LOCALIZATION OF INTRACRANIAL VASCULAR LESIONS
BY RADIOACTIVE ISOTOPES AND AN AUTOMATIC
CONTOUR BRAIN SCANNER*

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During the past ten years, more than 100 reports in the neurosurgical and
nucleonic literature have indicated that radioactive isotopes can provide a use-
ful, painless and safe method for the detection and localization of certain intracranial
lesions. Most authors have agreed that meningiomas, malignant gliomas, and meta-
static neoplasms are readily and sometimes strikingly detected. The degree of success
obtained in localizing other types of tumour and a wide variety of non-neoplastic lesions
has varied considerably among these reports. In this area, it appears that the use of an
appropriate radioactive substance, a satisfactory technique for scanning the head, as
well as suitable devices for discriminating and computing the resulting radiation, may
make all the difference between success and failure.4,6,13,20,21

The reports, for example, on the localization of subdural haematomas by the isotope
method will serve to indicate this variability. Using diiodofluorescein Moore13 found an
increased concentration in one case of subdural haematoma, although the material re-
moved at operation proved to contain very little of the radioisotope, and he suggested
that the increased rate of count over the side of the subdural haematoma might be ascrib-
able to edema of the brain. With the same isotope Peyton and others14 also detected
subdural haematomas, but Ashkenazy et al.1 in 8 subdural haematomas found little or no
evidence of localization.

The results using radioactive iodinated serum albumin (RISA) were reported highly
satisfactory by Dunbar and Ray7 who were able to localize subdural haematoma by this
method in 4 cases. Since they found that the subdural fluid has less radioactivity than
venous blood they assumed that localization was related to the radioisotope being con-
centrated in the brain beneath the region of the subdural clot. In 1 case of bilateral sub-
dural haematoma, Rhody and Nowlis17 were unable to get any localization by RISA.

Sweet and his co-workers5,12,22 reported that they were able to detect 7 out of 8 sub-
dural haematomas using arsenic 74, but that no positive scans were obtained in 3 subdural
haematomas using copper 64. In a chronic subdural haematoma of about 3 months' duration and 5 days following the injection of arsenic, they noticed a somewhat higher
concentration in the membrane of the haematoma as compared to the clot. Planiol,15
using RISA and a careful technique of manual scanning with repeated scans at 1 hour
and 24 hours, was able to localize subdural haematoma in 2 cases.

The reports concerning other types of cerebral vascular lesions, such as those re-
sulting from thrombosis or intracerebral haemorrhage, are even more variable. It
seems difficult to evaluate the usefulness of techniques of radioactive scanning in this
field at the present time. In addition to the points outlined above, the difficulty in
evaluating the isotope technique in terms of its clinical use is also dependent upon the
fact that the complex processes underlying
the differential uptake of radioactive substances, associated with certain intracranial lesions, require much further study. Evidence so far indicates that significant factors include: (1) increased permeability of the "blood-brain barrier" in and about the lesion, and (2) increased vascularity of the lesion as compared to the surrounding normal brain tissue. A third factor, metabolic uptake by the pathological tissue, may also be of considerable importance, particularly in actively growing lesions.

The present report will illustrate with selected cases that increased vascularity is a prominent feature of many intracranial lesions that are detected most readily and localized by the radioisotope method.

These studies were made with an automatic contour brain-scanning device that makes it possible to obtain reproducible scan records of the total and differential concentration of isotope in the head. By using human serum albumin tagged with radioactive iodine 131 (RISA) it was also possible to exploit the selective permeability of normal brain tissue to albumin, as well as the retention of RISA in the circulation for a biological half-life of 4 days which allows for repeated scans to be carried out.

Since the automatic contour scanner differs from the more familiar rectilinear scanning devices described by Sweet and Brownell and by Shy et al., a brief account of the principles will be given. The application of these principles to the localization of intracranial lesions will be evident from the examples described in the case reports. Details of design have been described by Reid and Johns and by Johns and Cederlund. The clinical evaluation of the method in a group of 281 patients with a variety of intracranial lesions has been reported previously. On the basis of assessment of the scans in 115 cases, which were verified as to the presence of intracranial lesions, good or excellent correlation was obtained in 90 per cent with failure of localization in the remaining 10 per cent.

Using the contour scanner and RISA, we have found that chronic subdural haematoma is distinguished by a characteristic pattern of radioactive uptake. The radioactivity of the fluid in the haematoma, as compared to that of peripheral blood, has proved to be surprisingly high.

Inert collections of blood within the cranium are associated with lower levels of activity.

Highly vascular lesions, such as arteriovenous malformation and vascular tumours, show the most intense concentration of RISA. This reaches a high peak immediately after injection and is maintained over a period of several days until the level of RISA in the circulating blood drops off.

These findings will be amplified by selected case reports.

METHOD OF CONTOUR SCANNING

The device utilizes twin scintillation detectors which scan each side of the head in a series of concentric arcs beginning in the parasagittal region (Figs. 1 and 2). The thyroid gland is blocked by Lugol's iodine solution 24 hours before the injection of 300-400 microcuries of RISA. The actual scan takes 30 minutes. Repeated scans may be carried out up to as long as 1 week on the basis of the single injection.

Some of the advantages of the contour

![Fig. 1. Contour brain scanner. (A) Brain scintillation detectors placed at starting position for the scan. (B) Remote-control push-button pedal for manual operation of scanner during positioning of patient. (C) Scan chart on which four metal stampers register counts. (D) Motor control, scaler and computer unit.](image-url)
CONTOUR SCANNING OF RISA IN VASCULAR LESIONS

In order to supplement diagnostic contrast studies, it was desirable that the scan pattern would closely survey the areas, including the parasagittal, anterior-frontal and occipital regions, which present the greatest difficulty in angiography and pneumoencephalography. It was also desirable for anatomical reasons to have the pattern of the scan match the curvature of the head. This, in addition, increases the physical efficiency because the detectors are more closely placed in relation to the tissue with radioactive uptake since the energy of gamma radiation decreases by the inverse-square law. This factor may allow for detection of sources of lower concentration.

Compared to the method of rectilinear scanning in a vertical plane lateral to the head or anterior or posterior to the head, the contour method has certain advantages. The volume of radioactive tissue "seen" is uniform. Because of the placement of the detectors on either side of the midline of the vertex during the first few scanning runs, the effect of the concentration in the sagittal sinus is balanced out. Moreover, the detectors look over the temporal muscle and the high activity in this muscle has not proved troublesome.

The crossed axes of the detectors, as will be described in the examples below, allow for a distinction on the scanning pattern between a lesion that is placed superficially and one that extends deeply into the brain. All the information is registered on a single chart of scanning which indicates the side and the 3-dimensional extent of the lesion.

The total body radiation, using 400 microcuries of RISA, is 50 per cent less than with the 2000 microcurie dose used for positron scanning.

In a more recent design, the Mark III Model, an additional scanning arc has been added, a new type of head holder has been introduced to permit better survey of the temporal region and pulse-height analysers have been used for more nearly accurate discrimination, and to provide for the use of multiple radioisotopes of different levels of energy.

Registration of activity on the scan chart is by a double row of dots, each row corresponding to one detector. Each dot may represent from 100-400 counts. Differences in the accumulated counts from the two detectors with a range of 20-100, are indicated by oblique dashes and demonstrate the lateralization of the increased uptake.

RESULTS

Case 1. Chronic Subdural Haematoma. J.V. was briefly unconscious after being struck by a car 6 weeks before admission to hospital. For 3 weeks he had complained of severe left-sided headache, and for 2 or 3 days prior to admission he began to be confused, vomited several times and had difficulty in speaking.

On admission he was drowsy, confused and mildly dysphasic. He had moderate stiffness of the neck, an irregular right pupil with minimal weakness, and intention tremour in the right upper limb. Deep tendon reflexes were increased and there was a questionable Babinski’s reflex on the right side with bilateral grasp reflexes. The left eye was blind from old scarring of the lens and iris. There was no evidence of papilledema in the right eye.

Roentgenograms of the skull were normal. There was no calcification of the pineal body.

Electroencephalogram showed widespread 5 to 6/sec. slow waves with episodic bursts of high-amplitude 2 to 3/sec. waves maximal in the fronto-central region on the left.

Brain Scan. On the day after admission he was given Lugol’s iodine by mouth, and 300 μc. of RISA intravenously. A scan, completed 5 hours and 15 minutes later, showed a diffuse left-sided increase of radioactivity mainly in the temporo-parietal region (Fig. 3).

Fig. 2. Diagram to show scan pattern traversed by the detectors.
On a repeated scan, completed 24 hours after injection (Fig. 4), there was development of greater differential concentration over the entire left side, particularly in the left temporal region, with some fading off in the occipital and posterior temporal regions. The absence of "see-through" by the opposite detector indicated a superficial lesion (Fig. 5), and the appearance of activity in all channels on the left side was consistent with a widespread lesion.

**Contrast Studies.** Pneumogram showed displacement of brain from left to the right and distortion of the ventricles by a diffuse space-occupying lesion, maximal in the left frontal and parietal lobes. Serial carotid angiography showed slow cerebral circulation, displacement of the midline vessels to the right, and absence of vessels in a zone 11 to 13 mm. wide over a large part of the left hemisphere (Fig. 6).

**Operation.** Immediately following the contrast studies, a left frontoparietal craniotomy was performed with removal of a subdural haematoma from frontal, parietal and temporal regions. The haematoma was 3 cm. thick in the frontoparietal region and 5 mm. thick inferiorly over the temporal lobe. The outer membrane was thick, partly gelatinous and stuck to the dura mater by vascular adhesions. The inner membrane was also gelatinous and not as well developed. The membranes contained red liquid blood and a few small blood clots along the parasagittal region.

**Radioactivity of Tissues.** Specimens of cerebrospinal fluid obtained 6 hours previously and of peripheral venous blood and fluid from the haematoma were measured and the radioactivity was checked in a well counter. Small samples of the membranes of the haematoma were rinsed in normal saline to remove blood on the surface and then weighed as wet specimens before counting. The rate of count of cerebrospinal fluid was in the range of background activity. The subdural fluid was 56 per cent and samples of subdural membrane were 53 per cent, as compared to the activity of venous blood.

**Comment.** This was a moderately large encapsulated subdural haematoma with a total duration of 6 weeks. This scan pattern of diffuse, somewhat patchy uptake appearing in all channels without evidence of deep extension, is characteristic, in our experiences with the contour scanning method, of a subdural haematoma. No doubt a subdural effusion might be expected to give a similar pattern. The increasing differentiation of the uptake over a 24-hour period is of interest. The high radioactivity of the subdural fluid and membranes in relation to that of venous blood undoubtedly plays a role in the localization of the lesion by scanning. The question of how much RISA may also be concen-
trated in the brain tissue of the underlying hemisphere remains to be answered.

Case 2. Angioma. A.J. had an extensive left-sided angioma supplied by the middle and anterior cerebral arteries (Figs. 7 and 8). Immediately after intravenous injection of 400 μc. of RISA, a single manual detector recorded a high peak of activity in the central region over the vascular malformation. Low counts were recorded as the detector was positioned over the frontal and occipital regions or over the opposite side of the head (Fig. 9). At a subsequent study cerebral circulation time was measured by means of a detector placed over the internal carotid artery during intracarotid injection of 60 μc. of RISA. The carotid-jugular time was measured at 2 sec. (Fig. 10) compared to the usual range of 7 to 10 sec. determined by this method.

Brain Scan. The automatic scan record (Fig. 11) showed the highest concentration of radioactivity in the left central region. Deep extension of the lesion was indicated by increased rates of count referred to the frontal, superior central and occipital regions as recorded by the detector on the opposite side of the head. The amount of "see-through" was somewhat higher on the 24-hour scan than on the 48-hour scan (Fig. 12). By plotting the channels that show ipsilateral concentration against the "see-through" from the opposite detector, an indication of the localization of the angioma in the coronal plane can be obtained (Fig. 13).
Fig. 11 (left). Twenty-four hour scan in Case 2. Note intense concentration in central region on left side and “see-through” in frontal and occipital regions recorded by right detector.

Fig. 12 (right). Forty-eight hour scan. Note persistence of concentration over the angioma.

Comment. The differential concentration developed immediately after injection, and persisted almost unchanged on the 48-hour scan except for some decrease in “see-through.” The distinction between this and less active collections of blood will be noted in some of the remaining cases. The rapid carotid-jugular time is of interest. The scans on this patient, given as an illustrative example in the report by Reid and Johns, were among the earliest in our series with the automatic scanner and indicated dramatically the fact that a pool of blood inside the head is one of the obvious factors responsible for a high local activity.

Fig. 13. Diagram to indicate site of the angioma as plotted out in the coronal plane.

Fig. 14. (left). Moderate isotope concentration over right frontal region in Case 3.  
Fig. 15. (right). More localized concentration in right frontal region with some “see-through” in left temporal-occipital regions at 48 hours.
Case 3. Intracerebral Haematoma. Twelve months before admission O.R. was briefly unconscious after being thrown from a car. She was found to have a fractured clavicle, a dislocated shoulder, several fractured ribs and a large haematoma over the right eye. Since then she had complained of right frontal headache.

Five days before admission, while eating breakfast, she had sudden severe headache with nausea and vomiting. The cerebrospinal fluid showed 6,000 red blood cells/ml.

A carotid angiogram showed some depression of the pericallosal artery and displacement of the anterior cerebral vessels to the left side.

Brain scan carried out 15 days after the onset of headache, showed a moderate increase of activity in channels 1 to 5 in the mid-frontal region indicating a right frontal localization (Fig. 14). Forty-eight hours after injection, the scan indicated a relatively low uptake in the mid-frontal region with some increase of counts in the frontal pole and temporal region and “see-through” channels 1, 2, 3 and 4 on the left side in the occipital region (Fig. 15), indicating deep extension of the lesion.

Following this, a pneumogram indicated a large mass in the right frontocentral region (Figs. 16 and 17).

Operation. The frontal gyri were yellow with an area of cortical destruction 2.0 cm. in diameter. Beneath this there was a cavity measuring about 10.0 cm. in its greatest diameter filled with thick, jelly-like blood clots, some of which were quite dark in colour. Histological sections of the blood clot showed a considerable amount of haemosiderin.

Comment. There was evidence of old haemorrhage in this patient’s clinical story, and this was confirmed by pathological examination of the blood clot. The scan was carried out 15 days after a clinical episode suggestive of an additional recent haemorrhage. The extent of the increased uptake was smaller than the area involved by the haemorrhage. On this basis it seems evident that the RISA does not penetrate, to any great extent, into an inert blood clot within the brain. It was concluded that the uptake here was mainly on the basis of the recent bleeding or the edema of the adjacent brain tissue about the clot.

Case 4. Vascular Glioma. R.R. had impairment of memory for 5 months with confusion and dysphasia over a period of 3 months. Lumbar puncture was reported to show normal pressure with a cerebrospinal fluid protein of 85 mg. per cent.

On admission the patient was stuporous, and had a right hemiparesis, bilateral Babinski’s reflex, but no papilledema.

Roentgenogram of the skull indicated medial displacement of the calcified left choroid plexus.

A left carotid angiogram depicted a highly vascular tumour in the left parietal region, the mesial surface being close to the falx (Figs. 18 and 19). Cerebral circulation was slow and the only veins shown on the late films were those running from the tumour to the sagittal sinus.

Brain Scan. In the day following admission, 400 µc. of RISA were injected intravenously after Lugol’s iodine had been given orally. The patient could not be scanned until 46 hours later, and at that time a high concentration was registered over the left temporoparietal region maximal in channels 3 to 8 (Fig. 20). “See-through” was recorded in channels 1 and 2 of the opposite side indicating deep extension of the lesion. Toward
the midline, in the parietal region of channel 2, one sees a "phase reversal" where the pickup by the ipsilateral detector from the superior margin of the tumour is almost balanced by the activity recorded by the opposite detector from the deep mesial extension of the tumour. Plotting the activity from the side of the tumour and the opposite detector shows the site of the tumour in the coronal plane (Fig. 21).

Operation initially was deferred because the patient's condition seemed very critical, and she had given a history of considerable difficulty with speech. However, she improved over the next 4 days with increasing responsiveness and some recovery of the right-sided paralysis.

A left parietal craniotomy was, therefore, carried out to define the histological nature of the tumour. The tumour presented on the surface in the superior parietal region about one convolution behind the postcentral gyrus. The convolution here was widened and greyish in colour, with unusually abundant vessels and veins carrying what appeared to be red arterial blood. This appearance covered an area of about 4 cm. in diameter. Most of the blood supply came from branches of the middle cerebral artery. Deeper in the tumour was grey, granular and yellowish, containing small cysts and areas of necrosis. Grossly its appearance was typical of glioblastoma multiforme. It extended in a wedge deep through the white matter toward the posterior end of the Sylvian fissure, and at its deepest extent was about 6 cm. from the surface. It was separated from the falx by a layer of grossly normal cerebral tissue.

Comment. This tumour was associated with an intense concentration of RISA. The localization was appropriate as to position and size of the region of vascularity, as depicted on the angiogram. Comparison of the lateral film of the angiogram and the scan...
chart would at first seem to show that the highest peak of concentration in the scan was placed lower down than the tumour, as seen on the roentgen-ray film. This, however, is incorrect, and it should be remembered that the channels of the scan chart correspond to points on the curved surface of the head beginning at the midline, whereas the roentgen-ray film is a projection and foreshortening of this curved surface onto a vertical plane. This may be easily confirmed by noting that channel 2, which shows the “phase reversal” indicating the mesial margin of the tumour, would be a recording activity from a parasagittal strip approximately 4 cm. from the midline.

RADIOACTIVITY OF HAEematoma CONTENTS

Subdural Haematoma. The activity of the fluid in the subdural haematoma is indicated in relation to the activity of peripheral venous blood taken as 100 per cent. A higher activity was present in the haematoma of 6 weeks' duration as compared to that found in clots of 3 weeks' and of 5 hours' duration (Fig. 33). In none of these cases was a sample of brain tissue available, and we therefore have no direct figure as to the content of RISA in the brain tissue underlying the haematoma as compared to the activity of venous blood. From a limited number of samples, the activity of brain not involved by any gross pathological lesion is approximately 15 per cent that of the venous blood within the first 30 hours after injection of RISA. While these findings on the activity of the membranes and subdural fluid clearly indicate that they play a very significant role in the detection and localization of these lesions, further studies will have to be carried out to determine what role, if any, the edematous brain underlying the haematoma may have in contributing to the increased activity.

This method incidentally offers a convenient approach to a possible identity of the age of subdural haematomas, and to their mechanism of continuing enlargement.

Intracerebral Haematoma. Low relative values here were to be expected on the basis of Case 3 outlined above, in which the concentration registered on the scan chart was surprisingly small considering the large size of the intracerebral haematoma. Unfortunately the scan in patient R.N., in whom the radioactivity of the haematoma was measured, was unsatisfactory technically.

Epidural Haematoma. A chronic haematoma of about 1 month's duration also appeared to be acting as an inert pool of blood with a low concentration of RISA, a fact in keeping with the clinical findings. This lesion was not detected on a single scan carried out at 19 hours after the injection of RISA. Repeated scans at a longer interval were not possible in this instance.

**CONCLUSIONS**

1. The principles of automatic contour scanning are outlined, and some of the advantages of this technique are compared to methods of rectilinear scanning. In brief, the method allows for a more satisfactory anatomical coverage of the head, increased physical efficiency of radioactive detection, elimination of some of the artifacts caused by sagittal sinus and the vertex "cap" and temporal muscle which interfere seriously with localization in some regions of the head when using the rectilinear scanning technique.

2. It is considered that the use of radioactive iodine tagged on to human serum albumin (RISA) exploits the selective permeability of the blood-brain barrier and
allows for development of better differential concentration than in the case of radioactive electrolytes.

3. The method of contour scanning allows, by means of crossed axes of the detectors, for indication of the surface and deep extent of the lesion with the information being registered on a single scan chart during a half-hour scan.

4. Because the method is not restricted to rectangular grid scanning, necessary for coincidence counting with the use of positron emitters, it is more flexible in regard to the use of multiple isotopes which can be selected out by pulse-height analysis.

5. Selected case reports are given to illustrate the importance of vascularity as a factor in the differential concentration of RISA in certain types of intracranial lesions.

6. By the contour scanning method, subdural haematomas are distinguished by a characteristic pattern of widespread superficial radioactivity appearing in all channels of the scan chart.

7. Samples of fluid and membranes from a small number of subdural haematomas show a high rate of count indicating their important contribution to localization of these lesions by scanning.

8. Intracerebral haematoma and a chronic epidural haematoma showed less radioactivity, and this is in keeping with the less striking concentration of RISA demonstrated by scanning these cases.

9. As noted previously, in the contour-scanning technique and by other types of scanning, angiomatous malformations show most intense concentration of RISA. Tumours, whether gliomas or meningiomas, with a high degree of vascularity, also show an intense concentration of RISA.

10. Further studies using multiple isotopes and techniques of pulse-height analysing with improved instrumentation will undoubtedly bring about a better understanding of the basic factors related to radioisotope concentration in intracranial lesions.

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