COMPARISON OF RECTILINEAR VERTEX AND TRANSVERSE SECTION VIEWS IN BRAIN SCANNING

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Both the rectilinear vertex scan (*1–4*) and the transverse section scan (*5–7*) are recommended as supplements to the usual brain scan examination to improve detection and characterization of lesions. Both can provide information unavailable in the usual study by providing a different frame of observation. In the vertex scan, an ordinary rectilinear scan over the top of the head views the entire thickness of the brain. In the transverse section scan, a sequence of scans tangent to a chosen cross section examines a transverse slice through the brain measuring approximately 2 cm in thickness. These fundamentally different viewing methods may produce pictures similar in appearance. This report is an attempt to clarify the important differences between rectilinear vertex scanning and transverse section scanning of the brain.

EXPERIMENTAL COMPARISON

Method. In these experiments the brain was represented by four water-filled plastic chambers stacked to a form a cylinder (Fig. 1). A brain tumor was simulated by a sphere that measured 4 cm in dia and contained solution that had a 10 times greater concentration of ^{99m}Tc than the surrounding water in the cylinder.

Separate rectilinear scans were made over the top of the phantom with the tumor positioned at different depths and either at the midline or against the side of the cylinder. Then a series of transverse sections were made through levels corresponding to each position of the tumor. The separation between the surface of the phantom and the collimator* was 3 cm in all scans.

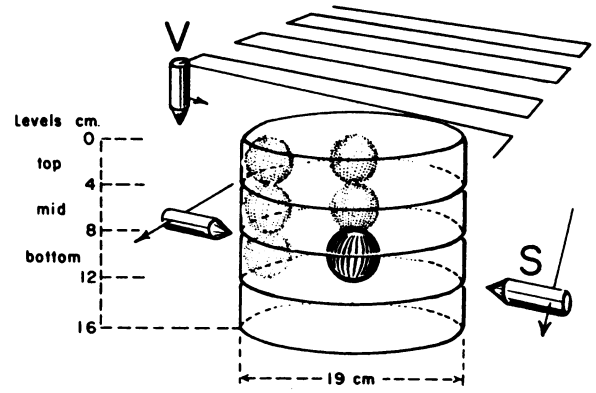

FIG. 1. Radioactive phantom for comparison of rectilinear vertex scanning (V) and transverse section scanning (S) of brain.

Scan data were recorded on perforated paper tape (*8*) for subsequent numeric analysis. The section data were translated into a rectilinear matrix using both single-sector (SSA) and double-sector (DSA) addition (*9*). To measure the tumor count (C_T) in each picture, the contributing counts were summed within a test disk measuring 3.25 cm in dia centered on the image of the tumor. The nontumor count (C_{NT}) was measured by adding counts contributing to a corresponding test disk positioned over an adjacent part of the picture. For vertex scans, C_T and C_{NT} represented counts printed directly on the picture; for section scans, C_T and C_{NT} represented the sum of the counts contributed to similar test disks from each of the 24 tangent scans. These data were then corrected to account for physical decay of the radionuclide during the study and to satisfy the assumption that the study time over the phantom was the same in each scan.† From these results we computed the tumor count (C_T), tumor contrast (C_T/C_{NT}) and figure of merit‡ (Q) for vertex and transverse section scans made with equal study time

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* Picker 19-hole collimator (#2107A) with 3 × 2-in. crystal in all scans. A single detector was used for vertex scanning and a double detector was used for section scanning.

† For vertex scans, we assumed the unnatural situation that the rectilinear raster was round and fitted exactly the top area of the cylinder (19 cm dia). In practice, a square raster was used, and time was wasted at the edges. For section scans, we assumed the length of each tangent scan equalled the diameter of the cylindrical phantom (19 cm). In practice, the tangent scan extended beyond the edges of the cylinder and time was wasted on each side.

‡ The figure of merit (Q) is given by: $Q = (C_T - C_{NT})^2/(C_T + C_{NT})$ and is inversely proportional to the time required to distinguish a significant difference between C_T and C_{NT} with a given statistical accuracy (*10*). When this statistical comparison is the sole criterion for detection, a system with a Q twice that of another system requires only half the time for detection of the tumor.

for either a midline or superficial tumor located in the top level (0–4 cm), the midlevel (4–8 cm) or the bottom level (8–12 cm) of the brain.

Results. Tumor count (C_T) is plotted in Fig. 2. The striking feature of these data is the superiority of tumor count with section viewing over vertex viewing, a disproportion that is further increased as the tumor is positioned deeper within the cylinder. Vertical depth of the tumor does not influence transverse section scan results.

Tumor contrast (C_T/C_{NT}) is plotted in Fig 3. For the vertex view, tumor contrast falls as the tumor position is made deeper, but contrast is superior to section viewing for most brain tumor locations. Reduction in contrast is inherent in the tomographic techniques because the nontumor part of the picture is exposed to tumor signals on every tangent scan (see Fig. 5 in Ref. *9*). With section viewing, contrast of a superficial (edge) tumor is better than that of a central (midline) tumor and can be further improved using single-sector addition for processing (*9*).

The combined influence of both tumor contrast and tumor count is reflected in the figure of merit (Q) plotted in Fig. 4. Because of superior tumor count, the figure of merit with section viewing is far better than that of vertex viewing in all situations except for a midline tumor in the top level of the brain.

The superior tumor count and figure of merit with section technique can be understood better by considering data corresponding to a midline tumor in the bottom level of the brain, the most unfavorable location for both vertex and section viewing. With a tumor in this position, the attenuation path (10 cm) and distance between tumor and collimator (13 cm) is the same for both techniques. Comparing vertex data with section data (double-sector addition), tumor contrast (Fig. 3) is almost the same for the two methods, but both the tumor count (Fig. 2) and figure of merit (Fig. 4) with the section method are approximately 14 times greater than with the vertex method. This difference in figures of merit implies that vertex viewing under these conditions should require 14 times greater study time than section viewing if this tumor is to be detected with equal accuracy, providing the sole criterion for detection is a statistical comparison of C_T and C_{NT}. This is an oversimplification if applied to visual interpretation of real pictures, but even so this approximate relationship is substantiated by another experiment.

Each picture set* in Fig. 5 is a vertex (V) and

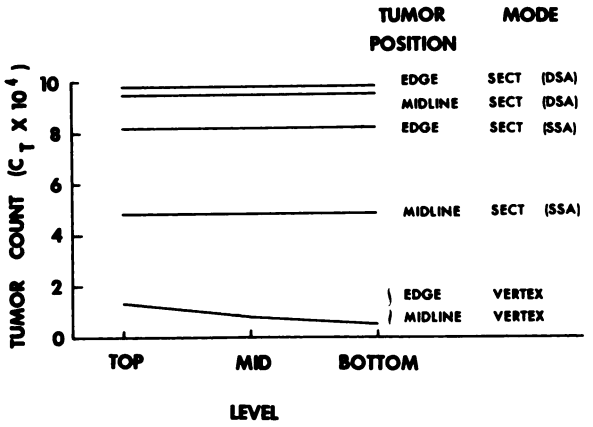

FIG. 2. Tumor count as function of position. Superiority of tumor count with section viewing over vertex viewing increases as tumor is positioned deeper within cylinder.

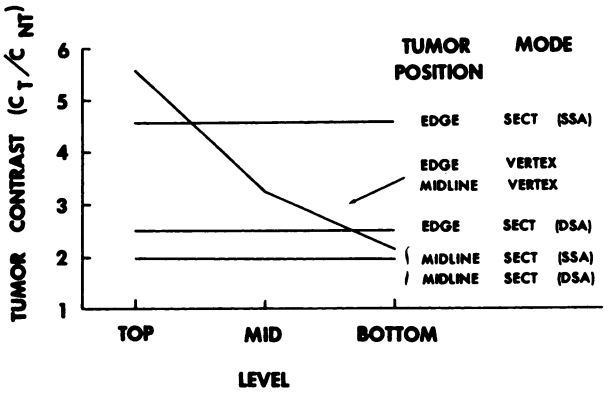

FIG. 3. Tumor contrast as function of tumor position.

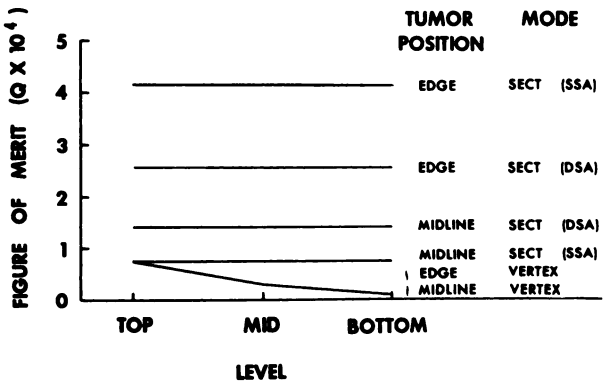

FIG. 4. Figure of merit as function of tumor position. Because of superior tumor count, figure of merit with section viewing is superior to that of vertex viewing for all tumor positions except in top level of brain.

section (S) view made with equal scan time over this same phantom configuration which represents a midline tumor in the bottom level of the brain. The initial vertex picture (V,T) contains 32×10^3 counts. Compared to the corresponding vertex data in each set, section data have approximately equal tumor contrast (C_T/C_{NT}), 1.8 times as many pho-

* Pictures were photographed from a CRT screen after adjustment for optimum contrast of each under visual control (*11*).

tons in the entire picture (two detectors) and 14 times as many photons in the test disk of the tumor image. Each succeeding picture in the series (T through T/32) has half the total number of photons and, consequently, represents a halving in scan time. The importance of this demonstration is that with section viewing the tumor can be identified positively using much shorter study times than required with vertex viewing. Each section view of the tumor is roughly equivalent to a vertex view requiring more than eight times, but not as much as 16 times, greater study time.*

There are several reasons for the 14-fold advantage predicted for section viewing of this phantom. First, in this experiment the double detectors used for section scanning provide a 2:1 advantage in sensitivity over the single detector used for the vertex scans. Next, and most important, in transverse section scanning the tumor is examined on *every* pass of the detectors; in vertex scanning, the detector passes over the tumor in only a fraction of the scan lines. This feature of the section scan may be considered as a reward for knowing and specifying the level of interest in the head. Because of this factor alone, even though the total study time is equal for the two methods, section viewing gains a 6:1 advantage in examination time over the tumor.† Finally, the section method gains a smaller advantage by viewing the thickest part of the spherical tumor on every pass.

* To compare a one-detector section study with a one-detector vertex study, match a section view with a vertex view taking twice the time.

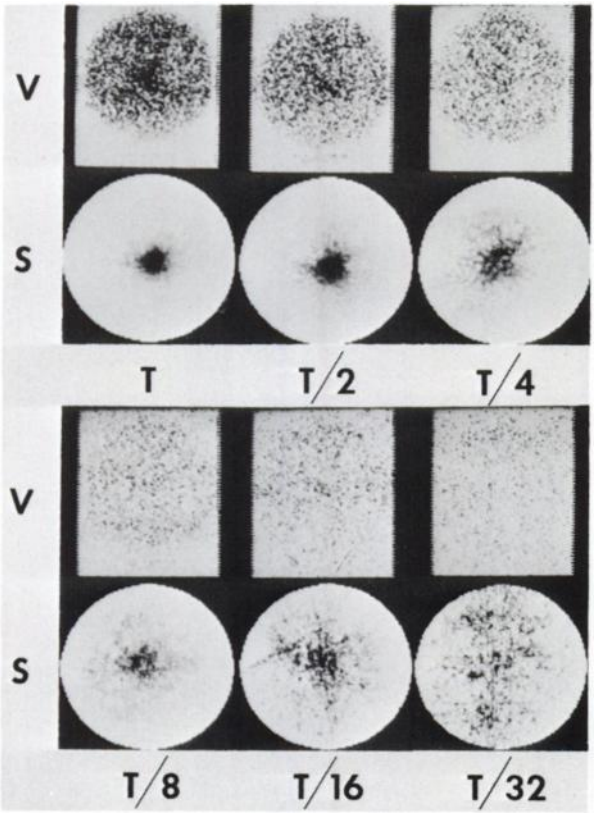

FIG. 5. Scans of phantom representing midline tumor in bottom level of brain. Each picture set is vertex (V) and section (S) view made with equal scan time. Each succeeding picture in series (T through T/32) has half total number of photons and represents halving in scan time. With section viewing, tumor can be identified positively using much shorter study times than required with vertex viewing.

CLINICAL COMPARISON

Method. The study group was 12 patients with confirmed brain lesions, 11 with tumors and one with a cerebral infarct. This series was subdivided into three groups of four patients, each with a lesion in the top level of the brain (0–4 cm vertical distance from the scalp), the middle level (4–8 cm) or the bottom level of the brain (8–12 cm), corresponding to levels used in the phantom experiment.

Each patient underwent two separate scanning sessions. On the first day, an anterior, posterior, left lateral and right lateral rectilinear scan was performed beginning approximately 15 min after intravenous injection of 10 mCi of ^{99m}Tc-pertechnetate and the oral administration of 400 mg of potassium perchlorate. Approximately 1 hr later, a transverse section scan was performed through the lesion, the level of which was identified in the rectilinear scan.

The following day the vertex scan was performed after administration of atropine to reduce interfering uptake in saliva and oral-nasal mucous membranes (*3*). First the patient received atropine sulfate (1 mg/kg body weight, i.m.), an oral dose of potassium perchlorate (6 mg/kg body weight), followed in 15 min by an intravenous dose of 10 mCi of ^{99m}Tc-pertechnetate. After an additional interval of 15 min, the vertex scan was begun. With the patient prone, the chin was elevated so that the orbitomeatal plane was maintained parallel to both the table top and the scan plane. The shoulders were covered with a lead apron during the vertex scan.

† Let A_t = area of tumor disk; A_p = area of phantom top; D_t = diameter of tumor disk; D_p = diameter of phantom; F_v = fraction of scan time over tumor test disk with vertex view; F_s = fraction of scan time over tumor test disk with section view; R = ratio of time over tumor test disk (section to vertex).

$$\text{Then: } F_v = \frac{A_t}{A_p} = \frac{D_t^2}{D_p^2} \qquad F_s = \frac{D_t}{D_p}$$

$$R = \frac{D_t/D_p}{D_t^2/D_p^2} = \frac{D_p}{D_t} = \frac{19.0\text{ cm}}{3.25\text{ cm}} = 5.8.$$

With a single detector, the section method views the tumor six times longer than the vertex method for equal scan times over the phantom.

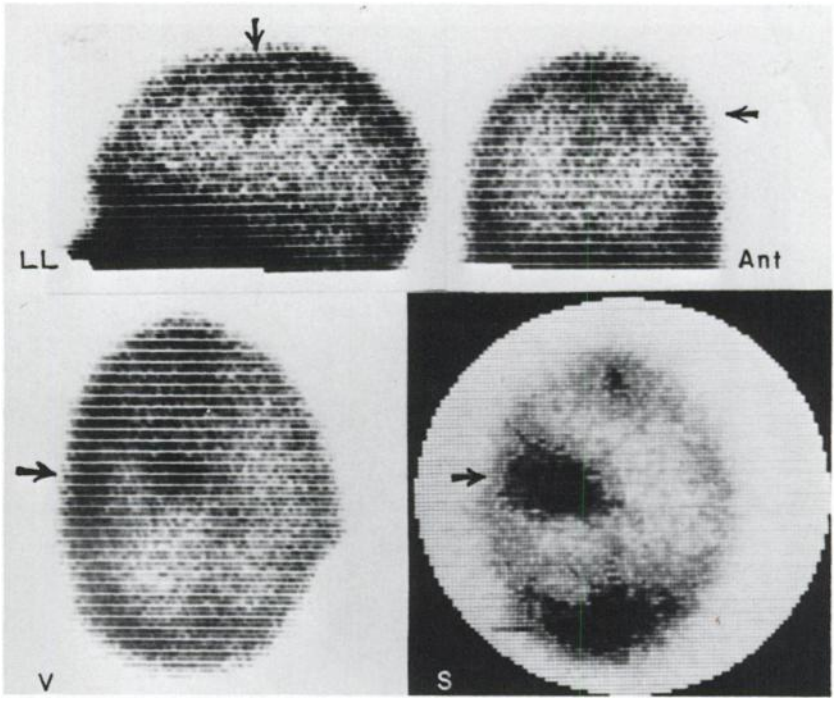

FIG. 6. Upper-level lesion. Bronchogenic carcinoma metastasis (arrows) in left parasagittal region is seen equally well in vertex (V) and section (S) views. Nasal uptake (poor atropine effect) and entire sagittal sinus are included in vertex pictures; only anterior and posterior cross sections of sinus appears in section picture.

Collimation for all scans was the same as described in the phantom experiments. The vertex scan and the transverse section scan on each patient were performed so that the total times spent by the detectors over the head (assumed to be 19-cm-dia disk) was 10 min in each. This required an actual study time of 18 min for the vertex scan (one detector, 1.5 cm/sec, 0.32-cm line space, 20 × 25-cm rectangular scan field, index time neglected) and an actual study time of 13 min for each transverse section scan (two detectors, 0.75 cm/sec, interval angle 7.5 deg, 25-cm-dia section plane, index time neglected).

Results. In all 12 patients, the brain lesions could be seen on at least two of the original four rectilinear views.

In the four patients with lesions in the top level (0–4 cm) of the brain, the lesion could be seen equally well in both the vertex and transverse section views. Both views distinguished the medial relationships of parasagittal lesions well (Fig. 6). But we incorrectly diagnosed an anterior uptake in one vertex scan that was really due to a combination of an angled head and a failure to completely suppress oral-nasal uptake with atropine. (The transverse section high in the head is unaffected by oral-nasal uptake.)

In the four patients with lesions in the middle level (4–8 cm) of the brain, the lesions were detected with both vertex and section scanning in all, but the section scans uniformly had better quality. In the vertex scan, there was poor definition of lesion edges because of poorer statistics and easy confusion with images of the overlying sagittal sinus and underlying oral-nasal uptake (Figs. 7, 8).

In patients with lesions in the bottom level (8–12 cm) of the brain, three out of four were missed with vertex viewing; only one was barely perceptible. All four were clearly demonstrated with section viewing (Figs. 9, 10).

The clinical studies confirm predictions based on the phantom experiment. In the lower levels of the brain, the vertex scan is at a definite statistical disadvantage compared to the transverse section scan. In addition, the ability of the section technique to separate images according to depth provides a further important advantage; underlying and overlying structures do not obscure the structure of interest.

DISCUSSION

There are advantages and disadvantages to both vertex and section scanning of the brain. Both studies supplement the routine rectilinear survey, permitting us to detect some lesions that might otherwise be missed and to characterize most lesions better as to size, boundaries, position and whether the lesion is single or multiple.

The special advantages of the vertex scan are that it can be performed with existing equipment and is efficient for lesions in the upper levels of the brain. It is especially advantageous for distinguishing parasagittal lesions that might otherwise be lost in the sinus image.

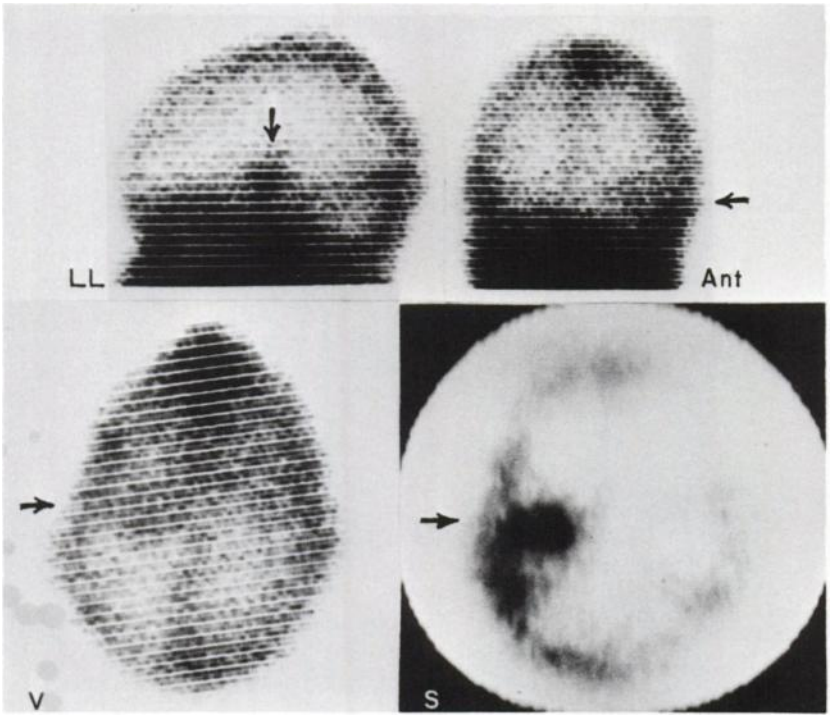

FIG. 7. Middle-level lesion; good differential tumor concentration. Recurrent astrocytoma gr ii (arrows) is shown in left insula 1 yr after left temporal craniotomy and radiotherapy. Tumor is easily detected in both vertex (V) and section (S) views, but distribution is better defined in section. Vertex picture again shows nasal uptake due to inadequate atropine effect and resembles corresponding view in Fig. 6.

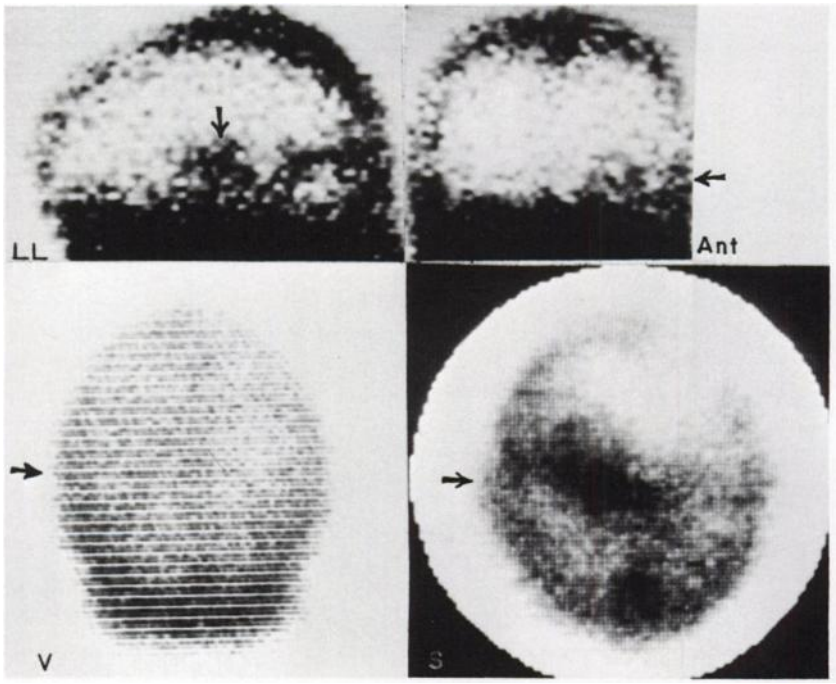

FIG. 8. Middle-level lesion; poorer differential tumor concentration than in Fig. 7. Astrocytoma gr iii (arrows) is shown deep in left angular gyrus. Tumor is detected in both vertex (V) and section (S) views but deep distribution of tumor is demonstrated well only in section. For vertex view, atropine effect is good, but tumor boundaries are indistinct due to poor statistics and masking by sagittal sinus.

The special disadvantages of rectilinear vertex scanning are that efficiency is poor for lesions low in the brain and lesions can be masked by radioactivity in overlying or underlying structures. Also, it is difficult to position an ill patient when an unmodified scanner is used.

The special advantages of the transverse section scan are that efficiency is good for lesions low in the brain, lesions are not masked by radioactivity in underlying or overlying structures (the study does not require premedication with atropine when ^{99m}Tc-pertechnetate is used) and the cross-section configuration of a lesion can be determined at several different levels (Fig. 10). It is not difficult to position an ill patient for a section scan.

The special disadvantages of transverse section brain scanning are that special equipment is required and, with our present equipment, it is neces-

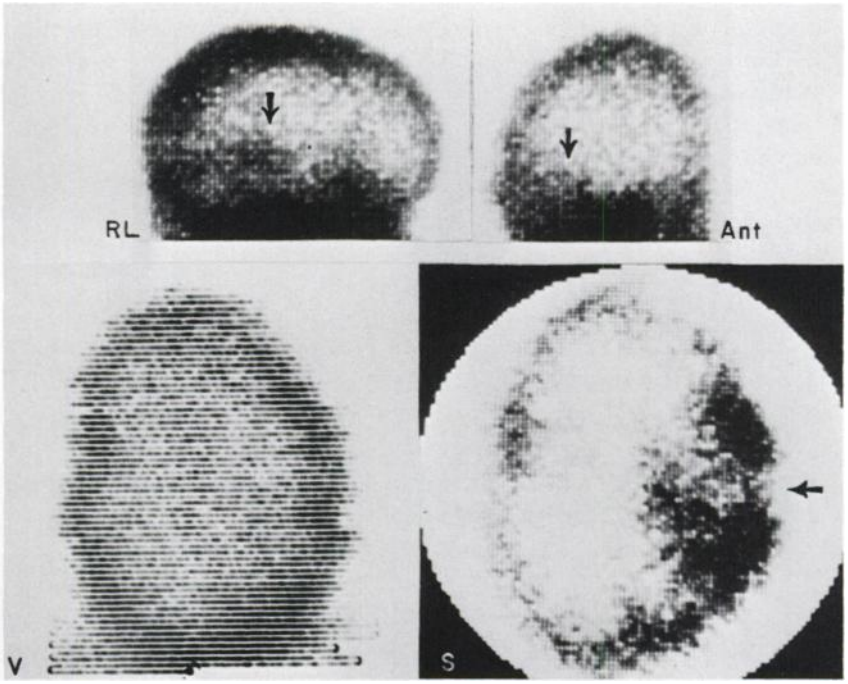

FIG. 9. Bottom-level lesion. Astrocytoma gr i (arrows) is shown deep in right temporal lobe. Tumor is not detected in vertex (V) picture, but in section (S) picture, not only is tumor detected, but also medial boundaries are clearly defined, adding information unavailable in rectilinear views.

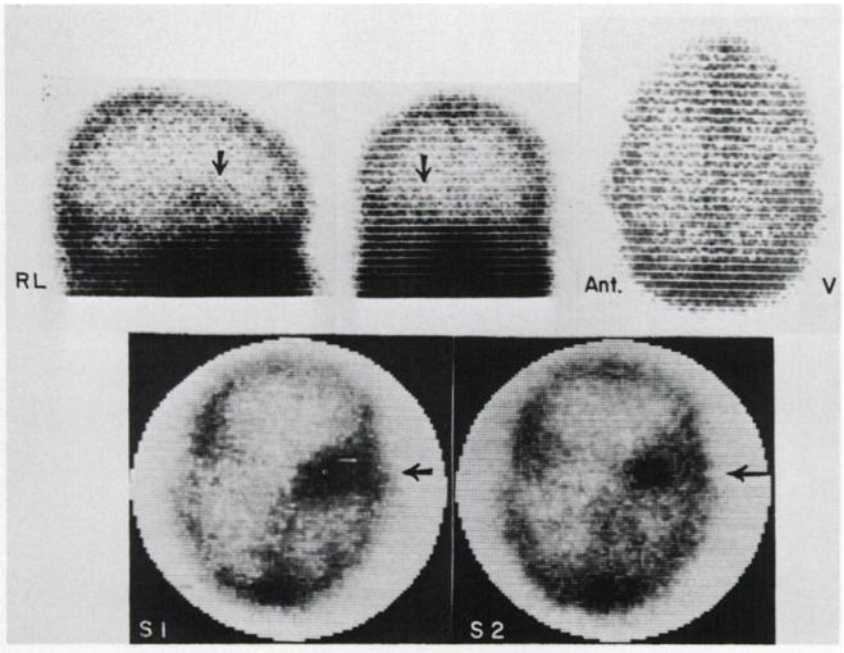

FIG. 10. Bottom-level lesion. Astrocytoma gr i (arrows) is shown in anterior right temporal lobe. Patient is 41-year-old man with history of olfactory seizures and headaches for 9 months. There are no visual field-cuts, motor or sensory abnormalities. Vertex (V) picture fails to confirm definitely presence of abnormal uptake suspected in rectilinear scans. Sections, made at two different levels 3 cm (S1) and 4 cm (S2) above orbital meatal plane, identify the tumor and define its pyramidal shape. Section study provided best preoperative description of tumor; carotid arteriography demonstrated only nonspecific midline shift and avascular region in right temporal lobe.

sary to preselect the level of interest, which may not be known clearly.

Our present policy is to choose the vertex view when relatively shallow lesions, especially parasagittal lesions, are suspected. We use the Anger camera for this vertex view, without administering atropine. The Anger camera has high efficiency for relatively shallow tumors, and it facilitates positioning of an ill patient for this view. For lesions deeper in the brain, we prefer transverse section scanning. We are now completing a rectilinear and transverse section brain scanner with improved design and hope that its introduction will encourage the wider application of this useful study method.

SUMMARY

We performed a series of experiments to clarify the important differences between rectilinear vertex

scanning and transverse section scanning of the brain. Because of superior tumor count, the figure of merit with transverse section viewing is far better than that of vertex viewing in all tumor situations except for a midline tumor in the top level of the brain. For a midline tumor (4 cm) in the bottom level of the brain, the difference in figures of merit implies that vertex viewing (one detector) should require 14 times greater study time than section viewing (two detectors) if this tumor is to be detected with equal accuracy. The major reason for this difference is that in transverse section scanning the tumor is examined on every pass of the detectors; in vertex scanning the detector passes over the tumor in only a fraction of the scan lines.

We performed ^{99m}Tc-pertechnetate brain scans on a group of 12 patients who had confirmed brain lesions. Atropine was administered only with the vertex scan. In all 12 patients, the brain lesions could be seen on at least two of the original rectilinear views. In the four patients with lesions in the top level (0–4 cm vertical distance from the scalp), the lesion could be seen equally well in both the vertex and transverse section views. In the four patients with lesions in the middle level (4–8 cm) of the brain, lesions were detected with both vertex and section scanning in all, but in the vertex scans definition was poor, and lesion images were easily confused with images of overlying sagittal sinus and underlying oral-nasal uptake. In patients with lesions in the bottom level (8–12 cm) of the brain, three out of four were missed with vertex viewing; all four were clearly demonstrated with section viewing.

We conclude that both studies supplement the routine rectilinear survey by permitting us to detect some lesions that might otherwise be missed and to characterize most lesions better as to size, shape and distribution. The vertex scan is best used for lesions in the upper levels of the brain and is especially useful to distinguish parasagittal lesions that might otherwise be lost in the sinus image. The transverse section scan is more efficient for study of lower levels in the brain and has the special advantage that lesion images are not masked by radioactivity in overlying or underlying structures.

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