CEREBRAL ANGIOGRAPHY IN “BRAIN TUMOR SUSPECTS”

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This is a report of the angiographic findings in a consecutive series of “brain tumor suspects” seen at the Johns Hopkins Hospital during a period of approximately one year. While the concept of “brain tumor suspect” is rather vague, we have used the term to include all cases in which diagnostic procedures such as pneumoencephalography, ventriculography or arteriography were carried out to eliminate the possibility of an intracranial neoplasm. We realize that our index of suspicion is rather high and that at times such procedures were done when we thought the possibility of neoplasm remote. Some patients, had they been seen on the average neurological service, would probably have been classified arbitrarily as having cerebrovascular disease and discharged without the benefit of these techniques. For example, we have made such special examinations in all cases of convulsive seizures occurring for the first time in adult life.

TECHNIQUE OF ARTERIOGRAPHY

Percutaneous puncture of the carotid artery was practiced after infiltration of the skin of the neck with procaine. If the vessel could not be cannulated within a reasonable time, an incision was made and the vessel injected by direct vision. In this series of cases, the carotid artery was successfully punctured percutaneously in 92 of the 96 patients.

The roentgenograms were made in series of 3 films, taken at 1 sec. intervals after the injection of 15 cc. of 35 per cent diodrast. Stereoscopic views were obtained by shifting the x-ray tube and repeating the procedure. As a routine, stereoscopic frontal and lateral projections were made, necessitating 4 injections of the contrast media. The 3 serial films usually demonstrated arterial, capillary and venous phases of the angiogram. There appeared to be great variation in the cerebral circulatory time. Occasionally the arterial phase of the cerebral circulation coincided with the capillary phase of the circulation within the neoplasm; at times the contrast medium remained in the tumor after it had disappeared from the cerebral vessels. These variations in cerebral circulatory time made it necessary to have serial films for good visualization of the intracranial vessels.

During the injection of the diodrast, the patient usually complained of a pain in the neck or head and occasionally jerked or jumped. With proper preparation, however, few complications occurred. Transient hemiparesis and/or aphasia has been seen in 4 patients of this series following angiog-
In only 1 case of suspected cerebral thrombosis could the procedure have been contributory to the patient's demise.

RESULTS OF ANGIOGRAPHY

Some 96 "brain tumor suspects" have been subjected to angiography. Of the 93 successful angiograms, we have been able to verify the diagnosis by subsequent operation or autopsy in 54 cases. In 8 cases the angiographic find-

![Fig. 1. A. (O. A.) Lateral angiogram (arterial phase) showing a large meningioma of the left olfactory groove displacing the anterior cerebral artery superiorly and posteriorly. A hyperostosis of the tuberculum sellae is apparent. B. (A. H.) Lateral angiogram (arterial phase) demonstrating a central astrocytoma displacing superiorly the anterior cerebral and inferiorly the middle cerebral arteries. Few vessels can be seen within the tumor.](image)

ings were indicative of a lesion (in 7 instances neoplasm, in 1 porencephaly) but for medical or personal reasons it was not verified; in 31 cases the arteriogram was interpreted as normal, and in 24 of these cases in which air studies were made, pneumoencephalograms did not suggest a space-occupying lesion. In 1 patient having a normal angiogram, a thalamic tumor was demonstrated by an air study.

LOCALIZATION OF TUMOR BY ANGIOGRAPHY

Angiograms may indicate the presence of a space-occupying lesion by distortion of normal vascular structures or by showing the intrinsic vascular pattern of the tumor.
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The site of an intracranial neoplasm may be determined by the displacement of the normal vascular supply of the involved area. In the frontal region, lateral displacement, elevation or depression of the anterior cerebral artery are the usual signs of a space-occupying lesion (Fig. 1A). In the central region, lateral displacement of the anterior cerebral artery and depression of the middle cerebral artery indicate a neoplasm (Fig. 1B). In the temporal lobe, distortion of the carotid siphon, elevation of the middle cerebral artery and lateral displacement of the anterior cerebral artery are common evidence of a tumor (Fig. 2). In the parietal lobe, depression of the middle cerebral artery is the most common finding. Tumors of the occipital lobe often do not distort carotid angiograms unless the posterior cerebral artery is filled fortuitously. Tumors at the base of the brain produce abnormalities in the shape of the carotid siphon, displacement of the middle or anterior cerebral arteries and/or compression of one of these vessels (Table 1). Tumors of the posterior fossa, as originally noted by Moniz and Alves may cause elevation of the posterior cerebral artery (Fig. 3A).

TABLE 1
Angiographic Findings in Sellar and Parasellar Tumors

<table>
<thead>
<tr>
<th></th>
<th>Craniopharyngiomas</th>
<th>Pituitary Adenomas</th>
<th>Meningiomas</th>
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<tbody>
<tr>
<td>Compression of carotid siphon</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<tr>
<td>Displaced 1st curve carotid siphon</td>
<td>4</td>
<td>4</td>
<td>1</td>
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<tr>
<td>Displaced supra-clinoid portion of carotid siphon</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Displaced middle cerebral</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Displaced anterior cerebral</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Compression of artery</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total number of cases</strong></td>
<td><strong>5</strong></td>
<td><strong>4</strong></td>
<td><strong>1</strong></td>
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In the entire group of 42 verified brain tumors, in only 3 instances was the lesion not localized by angiography. Two of these cases were neoplasms of the medio-inferior aspect of the temporal lobe. These patients had initial ventriculograms which were interpreted as normal. In both, on subsequent air studies, the ventricles were distorted by the tumor. In the case of the third normal angiogram two small meningiomas, localized by the type of focal epilepsy, were found over the motor cortex.

In 2 cases a space-occupying lesion was assumed from angiograms, but at operation found to be edema associated with vascular thrombosis.

ANGIOGRAPHIC CHARACTERISTICS OF TUMOR TYPES

The angioarchitectural characteristics of an intracranial tumor have been considered sufficiently specific to warrant a pathological diagnosis (Table 2). Four types of tumors are said to have specific vascular patterns.
I. Vascular Malformations and Tumors

It is to be expected that angiomatous malformations and tumors would be spectacularly demonstrated by angiography. The degree of visualization of such anomalies depends upon the type and extent of the lesion. The angiomatous conditions are divided into true tumors (hemangioblastomas) and vascular malformations. To the best of our knowledge no report has been made of the angiographic appearance of the former, which commonly occur in the posterior fossa. Green and Arana\(^7\) show the carotid angiogram of a

<table>
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<th>TABLE 2</th>
<th>Frequency of Angiographic Characteristics of Cerebral Tumors</th>
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<tbody>
<tr>
<td></td>
<td>Astrocytomas</td>
</tr>
<tr>
<td>Displaced cerebral vessels</td>
<td>4</td>
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<tr>
<td>Intrinsic vascularity</td>
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<td>Increased</td>
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<td>Decreased</td>
<td>3</td>
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<tr>
<td>Loops and sinuses</td>
<td>0</td>
</tr>
<tr>
<td>Total cases</td>
<td>4</td>
</tr>
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</table>

patient who they considered had a cerebral hemangioblastoma but the lesion was not verified by histological inspection.

The usual classification of malformations may be abbreviated for practical purposes as follows:

1. Cavernous angioma
2. Angioma racemosum
   a. Telangiectasis
   b. Venous angioma
   c. Arteriovenous angioma

_Cavernous Angioma._ These tumors, differentiated from the malformations by the fact that nervous parenchyma is not present between the walls of the vascular sinuses, are quite rare and so far as we have been able to ascertain, have not been demonstrated by angiography.

_Telangiectasis._ The common site for telangiectasis is the lower brain stem,\(^6\) which can be visualized but poorly by angiography. Telangiectatic lesions of the cerebral hemispheres are usually associated with some other evidence of phakomatosis. Owing to the small size of the vessels involved in this type of malformation and the poor resolution by the x-rays, it is difficult to demonstrate the lesion by carotid arteriography.\(^*\) Both Engeset\(^13\) and we have attempted the demonstration of the vascular telangiectasis

\(^*\) Although the literature has many references to visualization of individual capillaries by angiography it is impossible by the usual x-ray techniques to resolve an object smaller than 0.1 mm. in diameter. Since capillaries are generally considered to have a diameter less than 50 \(\mu\) it is obvious that individual capillaries cannot be seen in angiograms. The "capillaries" referred to probably represent arterioles 0.3-0.5 mm. in diameter.
associated with Sturge Weber syndrome without success. Green and Arana\textsuperscript{17} state that in one case of this syndrome "peripheral capillary loops" and "abnormal blood vessels of small calibre" were incorporated in the calcified area of the cerebrum.

\textit{Venous Angiomas.} No angiograms of this rare type of cerebral varix have been reported to our knowledge.

\textit{Arteriovenous Angiomas.} This is the most common type of angiomatous malformation encountered and the most favorable for angiographic demonstration.\textsuperscript{12,16,17,24,34,46} Small arteriovenous angiomas, consisting of a few tortuous or coiled vessels, such as illustrated by Govons and Grant in their Fig. 8\textsuperscript{6} and such as we have seen, are asymptomatic until a rupture occurs. The larger angiomatous malformations, commonly the basis of such neurological phenomena as epilepsy, hemiparesis or hemianopsia, may involve a considerable part of one lobe of the brain.

As expected from the pathological anatomy of these angiomas,\textsuperscript{6} angiomas of the arteriovenous malformations of the brain demonstrate enormous channels and sinuses fed by abnormally large, tortuous arteries and drained by hugely dilated veins. The arteries supplying the area are both more numerous and of larger calibre than normal, a fact which Tönnis\textsuperscript{46} and others have noted (Fig. 3B). The circulation of these angiomatous malformations appears to be unusually brisk because of the fistulous communications between arterial and venous channels, and accordingly the lesion is best visualized during the arterial phase of the injection. Yet there appear to be sinuses, perhaps diverticulae, in the malformation from which the blood slowly escapes, for small circular collections of diodrast are often seen within the lesion during the venous phase of the cerebral circulation. The calibre of the venous channels leading
from the malformation is much greater than that of the entering vessels. Angiography usually visualizes well the angiomatous lesion but rarely the normal vessels irrigating the cerebral hemisphere. From the surgical standpoint this finding is important as it suggests that the vascular supply of the cerebral structures is derived from the opposite carotid artery through collateral communicating channels. Thus if ligation of the carotid artery on the side of the lesion becomes necessary, there is presumptive evidence that the cerebral circulation will remain adequate.

II. Glioblastomas

That glioblastomas have a specific angioarchitecture has been recognized and described by many neuropathologists. Although Bailey and Cushing mention the vascular changes in these tumors, a more complete angio-architectural picture has been given by Deery and Hardman, who studied sections taken through the entire tumor. Both of these papers emphasize that the vascular pattern varies from the periphery to the centre of the tumor. In general the capillaries on the periphery of the tumor are dilated and tortuous. In the margin of the actively growing tumor these dilated capillaries have localized dilatations or diverticuli which may serve as arteriovenous fistulae. These aneurysmal sinuses frequently have adventitial thickening and internal proliferation which may be associated with thrombosis. Toward the central portion of the tumor the vessel walls are hyalinized, the lumen closed by thrombi and the tumor tissue necrotic, cystic and undergoing fibrosis. These pathological changes in the different parts of the tumor may be merely temporal stages in the neoplastic development. It should be stated that, although the above description applies to perhaps
two-thirds of the glioblastomas, there are many tumors that do not exhibit such a typical vascular pattern. We would presume that some of the difficulty in classifying a tumor as “angionecrotic,” “angiothrombotic” or “angioproliferative” arises from the fact that biopsy specimens, often small and from only one part of the periphery of a tumor, do not give the complete angioarchitectural picture of the neoplasm.

With this knowledge of the pathological anatomy of these tumors it would be expected that the angiographic picture of the majority of glioblastomas would be characterized by increased vascularity in the margin of the tumor with sinuses, irregular dilatations and vascular loops within the neoplasm (Fig. 4). This is the typical finding in glioblastomas and according to Busch and Christensen.

Fig. 5. A. (V. R.) A lateral angiogram (late arterial phase) to show the vascular pattern of a large parietal lobe glioblastoma. B. (M. M.) Lateral angiogram (arterial phase) to demonstrate the vascular distortion produced by an astrocytoma of the right temporal lobe. Except for one surface artery the tumor appears avascular.

it is suggestive of the angionecrotic type of tumor. This angiographic picture is present in from 53 per cent to 78.5 per cent of glioblastomas. In some angiograms, the typical angioarchitecture, peripheral vascularity to central necrosis (Fig. 5A), is well illustrated. In other cases the increased vascularity may be diffuse and resemble that seen in meningiomas. At times, the tumor may appear to be practically avascular except for one small area of fine angiomatous proliferation. Such gliomas, Engeset emphasizes, should be classified as glioblastomas or as astrocytomas undergoing malignant change.

III. Astrocytomas

It is generally agreed that astrocytomas are relatively avascular tumors. Elsberg and Hare found that in less than half of the astrocytomas examined there were grossly visible blood vessels in the deeper part of the growth and rarely discernible vessels in the periphery. Using a benzidine stain Sahs and
Alexander found that the astrocytomas had the least density of vessels, the smallest calibre of vessel and the most regular of sinusoids of all the glial tumors. Bailey states that the small vessels of astrocytomas are frequently calcified.

It is not surprising then that Engeset considers the angiographic char-
that Moniz’s observation is probably the result of the inclusion of cases that should have been classified as glioblastomas.

The temporal lobe astrocytomas, as noted by Conrad and Quarti, produce a typical angiographic picture characterized by curved elevated middle cerebral arteries overlying a relatively avascular mass (Fig. 6). Complete avascularity suggests, in our experience, a cystic tumor.

IV. Meningiomas

The intrinsic vascular pattern of meningiomas varies so greatly that no typical angioarchitecture can be ascribed to it. The specificity of the angiographic picture is more dependent upon the morphological structure of the lesion than upon its intrinsic vessels. Because meningiomas are circumscribed, encapsulated tumors, clearly demarcated from the brain, they produce regular deformities in the normal cerebral angioarchitectonics, as originally described by Moniz (Fig. 7A).

Moreover, since the blood supply of the tumor frequently is derived from cortical vessels coursing over its capsule and arborizing within it, a basket angioarchitectural appearance with a centripetal spray or network is characteristic of the angiogram (Fig. 7B). The intrinsic vessels, usually of precapillary size, may be so closely packed that the tumor has the appearance of a solid or slightly mottled mass, the so-called “opacification” (Fig. 8A).

Because the tumor invades the meninges and bone, its blood supply may be largely from the external carotid artery and the usual carotid angiogram may demonstrate only the displacement of major cerebral vessels. In some cases the vascular supply is from both internal and external carotid arteries.
For these reasons, it is necessary to inject both carotid arteries with contrast media when a meningioma is suspected.

Although the usual angiogram of a meningioma presents a circumscribed area of increased vascularity, the outline of the tumor may be indistinct, as List and Hodges have noted, and the angiogram resemble that of a vascular glioblastoma. In 3 meningiomas of our series the angioarchitectural pattern simulated that of a glioblastoma, but in only 1 of these cases was a differentiation impossible preoperatively (Fig. 8B).

V. Other Types of Tumor

Moniz, Hemmingson and Engeset describe the angioarchitecture of the oligodendrogliomas as similar to that of the astrocytomas. Metastatic carcinoma has much the same angiographic appearance as the glioblastoma. Lorenz describes a case of meningeal sarcoma in which there was a rich double circulation with arteriovenous anastomoses.

VALUE OF ANGIOGRAPHY

It is apparent that angiography is of value both in localizing the site of a tumor and in indicating its probable pathological structure.

There is evidence to show that the technique is not infallible. Our experience with angiography in tumors of the posterior fossa has been so meagre that we cannot make a statement of its value. But in supratentorial tumors carotid angiography may fail to show tumors of the basal ganglia and midline structures, the inferior temporal region and the occipital region. For the demonstration of such tumors ventriculography is preferable to angiography. In some 13 cases in this series both angiograms and ventriculograms were made either simultaneously or seriatim. In 11 instances the interpretations of the two procedures coincided; in 1 case, a thalamic tumor, the ventriculogram demonstrated the tumor but the arteriogram did not; and in 1 case the arteriogram was positive and the air study negative. In the majority of cases, air studies were not done because the arteriograms were adequate for localization of the tumor. Arteriography seemed to cause less discomfort to the patient than pneumoencephalography or ventriculography and had the distinct advantage that it did not aggravate the patient’s symptoms necessitating an immediate craniotomy.

In planning a craniotomy angiography helps the surgeon by indicating the position of major arteries irrigating the neoplasm. This is of particular value in vascular meningiomas and in some gliomas. This information is important in tumors about the sella turcica, where the internal carotid arteries are frequently involved in the tumor. With the knowledge that the internal carotid artery runs through a tumor, the surgeon is spared the humiliation of having a casualty from exsanguination and the patient, a fatal outcome.

SUMMARY

A series of 96 angiograms of “brain tumor suspects” is analyzed. In 3 cases the roentgenograms were technically unsatisfactory. Air studies or the
course of the disease, verified the angiographic diagnosis in all but 5 cases.

In the group of 42 verified brain tumors, with 3 exceptions, the angiograms were interpreted as correctly localizing the lesion. Tumors of the medial part of the temporal lobe and the midline structures failed to visualize by angiography.

Arteriovenous angiomas are characterized by a mass of tortuous channels and sinuses fed by large corkscrew arteries and drained by greatly dilated veins.

Approximately two-thirds of the glioblastomas have a typical angiographic appearance characterized by increased vascularity at the margin of the tumor with sinuses, irregular dilations and vascular loops within the tumor.

Astrocytomas have as angiographic characteristics the displacement of normal vessels by an avascular area or an area having few fine, uniform straight or slightly curved vessels.

Meningiomas do not have a typical intrinsic angioarchitecture, but the vascular abnormalities produced by their circumscribed nature give them specific characteristics.

Angiograms aid in the planning of surgical removal of the tumors and give information which may prevent surgical disasters.

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OKONEK, MONIZ, MONIZ, of LOMAN, lofistik. RSntgenstr., Klinik.


