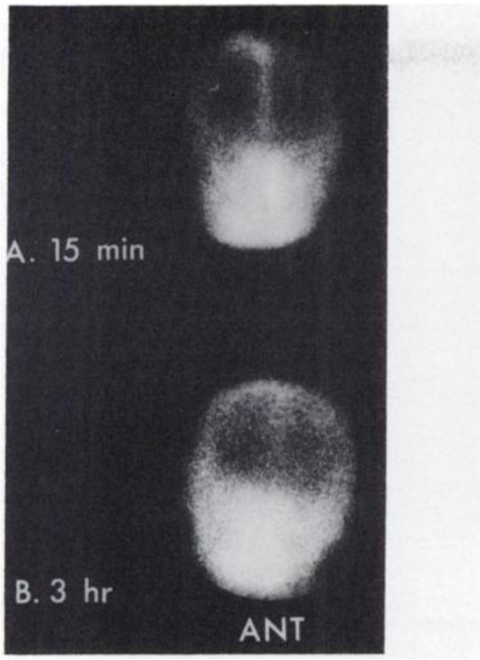

FIG. 2. Typical calvarial lesion: carcinoma of breast, metastatic to skull. (A) Early view shows lesion in calvarium. (B) Uptake in lesion fades in delayed view.

tiation of calvarial from intracerebral lesions may be difficult. Comparisons with recent skull x-rays and/or bone scans may be helpful but these studies may not be available at the time of scan interpretation. It would be quite useful to be able to make the distinction between calvarial and intracerebral lesions with some certainty on the basis of the brain scan alone.

In studies by other investigators (*2,7–10*), varying intervals of 10–30 min between injection of radionuclide and scanning are recommended. More recent reports (*11–18*) have indicated that in scans of most intracranial lesions, the activity is either similar or increased 3–4 hr following radionuclide injection compared with the activity measured soon after injection. Various delay periods have been studied and it now appears that the optimum time for visualizing most cerebral lesions is approximately 3–4 hr after injection of the radionuclide (*11,14,18,19*). Intracranial lesions which are not seen or are poorly seen on scans made soon after injection may be well delineated on the delayed views. Other investigators have used the delayed scan to predict malignancy versus benign lesions (*19*) and to differentiate between vascular and highly vascular or cystic lesions (*13*).

As previously noted, the peripheral or rim radioactivity seen on the brain scan consists primarily of ^{99m}Tc-pertechnetate in the extracellular fluid space of the scalp and skull (*20,21*). Calvarial lesions,

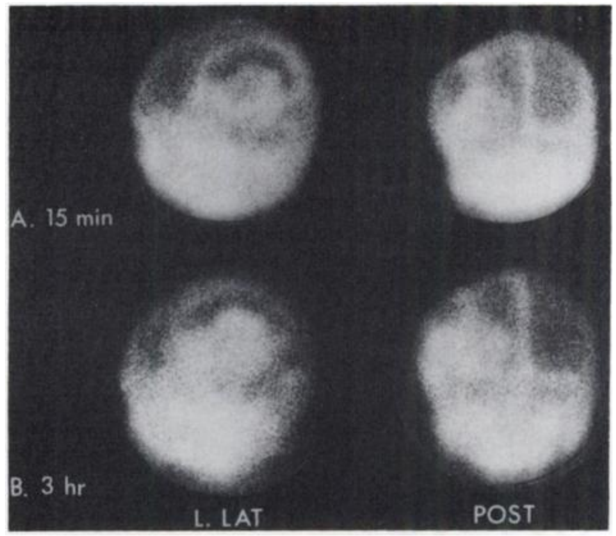

FIG. 3. Typical calvarial and intracranial lesion: recurrent left parietal glioblastoma. (A) Early views show bone flap activity with vague overlapping tumor activity. (B) Bone flap fades; tumor activity more prominent on delayed view.

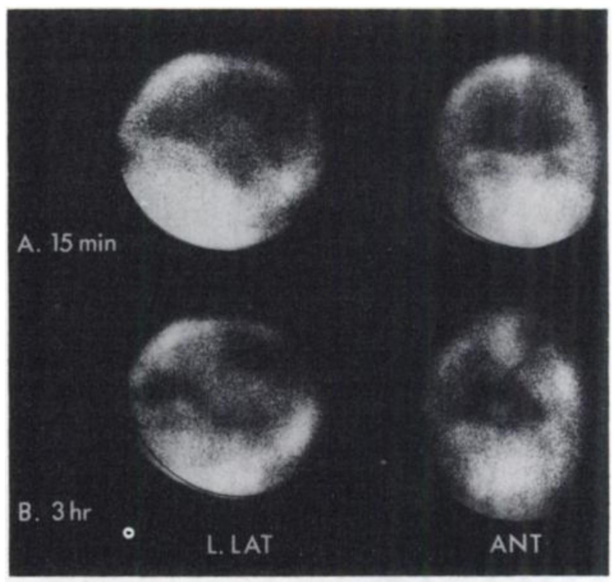

FIG. 4. Atypical or false localization in calvarial lesions: Paget's disease. (A) Early view shows patchy, irregular uptake which increases in relative intensity on delayed views. This paradoxical increase in uptake of delayed view occurred in only 4 of 34 calvarial lesions.

especially metastatic tumors, usually represent expansion of the vascular space. Since these calvarial lesions are primarily blood pool, it is not unreasonable that they should appear brighter than the rim activity on the early views where there is more pertechnetate in the vascular space than in the extracellular fluid space. The lesions then fade somewhat in radioactivity on the delayed views as the pertechnetate in the vascular space decreases while the radioactivity in the extracellular fluid space is present in relatively higher concentration.

Ordinarily, ^{99m}Tc-pertechnetate radioactivity in the brain is seen only in the vascular space because the normal blood-brain barrier prevents it from passing into the brain. Radioactivity seen in brain lesions on scan is due to an expanded blood pool and/or to leakage of radioactivity into the lesion because of a breakdown in the blood-brain barrier. If the vascular aspect of the lesion predominates as in the case of arteriovenous malformations, one would expect that the lesion would fade in relation to the rim radioactivity on the delayed views. If, however, the localization is due primarily to a breakdown in the blood-brain barrier and leakage of radioactivity into the brain, one would anticipate that the delayed view would show a relative increased uptake within the lesion compared with the rim activity.

This serves as a simple, if not wholly accurate, explanation of the tendency of the radioactivity in most intracerebral lesions to increase compared with the rim activity on the delayed views whereas arterial venous malformations and calvarial lesions tend to decrease in radioactivity.

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