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Cerebro-Pulmonary Scan Using Macroaggregated Albumin as a Quantitation of Intracerebral Arterio-Venous Shunting

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Recent advances in neurosurgical treatment of intracerebral arteriovenous malformations require more information about the abnormal hemodynamics of the shunt flow. Although some information can be obtained by a conventional cerebral angiographic technique, the potential value of angiography has not been fully exploited in the quantitative measurement of the blood flow through the vascular malformation. There is a need to establish a new technique for more precise quantitative measurement of the flow.

In the present investigation we have developed a new radioisotopic technique with I-131 labeled macroaggregated human serum albumin (MAA) for this purpose. This report is an assessment of the technique in six patients and two angiographically normal subjects who received a total of 13 intra-carotid injections. By means of this isotopic technique, pre-operative measurements have been compared with those after neurosurgery in conjunction with cerebral angiography.

METHOD

A dose of 50 to 200 μc of I-131 MAA (1 mc/1 mg of albumin), 20 to 100 microns in particle size, containing 0.05 to 0.5 mg of albumin, dissolved in 5 ml of warmed saline solution, was injected into the common carotid artery on the diseased side percutaneously. To prevent the accumulation of ^{131}I in the thyroid, following metabolism of labeled MAA, 0.5 ml of Lugol's solution was administered orally before the injection.

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Immediately after the injection, the uptakes of the isotope were measured over the skull, in anterior-posterior and lateral projections, over the four parts of the lungs and over the liver. In this study the sum of four individual radioactivities was considered to be the total radioactivity of the lungs. The measurements were performed with a 2 × 2 inches NaI(Tl) crystal scintillation detector having a wide-angle lead collimator. The inside of the collimator had an opening of 10 cm diameter and its length was 9 cm. The collimator was used for measurements over the whole skull. Distances between the crystal and the surfaces of the skin were 18 cm for measurements in lateral projection, 11 cm for measurements in anterio-posterior projection. The lungs and liver were

TABLE I

LOCATION OF ARTERIO-VENOUS MALFORMATION AND TYPE OF NEUROSURGICAL PROCEDURE

Case	*Age*	*Sex*	*Site of Lesion*	*Type of Treatment*
1	17	female	right centro-parietal region	artificial embolization with a liquid plastic[1] and clipping of the right anterior cerebral artery
2	20	male	right lower frontal region	extirpation
3	37	male	left parietal region	artificial embolization with a liquid plastic[1] clipping of the left anterior cerebral artery and ligation of efferent vessel
4	25	male	left parietal region	ligation of afferent and efferent vessels
5	41	male	left temporal region	ligation of afferent and efferent vessels
6	29	male	left lower frontal region	extirpation[2]
7, 8		male	angiographically normal	

[1]Intraluminal application of dimethyl polysiloxane (Phycon — 6500).
[2]Died after the surgery.

measured at the crystal-skin distance of 9 cm in anterior-posterior projection. Pulses from the detector were selected by a single channel pulse height analyzer set to accept the full width of the 360 keV photopeak.

Profile scans from the top of the head to the toe were performed in a supine position using a 3 × 2 inch. NaI(Tl) crystal detector housed in a lead slit collimator with 2 cm slit width and 15 cm length. Scanning speed was 16 cm per minute and chart speed was 4 cm per minute.

Following profile scan, area scans covering the skull and lungs were performed in some patients. The area scanner was equipped with a 3 × 2 inch NaI(Tl) crystal and 37 hole focused lead collimator. Dot and photo-display system were employed simultaneously to record scanning data. Cerebral hemisphere scans were carried out in anterior-posterior and lateral projections and lung scans were done in a supine position.

Since correction needs to be made in counting efficiency for differences in size of the different organs, an angiographically normal subject (case 8) served as an *in vivo* calibration standard for the uptake study. After measuring the uptakes, the same amount of ^{131}I MAA was injected into the antecubital vein

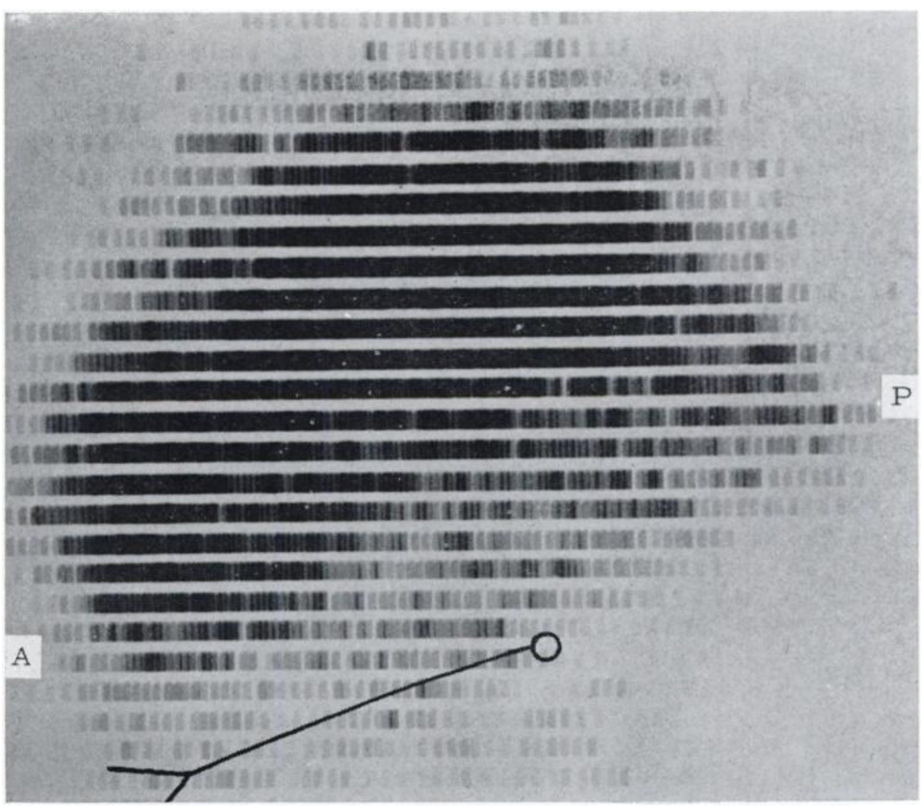

Fig. 1. Normal cerebral hemisphere scan with I-131 MAA.

of the subject; again, the skull and lungs were measured with the same method. A calibration factor (f) was calculated as follows:

$$f = S_1 / L_2 - L_1$$

where S_1 is radioactivity of the skull after intra-carotid injection and $L_2 - L_1$ is the net radioactivity of the lungs as a result of intravenous injection.

Using the following equation, the shunt blood flow through the malformation can be expressed in terms of percentages on the total blood flow in one side of the cerebral hemisphere.

$$\text{relative shunt flow} = (f\,L / S + f\,L) \times 100\%$$

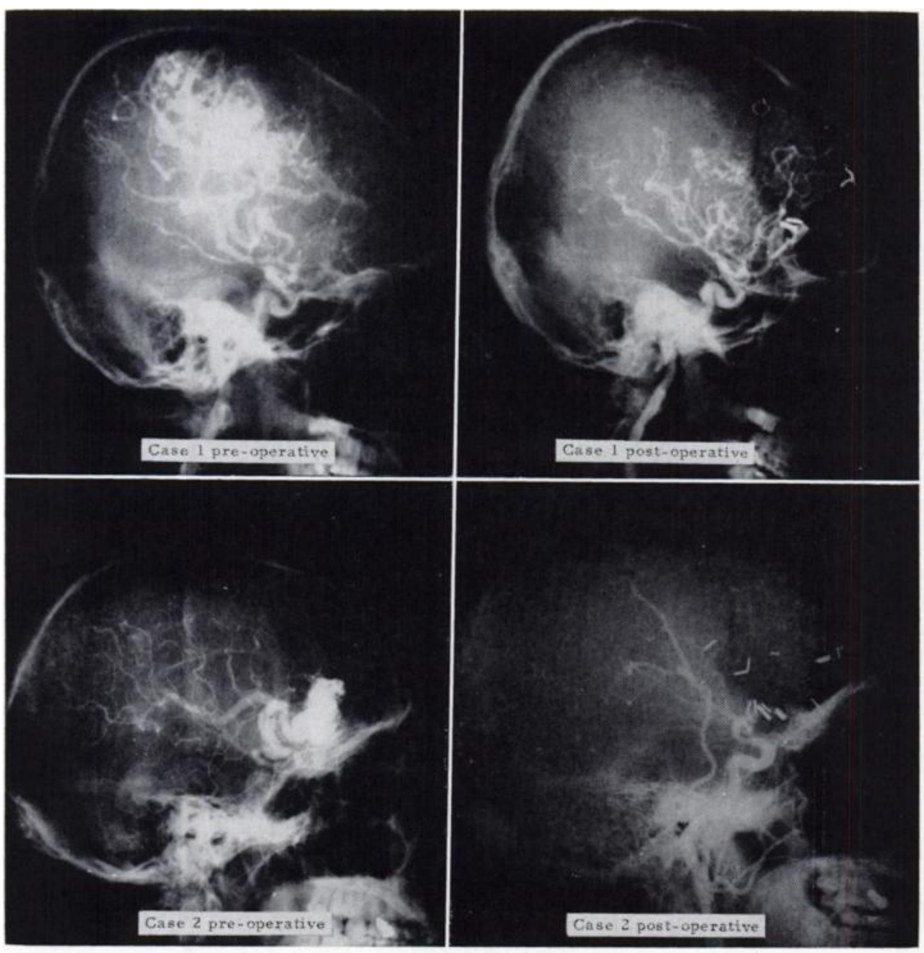

Fig. 2A. Angiographic views before and after neurosurgery.

RESULTS

Figure 1 represents a normal cerebral hemisphere scan. The normal scans show no significant evidence of the labeled particles entering the other side of the brain, but usually demonstrate the distribution of the external carotid artery.

Figure 2 illustrates pre-operative angiographic views compared with post-operative views. Figure 3 shows right cerebral hemisphere scans of Case I. The scans, before treatment, show the reduced concentration of radioactivity in the centroparietal region. The scans, after the neurosurgery, show the reduced concentration of radioactivity in the centroparietal region with some extension into the posterior region. Figure 4 represents a right cerebral hemisphere scan of Case 2 after the extirpation showing a markedly decreased radioactivity in the lower frontal and central regions. Note: the decreased concentration of radioactivity corresponding to the malformations, and to occluded and extirpated areas.

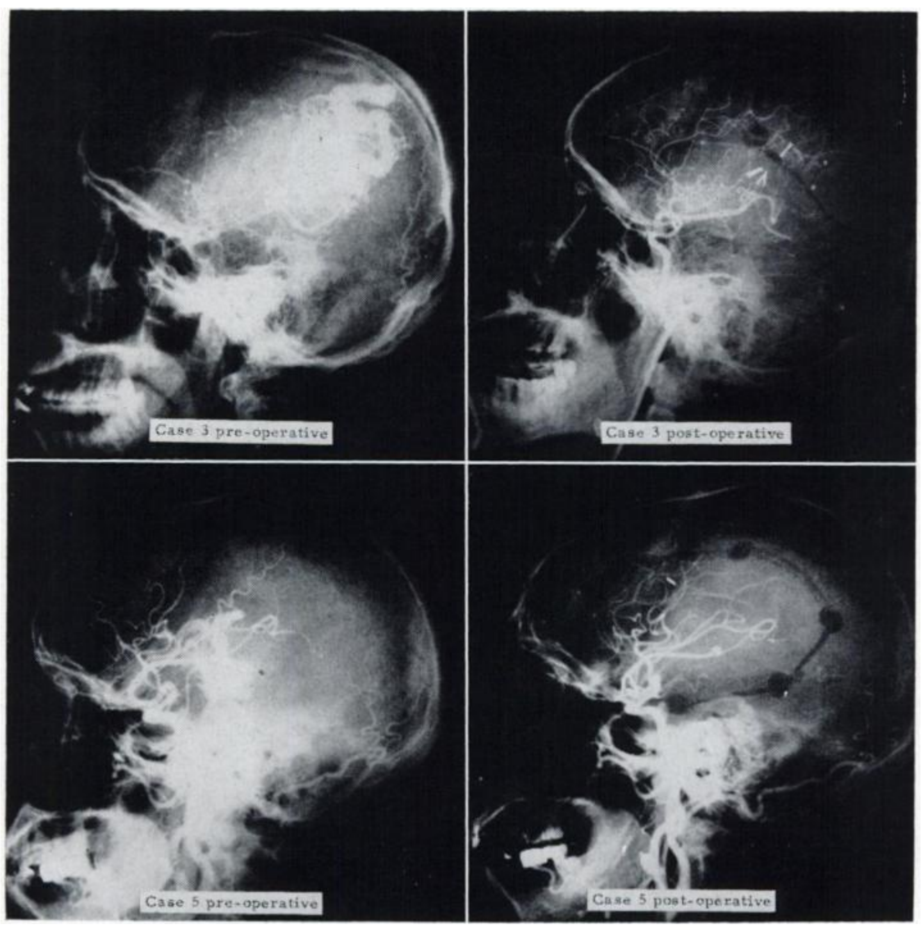

Fig. 2B. Angiographic views before and after neurosurgery.

Figure 5 shows lung scans of Case 2, before and after the neurosurgery. The pre-operative lung scan with an intra-carotid injection of ^{131}I MAA shows marked accumulation of the radioactivity in the lungs. This finding suggests that a large amount of the labeled particles could pass through the brain. After the extirpation of the arteriovenous malformation, the decreased concentration of radioactivity in the lungs can be seen, suggesting that its magnitude could indicate the degree of shunting. The thyroid is visualized, because this patient accidentally failed to receive Lugol's solution prior to the scan.

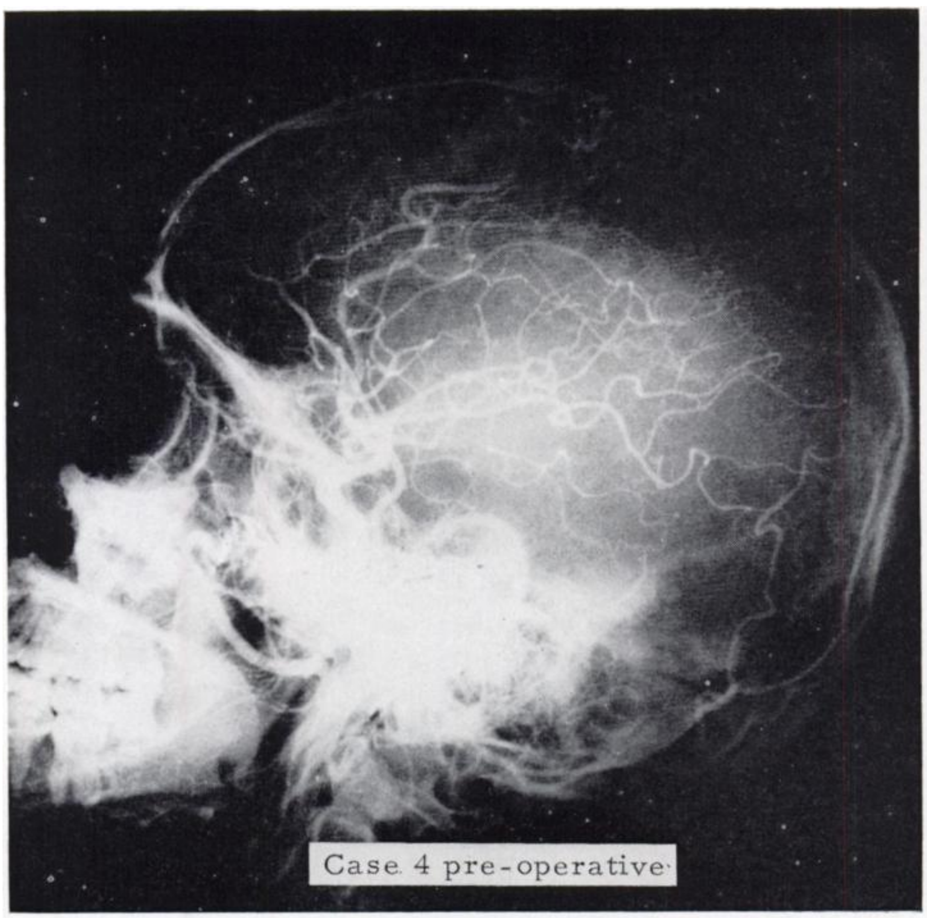

Fig. 2C. Angiographic view before neurosurgery. (See Figure 2D.)

Figure 6 represents profile scans of a angiographically normal subject showing no peak which corresponds to the lungs. Figure 7 shows pre-operative profile scans of the patients compared with post-operative profile scans. The absence or decrease of the accumulation in the lungs shown by profiles, served as a post-operative control to indicate that the neurosurgical treatment had been effective.

In Table II, the relative shunt flow, before and after the treatment, is shown. It is clear that the resulting figure is helpful in assessing quantitatively the shunt flow and that the figure can be taken as an index of the effectiveness of the surgical procedure.

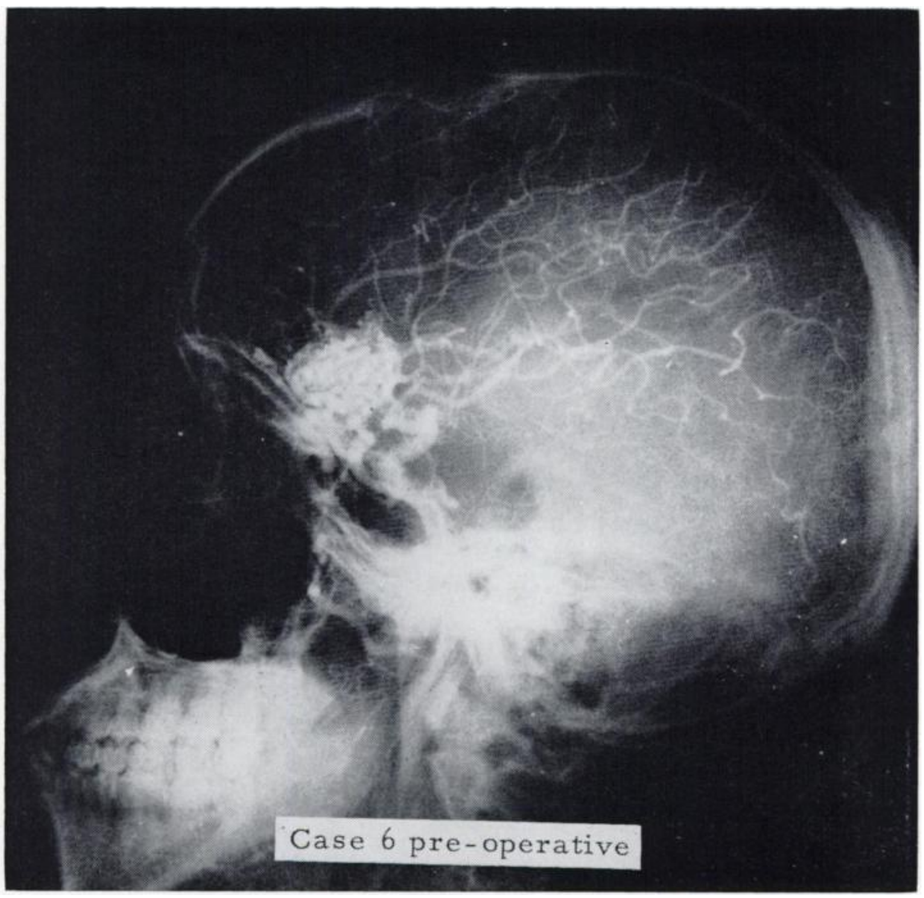

Fig. 2D. Angiographic view after neurosurgery. (See Figure 2C.)

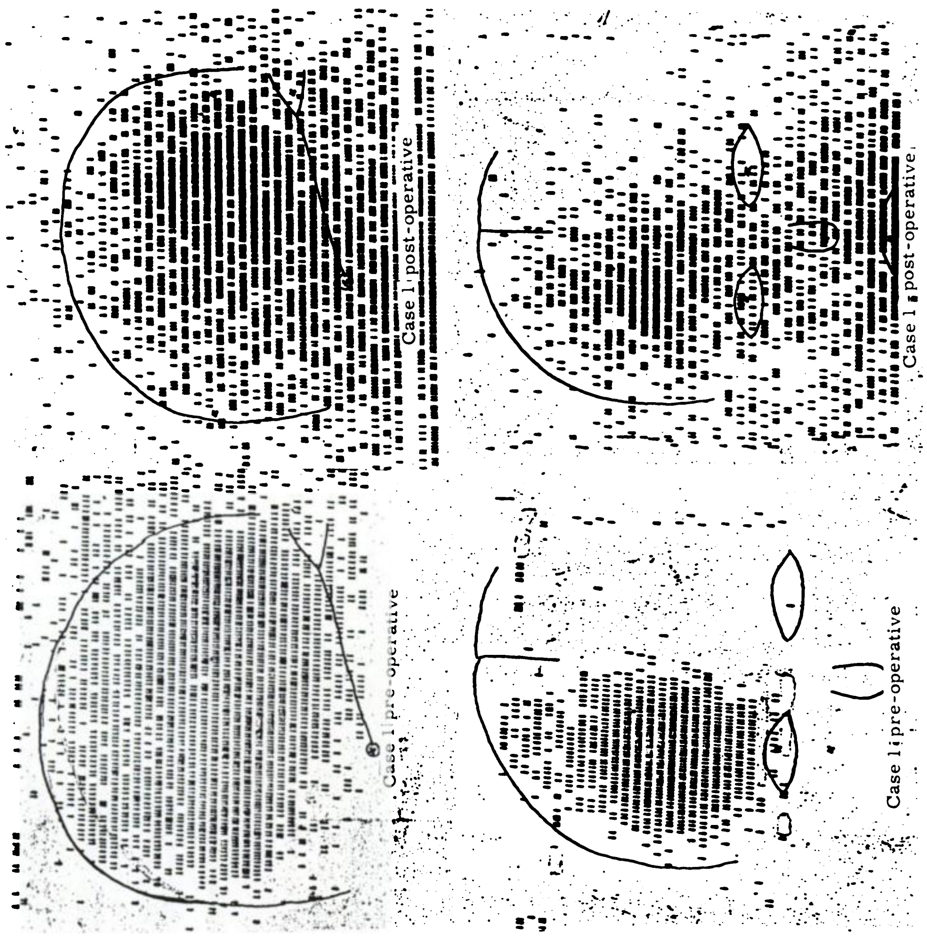

Fig. 3. Right cerebral hemisphere scans of Case 1.

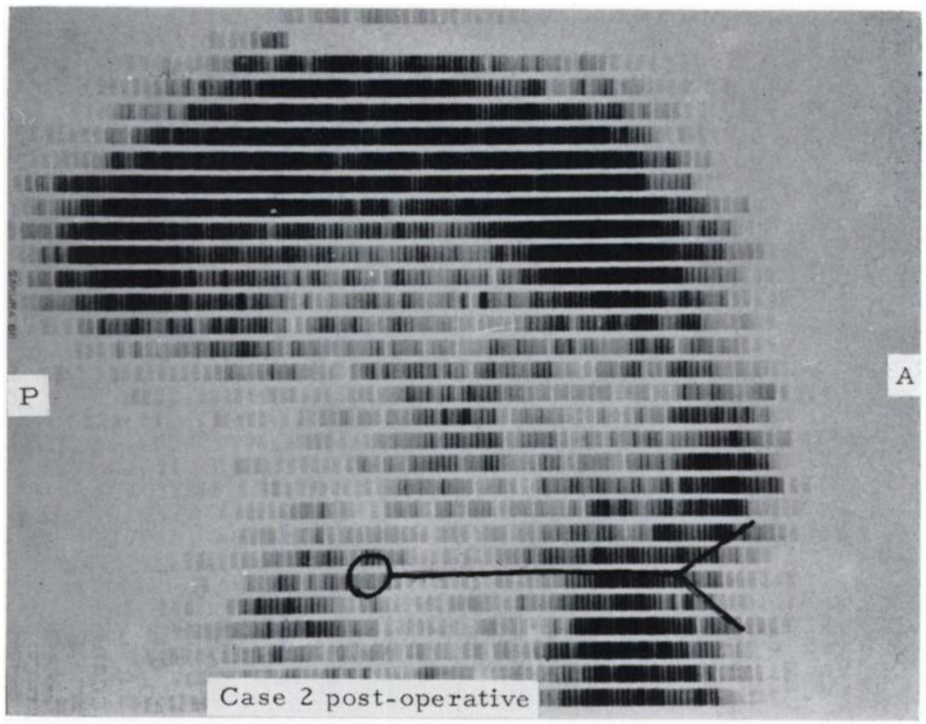

Fig. 4. Post-operative right cerebral hemisphere scan of Case 2.

TABLE II

RELATIVE SHUNT BLOOD FLOW BEFORE AND AFTER NEUROSURGERY

Case	*Relative Shunt Flow (%)*[1]	
	Pre-operative	*Post-operative*
1	76.75	54.23
2	61.22	4.58
3	62.45	8.90
4	26.92	13.90
5	54.03	13.72
6	31.15	/
	Normal Value	
7		9.36
8		5.73

[1]Expressed as a percentage of hemispheric blood flow.

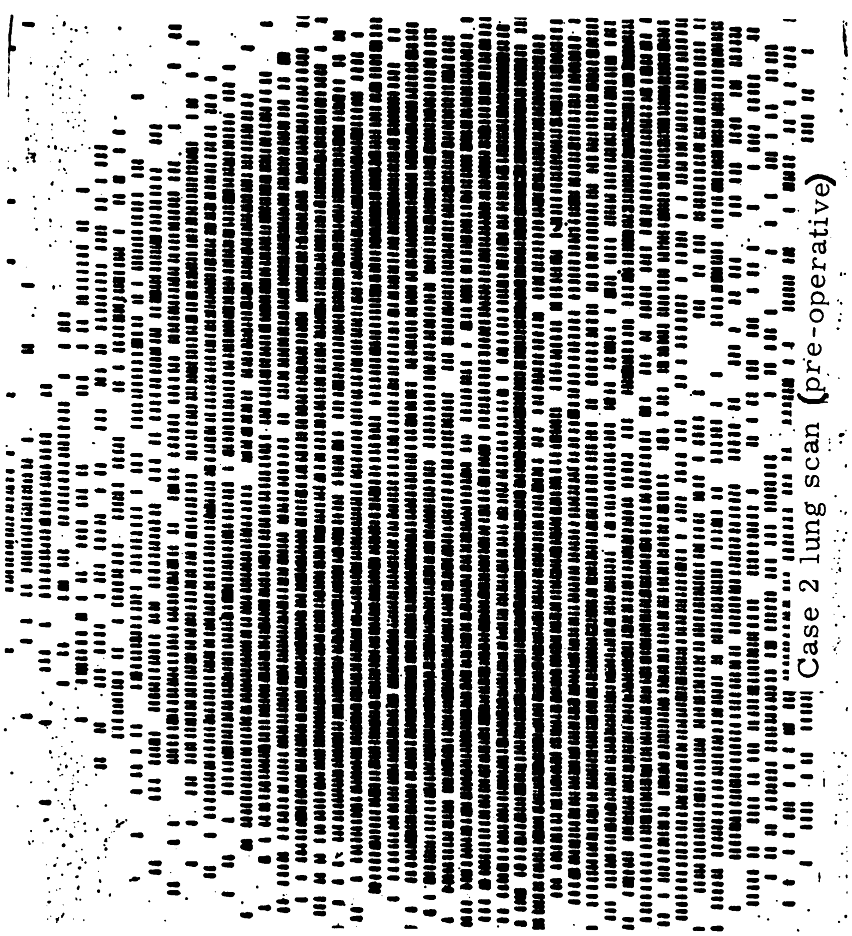

Fig. 5A. Lung scan of Case 2 before neurosurgery. (See Fig. 5B.)

DISCUSSION

Arteriovenous malformations usually produce a reduced concentration of radioactivity on the cerebral hemisphere scans with MAA, because the labeled particles which are expected to lodge in the capillary bed in the areas pass instead through the abnormal vascular fistulae. Findings on the area scans are compatible with the observations of cerebral angiography, but hemispheric scanning does not replace angiography, as the area scanning does not directly locate the site or delineate the type of malformation.

Available tracer methods assessing the intracerebral shunt flow are based upon the clearance curve of ^{85}Kr or ^{133}Xe injected into the carotid artery (2), and the uptake curve of ^{131}I labeled iodoantipyrine injected intravenously (3). Only gross differences, however, may be demonstrated with such methods.

Since the introduction of MAA for use in lung scanning, Taplin and associates attested to the safety in animals of intra-carotid injections of the material (4-6) and Rosenthall and associates reported an assessment of brain scanning in 42 patients with intra-carotid injections (7, 8) and in 7 patients with the vertebral artery injection of MAA (9). One case with intracerebral vascular malformation

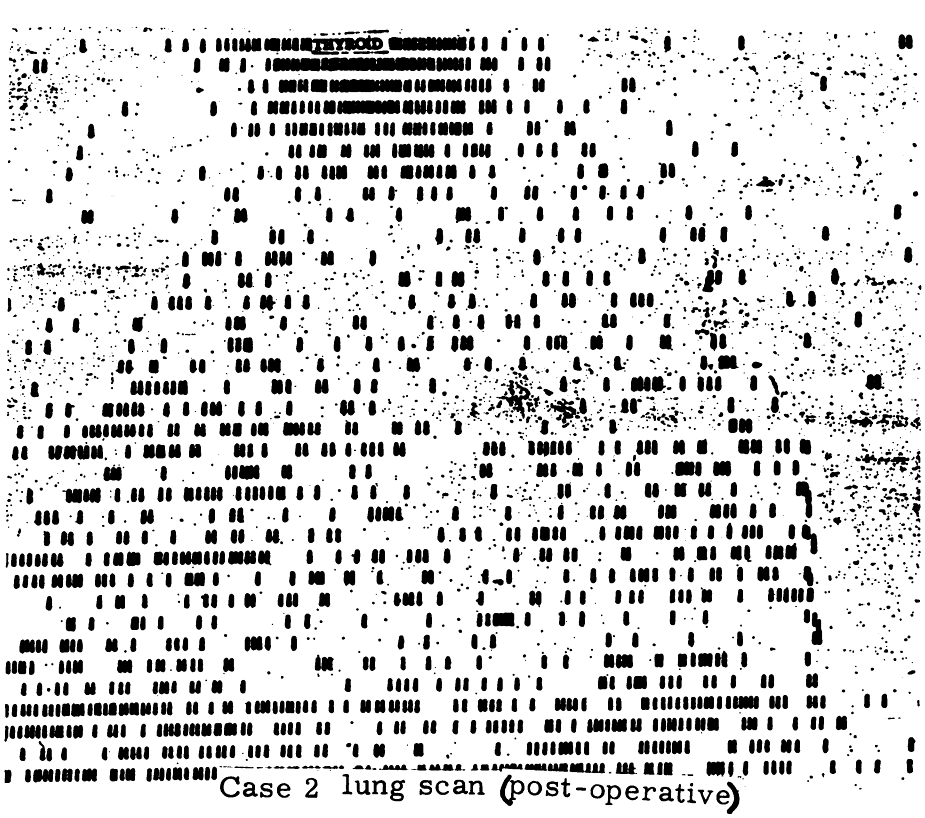

Fig. 5B. Lung scan of Case 2 after neurosurgery. (See Fig. 5A.)

which could be detected by monitoring the lungs was reported by Rosenthall (8). Using a similar principle, the portal systemic shunts were detected by Ueda and associates (10) and Tauxe introduced I-131 MAA for detection of cardiac shunts (11).

The relation between the radioactivity over the skull and lungs, however, may be useful in a quantitation of shunt flow, because in normal cerebral circulation there can be no significant pathway for the labeled particles to traverse the brain microcirculation and lodge in the lungs.

Our experience indicates that the uptake study and cerebropulmonary scanning serve as valuable adjuncts to cerebral angiography. The fact that our method described herein is a useful technique suitable for pre-operative and post-operative follow-up, makes it of great value to surgeons involved in the neurosurgical procedures of the intracerebral arteriovenous malformation.

To measure the actual volume of the shunt flow, direct measurements of blood flow in the carotid artery are now in progress.

In this study, no brain insult was revealed clinically, but great care must be taken about the safety in the human use of MAA by carotid injection and this technique should be limited to selected cases until the safety of intra-carotid injection of the material is firmly established in man.

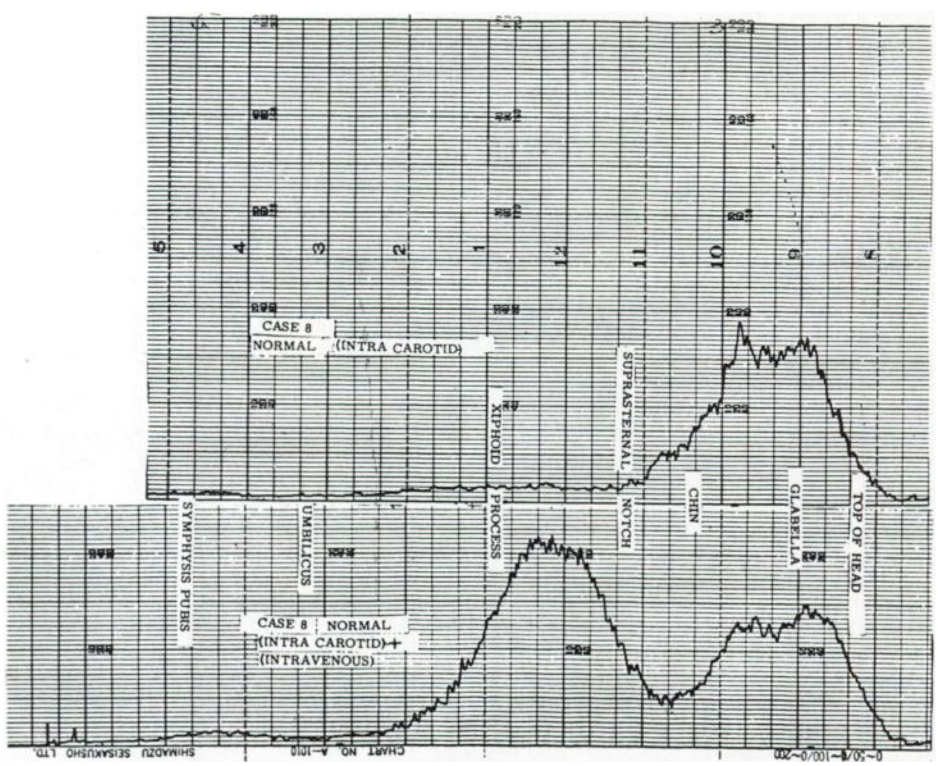

Fig. 6. Profile scans of a normal subject (Case 8) after intra-carotid injection, followed by intravenous injection.

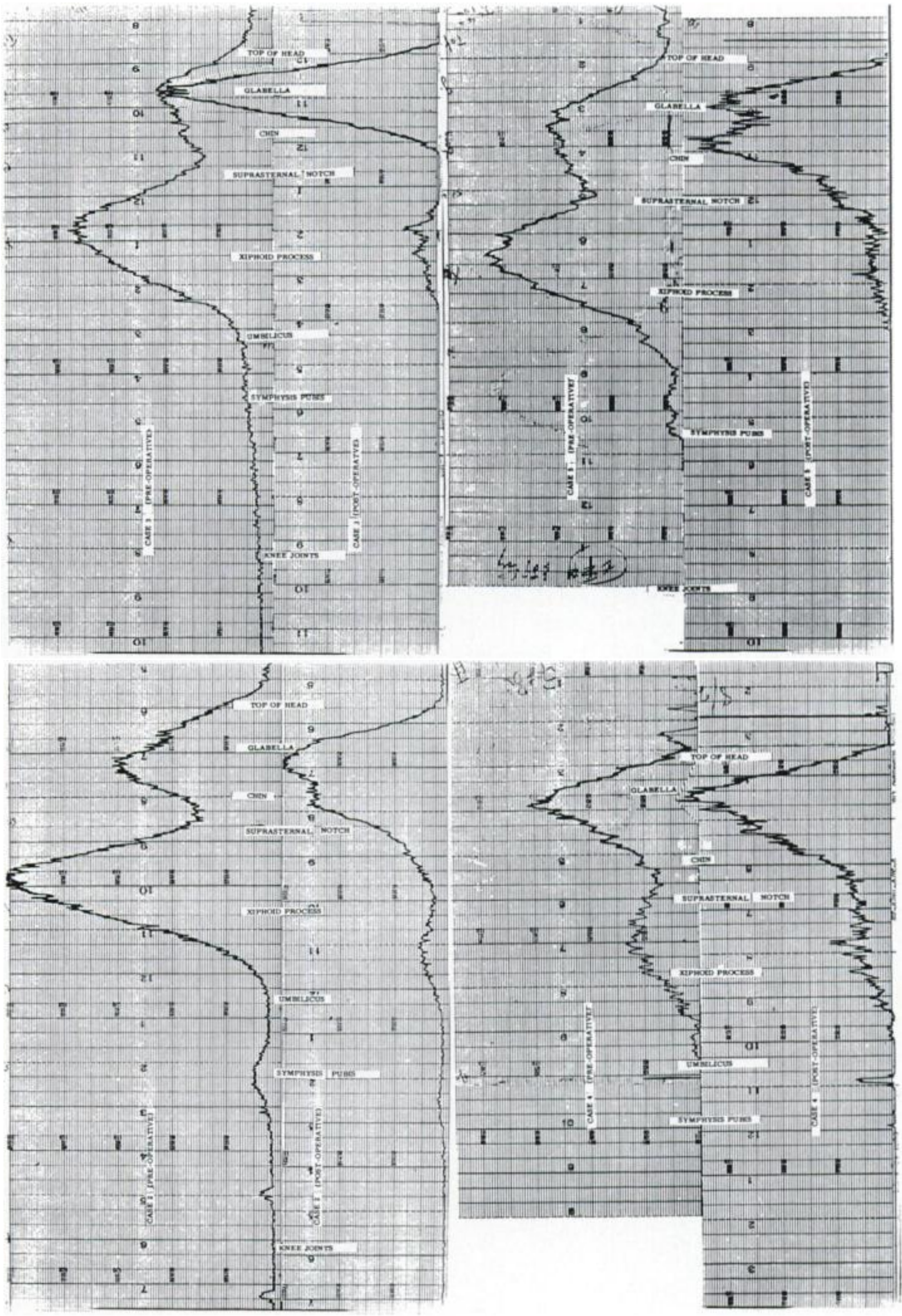

Fig. 7. Profile scans of patients before and after neurosurgical treatment.

SUMMARY

A technique for cerebro-pulmonary scanning with ^{131}I labeled macroaggregated human serum albumin was developed for quantitative measurement of the shunt flow through intracerebral arteriovenous vascular malformations. This report is an assessment of the technique in six patients and two normal controls with intra-carotid injections before and after neurosurgical treatment.

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