BRAIN SCANNING OF SUBDURAL HEMATOMA IN INFANTS AND CHILDREN

BY

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Abstract

We performed ^{99m}Tc pertechnetate brain scanning 27 times on 15 infantile subdural hematoma cases. These scannings gave positive results in 74%, doubtfully positive in 18%, and negative in 8%.

In selected cases, scans were obtained after appropriate delay periods as well as at conventional times. In some cases, scans which were initially interpreted as borderline or negative were read as definitely abnormal on delayed studies.

The radioactivity in the serial blood and subdural samples was measured in a well-type scintillation counter. This study clarified a part of the biodynamic mechanism underlying the successful detection of infantile subdural hematomas by external scintillation scanning. Our result shows that both the subdural fluid and subdural neomembrane influence the production of a positive scan, but whether the isotope is localized predominantly in the membrane or in the subdural fluid depends upon the kind of radioisotope used, hematoma age, the nature of the subdural fluid and the time interval between the injection of radioisotope and scanning.

The total volume of the subdural space is assessable more exactly by the isotope dilution method than by the simple 2-dimensional gamma ray image of the subdural hematoma. This tells more of the clinical value because of its importance in planning the therapy.

Introduction

Since Peyton and his associates[1] in 1952 reported on the localization of a chronic subdural hematoma using radioactive diiodofluorescein, the value of the brain scan in the detection of subdural hematomas has been well documented. The relative merits of brain scanning for subdural hematomas in infants and children, however, are not well defined (Mishkin et al.[2]).

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We performed ^{99m}Tc pertechnetate brain scanning 27 times of 15 cases with subdural hematoma in infancy and childhood. We will also discuss in this paper the mechanism of the development of the positive scan.

MATERIALS AND METHODS

We performed ^{99m}Tc pertechnetate brain scanning 27 times on 15 sub-dural hematoma cases in infancy and childhood and the diagnoses of all these cases were ascertained by subdural taps and/or operations.

There was an excess of males, as the ratio of male to female was 73 to 27. The age distribution according to the first examination was as follows; 8 cases were under one year old (57%), 3 cases were 3 years old or above and the remaining 4 cases were between 1 and 3 years old (Fig. 1). Th hematomas were bilateral in 6 cases (40%), left-sided in 6 cases (40%) and right-sided in 3 cases (20%).

Subdural hematomas occurred as a result of postnatal head trauma in 7 cases (47%), meningitis in 1 case (7%) and as a result of unknown or perinatal head injury in the remainder.

Plain skull roentgenograms were taken in all cases, carotid angio-graphy in 9 cases, electroencephalography in 8 cases, pneumoencephalo-graphy in one case and echoencephalography in 9 cases. Five cases were treated by subdural taps alone, 8 cases by irrigation, one case by external drainage and one case by subduro-peritoneostomy (Table 1).
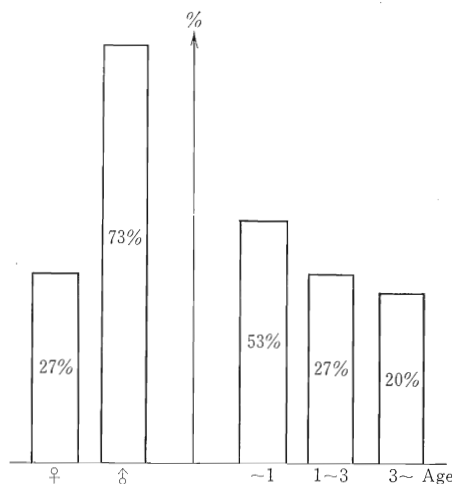

Fig. 1. Age and sex distribution in the entire material
(15 patients, 27 scans)

Table 1. List of all materials

Name	Age (month)	Sex	Side of hematoma	Cause	Result of scan	Avascular area in AG	Treatment
M.I.	17	M	L	PoHT	2–3	L–6mm	tap
K.I.	3	M	B	PeHT	2	L–6mm R–4mm	tap irrigation
M.O.	6	M	B	PoHT	2	L–17mm R–15mm	tap ED SD–PTS
K.K.	5	M	L	PeHT	1–2–3	L–7mm	tap
M.K.	2	M	R	PoHT	1–2	UN	tap
K.S.	78	F	L	PeHT	3	L–1.5mm	irrigation
I.T.	14	M	B	PeHT	0	L–1.5mm R–1.5mm	irrigation
M.T.	44	M	B	PoHT	2	L–1mm R–1mm	tap
A.T.	20	F	L	E	2	L–6mm	irrigation
Y.T.	24	F	L	PoHT	2	L–5.5mm	irrigation
R.H.	6	F	R	PeHT	1	UN	tap
S.M.	11	M	B	PoHT	3	L–2mm R–2mm	tap irrigation
M.M.	15	M	B	PoHT	1–2	L–5mm R–UN	tap irrigation
Y.Y.	36	M	L	PeHT	3	L–4mm	irrigation
I.Y.	3	M	R	PeHT	0–1–2	R–7.5mm	tap irrigation

Abbreviation:

M, male; F, female; L, left side; R, right side; B, bilateral; PoHT, postnatal head trauma; PeHT, perinatal head trauma; E, encephalitis; SD–PTS, subdural-peritoneostomy; ED, external drainage; Result of scan: 0, normal; 1, doubtfully positive; 2, positive; 3, convincingly positive; UN, unknown.

Brain scanning was performed 30 minutes after the intravenous and intramuscular injection or oral administration of 2–5 mCi of ^{99m}Tc per-technetate.   Five cases whose initial scans were normal or in doubt had repeated scannings at intervals of 2–3 hours. As premedication, potassium perchlorate dissolved in simple syrup was administered one hour before brain scanning. In some cases 5 mg/Kg of secobarbital sodium or 1 ml/Kg of trichlorethyl phosphate sodium syrup was administered for the purpose of sedation. A sand cast was used for the fixation of the head. Toshiba 5-inch scanner and 85-hole honey-comb collimator were used for brain scanning.

In our ten cases we compared the brain scan results with the thick-

ness of the hematoma membrane observed at the time of the operation.

In our two cases in which ^{99m}Tc pertechnetate was administered, the counts of the serial blood specimens and subdural fluid were measured by a well-type scintillation counter, and the count ratio of the radioisotope between the subdural fluid and peripheral blood was calculated. The test described above was repeated using RISA and these results were compared with each other.

One hundred mCi of ^{99m}Tc pertechnetate solution diluted 10 times were injected into the subdural space and the head was shaken 1–3 minutes so that the subdural fluid and the radioisotopes injected are mixed completely.

Samples were drawn repeatedly from the subdural space and antecubital vein and the gamma activity of these samples was serially counted. All radioactive counts were corrected for background activity and for decay. The volume of the subdural space was calculated from the total counts per minute injected into the subdural space divided by the counts per minute per milliliter in the subdural fluid. In other words, providing that the volume and the count per ml of the ^{99m}Tc pertechnetate solution injected into the subdural space are a ml and Ca/min., respectively, and the count of the subdural fluid mixed with ^{99m}Tc pertechnetate solution is Cb, the size of the subdural space is calculated by the formula (Ca-Cb) a/Cb.

The density of the hematoma area obtained using a multiple photometer of Tokyo Koden Institute was compared with that of the nonhematoma area. This hematoma to nonhematoma ratio was obtained at 30 minutes and 3 hours after the injection.

Results

Twenty seven brain scannings gave positive results in 74%, doubtfully positive in 18%, and negative in 8% (Table 2).

Attempt was made to correlate the thickness of the hematoma membrane with the grade of positiveness in brain scanning. The result revealed that the thicker the former is, the greater is the latter (Table 3). So the frequent occurrence of a normal or doubtfully positive scan in the absence of a definite membrane or in the presence of a thin membrane, if any, is well recognized.

The transfer of ^{99m}Tc pertechnetate between the subdural space and plasma is illustrated graphically by the activity time curves (Fig. 2). There was a significant and sustained increase in the ^{99m}Tc pertechnetate con-

Table 2. Relationship of abnormal brain
scan to subdural membrane in 8 cases

Scan	Well developed	Thin	None at surgery
Convincingly positive	2		
Positive	1	2	
Doubtful		2	
Negative			1

Table 3. Results of scan

	No.	Percentage
Convincingly positive	6	22%
Positive	14	52%
Doubtfully positive	5	18%
Negative	2	8%
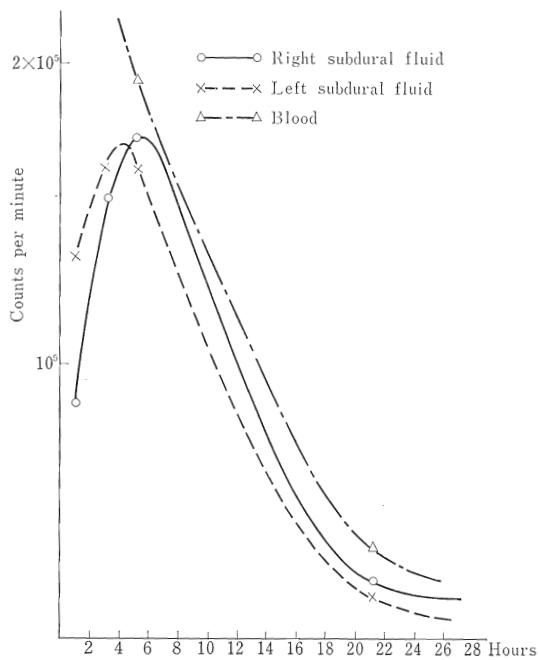
Fig. 2. Concentration of ^{99m}Tc pertechnetate in the blood and subdural fluid after RI was injected intravenously.

centration of the subdural fluid and the peak is between 3–6 hours after intravenous injection. On the other hand, the activity of the peripheral blood declined rapidly after the injection. The ratio of the count in the subdural fluid to that of the peripheral blood was serially calculated. This gave the highest ratio of 90% with ^{99m}Tc pertechnetate which was achieved between 3–6 hours (Fig. 3), but with RISA 49% between 5–7 days after the intravenous injection (Figs. 4 and 5).

The volume of the subdural space was determined by the isotope dilution method in two patients. These values for one patient were 27 ml on the right and 8 ml on the left and for the other patient, 68 ml and 87 ml, respectively. In addition, a study was made on how ^{99m}Tc pertechnetate escaped after it was injected into the subdural space in the former case. Immediately after the radioactive isotope was injected, the counts of the subdural fluid were 249254/ml/min. on the left and 74613/ml/min. on the right but after 4 hours, the counts were 26124/ml/min. and 52243/ml/min., respectively. This shows that the radioactivity decreased more markedly on the left than on the right (Fig. 6).
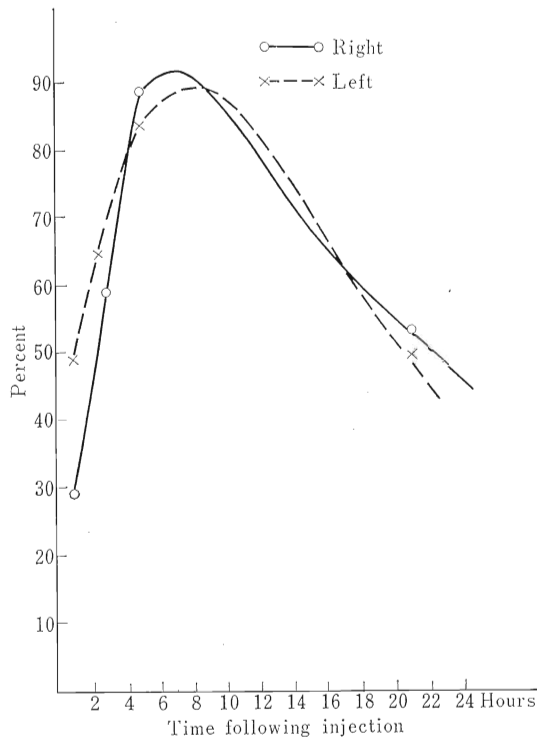

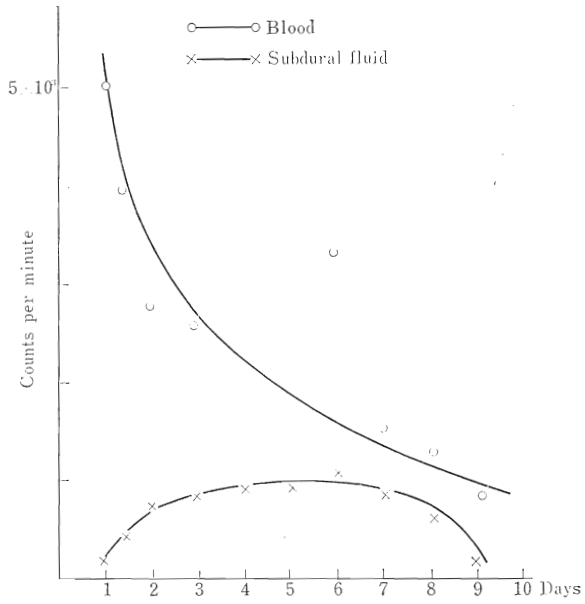Fig. 3. Count ratio of subdural fluid to blood of ^{99m}Tc pertechnetate.

Fig. 4.   Concentration of RISA in the blood and subdural fluid
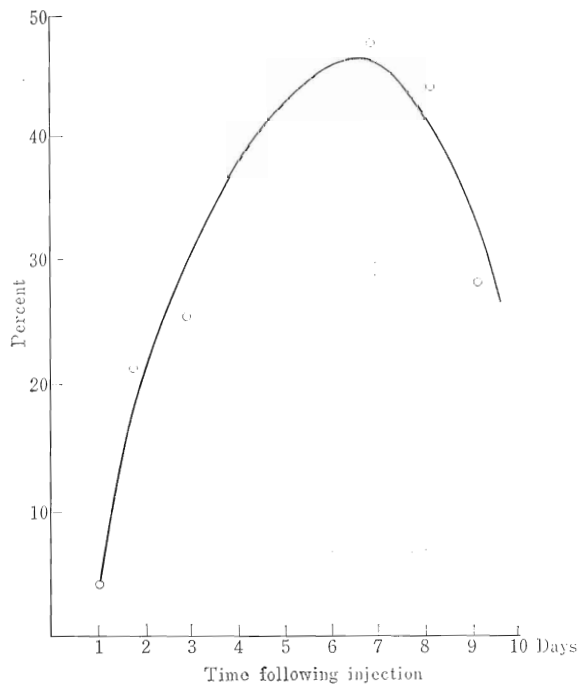   after RI was injected intravenously.
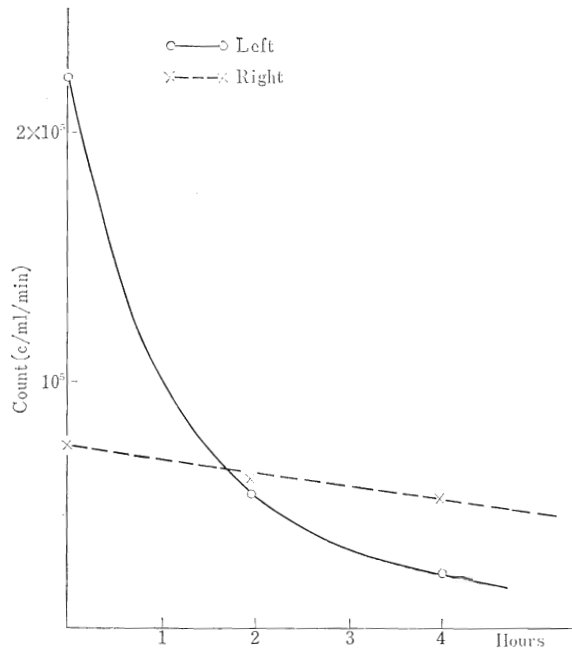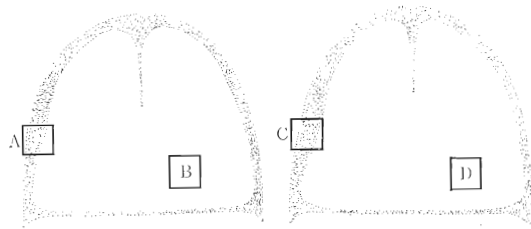
Fig. 5.   Count ratio of subdural fluid to blood of RISA.

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Fig. 6.   Concentration of ^{99m}Tc pertechnetate in the subdural
fluid after RI was injected into the subdural space.

$$\frac{A}{B} = 1.17 \qquad \frac{C}{D} = 1.56$$

$$1 : 1.33$$

Fig. 7.

The hematoma to nonhematoma ratios of a 5-month old subdural
hematoma patient were 1.17 thirty minutes and 1.56 3 hours after the
intravenous administration of radioisotope.   This means that the ratio
is 1.33 times as great after 3 hours as after 30 minutes (Fig. 7).

Discussion

As described earlier, the value of the brain scan in the detection of adult subdural hematomas has been well documented. A review of 17 series in which several radionuclides were used gives an over-all accuracy of 81% in the report of Cowan et al.[3] but the indications and diagnostic efficacy of conventional brain scanning for subdural effusions resulting from head trauma or purulent meningitis in infancy are not defined. David et al.[4] reported positive or suspicious [197]Hg chlormerodrin scans in six children with subdural collections. However, experience by Mishkin et al.[2] with [197]Hg chlormerodrin and ^{99m}Tc pertechnetate in twelve cases does not look as promising. Nine of their cases were infants with traumatic effusions or subdural hematomas. Scans with [197]Hg were normal in three patients with large bilateral subdural fluid collections. Four of the six infants scanned with ^{99m}Tc pertechnetate did show abnormal foci, but only one of the positive studies correlated with the clinical findings and location of the subdural hematoma. Scans were abnormal in three infants who developed subdural effusions in association with purulent meningitis. One of the postmeningitic cases showed symmetrical crescentric increases in the uptake of [197]Hg chlormerodrin corresponding to the unencapusulated viscous fluid collection over both cerebral hemispheres. The other cases had bilateral effusions and membranes, but [197]Hg chlormerodrin in one and ^{99m}Tc pertechnetate in the second disclosed only a single focus of increased radioactivity over one side of the head on the anterior scans.

In contrast, we found in our series of 15 cases that scanning was positive and suspicious in 92%. This accuracy is somewhat lower than that ever reported in adult subdural hematomas, but far higher than that in infantile subdural hematomas ever reported. The accuracy depends, we believe, in addition to the scanning equipment, technique of investigation, and nature of the isotope, on the hematoma age, the nature of the subdural fluid, the thickness of the hematoma membrane and the interval between the injection of radioisotope and scanning, as will be described later.

Neurological examination is mandatory in diagnosing subdural hematoma, but there is no clinical picture which is absolutely characteristic of this lesion in infancy (Ingraham et al.[5]). Fujiwara[6] reported on the cases which had been present for a long time with no apparent symptomatology. Of added interest in the fact reported by Rabe[7] that patients with focal neurologic deficits on admission had a poorer prognosis than

those without.   Matsumoto et al.[8] reported that in some of their cases severe signs and symptoms which had been present for 2–3 days after head traumas subsided gradually and disappeared in 2–3 weeks.   According to Nakamura et al.[9], the chance for developing increased intracranial pressure from volumes of subdural buid seems to be less than in the adult. However, once the signs and symptoms of increased intracranial pressure in the infants develop, this pressure can lead promptly to serious chronic or acutely fatal results.   All these facts described above suggest that early diagnosis and treatment is mandatory in preventing infants from irreversible sequelae resulting from too late management, because the brain in the early stage of rapid development can easily result in irreversible damage from subdural hematoma (Crosby[10], Matsushima et al.[11]).

The typical scan pattern is that of an abnormal peripheral increase in radioisotopic uptake visible primarily in the anterior and posterior views. This "crescent" configuration is not, however, pathognomonic of a subdural hematoma, and similar scans have been associated with a variety of conditions including scalp trauma, scalp infection, craniotomy defects, subdural or epidural abscesses, pachymeningitis, peripheral metastatic tumor, Paget's disease and brain infarcts (Bernard[12], Ciric et al.[13], Cowan et al.[3], Mishkin et al.[14], Quinn[15] and Williams et al.[16]).   Quinn et al.[17] and Wang[18] both reported respectively on cases of dural metastatic tumor with crescent configuration by brain scans and we[19] reported on a subdural empyema with the same configuration.   This occasional lack of specificity does not detract greatly from the usefulness of this procedure to the clinician and it functions greatly as a screening test not only because of its ease of performance, lack of morbidity, and relative accuracy but also because reexamination is possible also in severely ill children.

A true indication of the intracranial extent of a subdural effusion may be gained by rectilinear scanning after ^{99m}Tc pertechnetate is injected directly into the subdural space.   This subdural scintigraphy and radioisotopic dilution method described above remains a safe and useful radiologic test to study the degree of craniocerebral disproportion associated with this disease and to observe a definite correlation with the success of treatment and the prognosis in individual cases (Mishkin et al.[2], Rabe et al.[20]).

According to Morel[21], the detectability of this lesion depends greatly upon the interval between the injection of radioisotope and scanning. Considerable blood levels of radiopharmaceuticals persist when brain scans are performed in the early phase after injection, obscuring the area of lesions.   If the scans are delayed over 3 hours in the case of ^{99m}Tc per-

technetate, the blood vascular background is diminished and the resulting scans show lesion enhancement. His selected cases were studied by the delayed scan and significant improvement was noted in the scan interpretation. These findings, he described, were frequently noted with subdural hematomas. We ascertained this fact using a densitophotometer. The result is that the hematoma to nonhematoma ratio in density is greater at 3 hours than at 30 minutes after injection. So repeated brain scanning has been advocated for a better definition of hematomas which are not clearly demonstrated or missed on scans obtained soon after the injection of radioactive test materials.

The mechanism of development of a positive scan remains in dispute despite studies by several investigators. There are 14 papers which dealt with it (Table 4.) The sites of the source of positive scan advocated are classified as follows: 1) A well-developed, well-organized subdural membrane; 2) The brain immediately subjacent to the subdural hematoma; 3) The subdural fluid; 4) Both the subdural fluid and membrane. The first site was advocated by the following two authors: Using diidofluores-

Table 4. List of the authors who dealt with mechanism of development of a positive scan

Author	Year reported	RI used	Adjacent brain	Subdural membrane	Subdural fluid
Moore	1953	Rdlf[1]	*		
Dunbar et al.	1954	RISA	*		
Crosby	1956	32_P			*
Sweet et al.	1961	74_{As}		*	
Feindel et al.	1961	RISA		*	
Brinkman et al.	1962	203_{Hg}		*	
Mealey	1963	74_{As} RISA		*	
Kramer et al.	1964	203_{Hg}			*
Williams et al.	1965	197_{Hg}		*	
Gilson et al.	1965	197_{Hg} 203_{Hg}		*	
Zingesser et al.	1966	197_{Hg}			*
Nagai et al.	1967	197_{Hg}		*	
Mishkin et al.	1969	203_{Hg} 99_{Tc}		*	*
Cowan et al.	1970	RISA 99_{mTc}		*	*

[1] Radioactive diiodo-fluorescein

cein Moore[22] found an increased concentration in one case of subdural hematoma, although the material removed at operation proved to contain very little radioisotope, and he suggested that the increased rate of count over the side of the subdural hematoma might be ascribable to the edema of the brain. Similar studies by Dunbar et al.[23] with RISA showed that the subdural fluid of four patients contained much less of this substance than was found in the venous blood. They suggested that the hematoma caused alterations in the vascularity of the brain permitting "leakage" of additional isotope into the entire ipsilateral hemisphere.

The second site was advocated by Sweet et al.[24] using [74]As, by Feindel et al.[25], RISA, by Gilson et al.[26], [197]Hg and [203]Hg and by Mealey[27], [74]As. They noticed a higher concentration in the membrane of the hematoma as compared with the clot and suggested that the one common denominator for positive scans seemed to be the subdural membrane. Similar reports by Brinkman et al.[28], Macginnis et al.[29] and Nagai et al.[30] were made through the configuration of positive brain scan.

The third site was proposed by the following authors. That is, the subdural fluid plays the most significant role in the localization of the lesion by scanning. According to Crosby[31], radioactive phosphrus (P-32) was injected intravenously in 29 subdural cases. Samples of subdural fluid and blood were obtained 3 hours later. Then the contents of RI in the subdural fluid was expressed in comparison with that in the plasma (subdural activity), and he suggested a higher concentration of RI in the subdural fluid than in the subdural membrane. Similarly Kramer et al.[32] in 1964 and Williams et al.[33] in 1965 reported that the injected [203]Hg remained more in the subdural fluid than in the subdural membrane and peripheral blood. The same idea was proposed by Zingesser et al.[34] in 1966.

Mishkin et al.[14] using RISA, [203]Hg and ^{99m}Tc and Cowan et al.[3] using ^{99m}Tc reported that the values for RI after injection reflected a progressive transfer of this substance into the subdural fluid and equilibration with the contents in the samples of the membrane. Compared to the decreased plasma levels there is a relatively increased level of radioactivity in the lesion.

Among the four sites described above, our result agrees most with the last one. We would like to conclude here that in the case of ^{99m}Tc pertechnetate the presence of both the well-developed, well-organized subdural membrane and subdural fluid would influence the production of a positive scan. Firstly, correlation of the thickness of the membrane with the production of the positive scan (Table 1) supports the idea that the

presence of the subdural membrane can be a common denominator in the production of a positive scan.

And we observed that the injected ^{99m}Tc pertechnetate solution progressively transfered into the subdural fluid and the value for the RI in the subdural fluid reached equilibration with the contents of the peripheral blood or even became greater in some cases, 3–6 hours after injection of RI. ^{99m}Tc pertechnetate is the first RI ever reported in these kinds of experiments. In the case of RISA, however, its highest value in the subdural fluid was 49% of that in the peripheral blood. So it is concluded here that the subdural fluid influences the production of the positive scan more significantly in the case of ^{99m}Tc pertechnetate than in the case of RISA, though we have to compare, in the strict sense, the contents of the RI in the subdural membrane with that in the subdural fluid serially after the RI injection. Whether the isotope is localized primarily in the membrane or in the subdural fluid depends not only upon the kind of radioisotope used but also on the hematoma age, the nature of the subdural fluid and the time interval between the injection of radioisotope and scanning.

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