PERCUTANEOUS VERTEBRAL ANGIOGRAPHY

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The purpose of this study is to describe the modifications of form and situation of the blood vessels produced by neoplasms situated in the territory of the vertebral artery, with some remarks about thrombosis. Reference will be made only to gross anatomy of radiological significance, by means of brief examples chosen from the 162 vertebral angiographies performed in the neurosurgical clinic of the Pitié between 1948 and July, 1953. The principal characteristics of the normal and pathological angiogram will be set forth, with insistence on the harmlessness and relative simplicity of the method and description of a personal technique.

HISTORY

Vertebral angiography began in 1933 when Egas Moniz succeeded by exposing the artery in the subclavicular region, temporarily ligating the peripheral end and making a retrograde injection. Many scattered attempts followed; many methods were proposed and were soon abandoned. It was only in 1947 that three independent schools developed valid techniques and soon three series of results were available. In 1949, Sugar, Holden and Powell published a series of 20 angiograms obtained by transcutaneous puncture in the vertebral canal by an anterior approach. In 1950, Lindgren published a series of 60 obtained by a similar method. Radner used an entirely different method. He introduced a catheter into the radial artery and guided it into the vertebral. In 1951, he published the results of his method in 221 cases with a remarkably large percentage of successes. Finally, in 1952, Sergent et al. published a study of a series of 130 vertebral angiograms obtained by the technique described below.

TECHNIQUE

We utilize a needle similar to a lumbar puncture needle, 7 cm. long, 0.8–1 mm. in diameter, with an obturator. The bevel should be as short as possible. The adjustment of the syringe to the needle is made directly without the interposition of any adaptor. The syringe is a simple glass syringe of 10 cc. capacity, of which the advantage is its lightness. The contrast medium employed is diodone, a soluble salt of iodine in feeble concentration (40.5 or 45 per cent). The quantity of the mixture in each injection does not exceed 6–7 cc. We make rarely more than three injections. In the interval of the injections we do not use citrated solution by the drop method. We are content to put the obturator in the needle, after having placed it in the citrated solution with which we rinse the syringe.

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We use general anesthesia only in infants and in some pusillanimous or agitated subjects. In the same way, we reduce the local anesthesia to the minimum, using only a few drops of novocain in contact with the artery. As a matter of fact, we prefer to give the patient some medication, usually phanergan rather than derivatives of morphine, of which the depressor effect is known, preceded or not by an enema of 4 gm. of chloral.

We have used two methods for puncturing the artery; we may approach it from the anterolateral region of the neck or at the base of the cranium. In the anterolateral region of the neck, the artery is in the transverse canal and must be punctured between two transverse processes, generally between C5 and C6, or C4 and C5. The artery is here accompanied by the vein which is lateral to it, and a cervical root which crosses its posterior face. The patient is lying on his back with the head in moderate hyperextension. With the left index finger one depresses the tissues of the neck just below the great horn of the hyoid bone, in contact with the lateral border of the thyroid cartilage, or better, the cricoid thyroid space, so as to push the package of nervous and vascular tissue laterally. The needle is thrust into the depression thus created and comes to strike against the transverse process. One inclines it then upward to engage it in the intertransverse space in the direction of the superior transverse aperture.

Usually, as soon as the obturator is withdrawn, a flow of blood shows that one is in the lumen of the artery. Sometimes it is necessary to displace the needle slightly—to slightly withdraw it a little—for it is rather frequent that one has penetrated entirely through the artery. Sometimes a pain shoots into the shoulder showing that one has touched the cervical root. One must withdraw the needle a bit for it is too deep. Sometimes darker blood flows slowly in a regular flood showing that one has punctured the vein. The needle is then too far lateral and it must be replaced more medially.

Ordinarily it is easy to puncture the artery in the transverse canal; it is easily found and usually well fixed. On the contrary, it is rather frequent that the injection is made in part, or wholly, in the sheath of the artery, for it is rather difficult to maintain the needle well placed. In this case there is provoked a spasm of the artery, without any clinical signs, which permits one to obtain only poor images of difficult interpretation. The reason is that the direction of the needle tends to be perpendicular to that of the artery. Even on giving the needle a direction as oblique as possible it is difficult to catheterize the artery sufficiently. Also the needle traverses the subhyoid muscles which contract considerably during movements of swallowing. The needle is then subject to important displacement which can alter the position of the point. Because of the frequency of this accident, we have searched for another method that avoids this difficulty.

When the vertebral artery has left the transverse passage in the atlas, it changes its course and is directed a little bit backward, especially medially, to come into contact with the superior face of the posterior arch of the atlas where its passage marks its course by a little excavation, sometimes transformed into a tunnel visible in a lateral radiogram. The artery in this passage turns about the lateral mass of the atlas to which it is adjacent. It then perforates solid fibrous planes between laterally the capsule of the occipital atlantoid articulation, and medially the posterior occipital atlantoid membrane. The artery at this level is not accompanied by its vein; it is not yet formed. The first cervical nerve is not of importance. There is here, therefore, a segment of the artery that is easily catheterizable because of its direction.
It is covered by muscles that are very little movable, in a region where the sensitivity is particularly obtuse. Therefore it is believed that once the needle is introduced into the lumen of the artery it penetrates for several millimeters and maintains itself fixed. Although this puncture, like any manual maneuver, requires a little practice it is, after all, rather easily successful.

The patient is placed usually flat on his abdomen with his forehead on the table. The needle is plunged in a transverse plane, in a little depression between the sternocleidomastoid and the trapezius, just posterior to the point of the mastoid process. At a depth of about 2 cm., the needle comes into contact with the lateral masses. Bony contact is fundamental. One must find it before going ahead with the puncture. Moreover it is usually easily found. Then one directs the point of the needle a little bit posteriorly and below and one searches the contact with the posterior arch of the atlas, of which one follows the superior face about 2 or 3 mm. Then one withdraws the obturator and, generally, arterial blood flows out. If one does not succeed it is well to make a radiogram centered on the atlas, leaving the needle in place by which one will see the situation of the point of the needle in relation to the vascular notch of the atlas. It is then easy to correct its direction.

With this method we have had the most regular successes, never a spasm of the artery. For a long time we used this method only in those cases in which we had failed with the usual anterolateral method. One must remark, however, about the possibility of puncture of the cisterna magna, which will be demonstrated by a flow of spinal fluid. This happened to us twice. This accident makes one stop the operation, but it is without any gravity and can be avoided. For this purpose one must (1) always search for the bony contact of the lateral masses, which is the best protection, (2) never seek to overcome the fibrous resistance of the occipital atlantoid membranes, and (3) never make an injection when there is any doubt. As a matter of fact, it is easy to puncture the artery and it is still easier to keep the needle in place because there is no risk of secondary displacement at the time of the injection. We have no experience of what might happen if the injection were made into the cisterna magna, and do not wish to have. We believe that that could only be the result of a gross error and not apt to happen to a surgeon.

RADIOLOGICAL TECHNIQUE

We utilize an apparatus of 4 kenotrons. With a rotating anticathode it makes several exposures with one single activation. We usually used these constants: 200 ma., 80 kv., 0.2-0.3 sec. exposure. We use a plate changer of very elementary principle, regulated by the hand. It enables one to take easily 6 pictures in 4 seconds. Usually we are content with 3 pictures for each direction just about 1 sec. apart. The first gives an image of the arterial phase; the second of the arteriolar phase, and the third of the venous phase. As a matter of fact, there is usually some difference in the timing of the venous phase, the superficial veins being filled sooner than the deep veins in the system of Galen.

In order to protect the operator, we use a diaphragm, a localizer and a lead screen which is interposed in front of the head of the patient and the hand of the surgeon because naturally it is not possible to use gloves which contain lead.

We take two or three series of plates successively. The first one is lateral and cen-
tered a little posterior to the sella turcica. The second is anteroposterior in the sagittal plane, with an obliquity of about 30 degrees, the rays entering 3 or 4 cm. in front of the coronal suture and leaving at the external occipital tuberosity, that is, in the frontosuboccipital plane of Worms and Bretton (if the patient is lying on his abdomen, this will be a suboccipital frontal, with the same angle). The third is in the plane of Hirtz, the head being strongly retracted, the rays entering submentally and leaving at the apex. This view seems to us much less useful than the preceding one, for it is used only in special cases.

ANATOMICAL STUDIES

Reading the plates obtained may be the source of numerous difficulties, because of the superpositions and extraordinary tortuosity of the vessels. Classical dissection is not easy because of the overlapping and deep vessels. For this reason we have applied to the study of the vertebral system a method utilized for other organs, particularly the liver, in the laboratory of Doctor Delmas, Professor of Anatomy, Faculty of Medicine, in Paris.

A plastic material is used, soluble in acetone, easily colorable, injected into the vessels of a brain freshly removed, after washing out the vessels previously. This material solidifies in contact with the trace of water which is in the vessels. One has only to destroy all organic substance by prolonged immersion in a strong acid for several days to make a perfect mould of the arterial and arteriolar systems.

We thus treated 20 human brains and the study of these 20 moulds, thanks to the irreplaceable three dimensions, led us to a clearer understanding of the somewhat mysterious revelations of the X-ray plates. The venous system, unfortunately, does not lend itself to this sort of study, not only because the sinuses are frequently embedded in bone, but especially because a recurrent injection could not remount the course of the normal physiological circulation and would lose itself in the carotid territory. From the study of our moulds and of our numerous plates, we have come to a certain number of conclusions, some personal and others confirming previous works by the Portuguese, Swedish and American schools. We shall describe them as they were seen on the radiological plates.

THE ARTERIOGRAM

The lateral plates show a projection in the sagittal plane of the basilar trunk and of the vertebral injected, of which it is the continuation. This vascular trunk, from the posterior arch of the atlas to its termination, describes consistently a triple curve like a cupid's bow. The first curve is concave posteriorly; the second is concave anteriorly; the third is concave posteriorly. The principal trunk remains at a slight distance from the clivus. The preprotuberant cistern is in front of it. We insist on these two signs: the triple curvature and the interclivoarterial space, the importance of which will be shown in the discussion of tumors of the cerebellum.

The principal vascular trunk is at a rather variable angle with the plane of Frankfort. The angle has an average of 73 degrees; it varies from 50 to
80 degrees. It never terminates below the clinoidal line (a line parallel to the Frankfort plane but passing through the anterior clinoid process). It can be as much as 2 cm. above the Frankfort plane but generally is about 0.6 cm. The distance from the point of termination of the basilar trunk to the prolongation of the quadrilateral plate varies between 1.2 cm. and 1.5 cm. depending upon whether the trunk penetrates more or less into the interpeduncular cistern. On the average it is 0.6 cm.

The inferior cerebellar arteries are most variable; they seem to be always present but unequal on the two sides, and take origin either from the basilar trunk or from the vertebral, varying through a range of 4 cm. One sees always clearly the external superficial branch which descends in a sinuous course in the direction of the amygdala, without reaching its pole, and therefore is not of any very great value for orientation. The other lateral branches of the basilar trunk are hardly seen from this direction because they are covered by the mass of the petrous bone, with the exception of the superior cerebellar arteries, of which the origin is remarkably fixed and symmetrical on the basilar trunk just before its termination. One can see clearly their passage around the cerebral peduncle parallel to that of the posterior cerebral arteries.

The posterior cerebral arteries, of which we have seen the origin in the interpeduncular space, are seen throughout their extent in this view. At their origin they give rise to the oblique thalamo-perforating arteries. In their first third, the circumpeduncular, they are a little concave superiorly, to the region of the pineal body, where the posterior choroidal artery separates. It is always visible, extending obliquely above and forward, curvilinear with an anterior concavity. This vessel tells one the situation of the choroidal sheet of the posterior part of the roof of the third ventricle as far as the foramen of Monro. In its second third the posterior cerebral artery is almost straight or slightly concave upwards. It continues in the general direction of the first segment, generally perpendicular to the basilar trunk. It gives off here its temporal branches destined for the inferior face of the temporal lobe which, in this view, are superimposed on the branches of the superior cerebellar artery. The last third, in which there is the occipital branching, destined for the inferior surface of the lobe, prolongs the direction of the trunk. Those destined for the internal surface deviate upwards, outlining the anterior border of the cuneus.

The lateral arteriogram, therefore, gives us evidence concerning: (1) the brain stem, the preprotuberinal cisterns, the circumpeduncular cisterns; (2) the situation of the pineal body and the quadrigeminal tubercles; (3) the state of the roof of the third ventricle; and (4) the cuneus of the occipital lobe.

The fronto-occipital views give a very bad picture of the basilar trunk, lying in about the same direction. They give a projection on the plate which is almost a point. We think that there is very little to be gained from the form of the basilar trunk as it is seen from this direction. In fact, it has a
variable origin, most often at the level of the bulboprotuberential fissure, rarely in the midline, and sometimes even lateral. The course is rarely rectilinear; most often sinuous, nothing fixed, nothing regular, nothing that can serve to orient one.

On the contrary, the point of division of the basilar trunk is always strictly in the midline. This is by far the most important sign perhaps in all vertebral angiography, as Sergent et al. have insisted. The view from this angle shows the situation of this point admirably. Moreover the posterior cerebral arteries are seen in all of their extent. One sees clearly the curve that they make around the cerebral peduncles, trapezoidal in form, never closed posteriorly, and superimposed on the more regular ring of the superior cerebellar arteries. The temporal branches are easily visible, and also the occipital branches. They, however, are so sinuous that they cannot have the value that, for example, the anterior cerebral arteries in the carotid angiogram have in indicating the midline.

An arteriogram taken from the direction recommended by Worms and Bretton, therefore, gives information principally on the situation of the cerebral peduncles, of the ambient cistern and of the interpeduncular cistern, and also of the postero-inferior part of the cerebral hemispheres. Plates taken as recommended by Hirtz do not give a good image of the basilar trunk; as we have seen, aside from its point of division, it has little topographical significance. As a matter of fact, we use it only in searching for vascular malformation of this trunk and its collateral branches.

THE PHLEBOGRAM

The phlebogram has not retained our attention as much as the arteriogram. It gives a variable opacification, intense in those veins that receive blood only from the vertebral, such as the cerebellar veins, and on the contrary, often very obscure in the superotentorial veins, in which there is a mixture of blood draining from the carotid territory and the vertebral territory. Cerebellar veins running on the surface of the hemispheres defy any radiological description; the same is true of the superficial occipital veins which form often a star centered by a granulation in the neighborhood of the lambda. The deep veins are more important. One sees clearly, especially in profile, the posterior part of the veins of Galen, lying in the choroidal roof of the third ventricle. They unite, in the neighborhood of the pineal body, with the basilar veins at the end of their circumpeduncular course, of which one sees well the last centimeter. The curve formed by Galen’s ampulla, around the splenium of the corpus callosum, is always clear, whereas the straight sinus at the summit of the tentorium, which forms its continuation, is less visible. One can see also the last centimeter of the inferior longitudinal sinus, the last quarter of the superior longitudinal sinus, and the lateral sinus, of which one, usually the left one, always is seen better than the other in the fronto-occipital view.

The phlebogram tells us, therefore, principally about the splenium of
the corpus callosum, the posterior part of the third ventricle, the pineal body and the quadrigeminal tubercles, and the tentorium of the cerebellum. If, now, we group all of the information that the vertebral angiogram can give us, we are in a position to diagnose a certain number of neoplasms lying in the territory of this artery, as will be shown by several examples.

PATHOLOGICAL VERTEBRAL ANGIOGRAPHY

The illustrations in this section have been taken from the writer's thesis. A certain number of these angiographies were made in the service of Professor Alajouanine, whom we wish to thank for the interest that he has always manifested in our technique. Some of the photographs have been retouched, as will be evident from the reproductions.

1. Vascular Malformations. They are evidently the major indication for angiography. They do not need explanation, but often necessitate plates taken from several directions in order to show them clearly.

Case 1. Cerebellar angioma, involving especially the vermis (Fig. 1). Beyond surgical help. (Patient of Professor R. Garin.)

![Fig. 1](image)

2. Tumors in the Angle. Most of the triumphs of vertebral arteriography concern them. We shall not describe new-formed vessels, which are always variable in their existence and significance. But the pathognomonic sign of a tumor in the angle, in the anteroposterior view, is the lateral displacement
of the point of division of the basilar trunk. This is never absent and betrays a tumor of the angle, accompanied always by more or less evident deformation of the peripeduncular arch. A lateral view will enable one to appreciate a prepeduncular extension of the tumor. Though usually the diagnosis of a tumor in the angle needs no complementary examination, there are cases, nevertheless, in which these examinations are not useless, especially those in which there are very few symptoms. However, vertebral angiography has given us help in indicating the extent of a tumor that was not evident from the symptoms, especially by demonstrating that there was a recurrence of the tumor in a case of meningioma previously operated upon and which had again given trouble.

*Case 2.* Typical anteroposterior view of the deformation of the arterial system caused by a tumor of the cerebellopontine angle (Fig. 2). The point of division is pushed laterally; the vascular fork is deformed in a characteristic fashion by a neurinoma of the trigeminal.

![Image](image.png)

**Fig. 2**

*Case 3.* An acoustic neurinoma, the diagnosis of which was doubtful. Angiography brought proof of displacement of the point of division of the basilar trunk and a slight deformation of the arterial fork (Fig. 3).

*Case 4.* Lateral view (Fig. 4), of which the interest is to demonstrate the unusual
preprotuberical development of a tumor, seemingly well lateralized on the antero-posterior plate. It was a very large cholesteatoma.

3. Supra- and RetroseUar Tumors. These are very easily demonstrated by vertebral angiography in lateral plates.

Case 5. Enormous posterior displacement of the terminal portion of the basilar trunk and the origin of the posterior cerebral arteries (Fig. 5) in a case of benign tumor of very slow development (20 years), possibly a chordoma. No indication for operation.

4. Pinealoma.

Case 6. The tumor occupies the seat of the pineal body and is partially injected (Fig. 6). In addition, it deforms the posterior cerebral artery, displacing it downward and stretching it. Diagnosis verified.

5. Stenosis of the Aqueduct.

Case 7. The first two thirds of the posterior cerebral artery are stretched and pushed downward (Fig. 7). It is a sign of hydrocephalus, just as the unrolling of the anterior cerebral artery.
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Fig. 4

Fig. 5
6. *Tumor of the Cerebellar Hemisphere.* These tumors are the sources of great disappointments with our method. There are no angiographic signs which permit one to tell which is the hemisphere invaded by the tumor.

*Case 8.* A least there exists an indirect sign of a cerebellar tumor—the unrolling of the principal arterial trunk, which loses its habitual triple curvature (Fig. 8). The vertebral and the basilar trunk form a regular course, continuing from the atlas to the clinoid process, and are pushed against the clivus; there is no preprotuberinal cistern. This was a cystic hemangioma.


*Case 9.* The tumor is injected during the arteriolar phase. It can be seen above and below the tentorium (Fig. 9). Moreover the vessels are deformed. In this case angiography was particularly valuable. It confirmed the diagnosis of a tumor and outlined its extension exactly (both above and below the tentorium). Also it diagnosed the nature of the growth. Only a meningioma is injected thus, with a certain retardation during the arteriolar phase.

8. *Thrombosis of the Posterior Cerebral Artery.*

*Case 10.* Angiogram (Fig. 10) of a man who had sudden development of complete paralysis of the right oculomotor nerve. The anteroposterior plate shows interruption of the right posterior cerebral artery where it crosses the third nerve. Carotid angiography done subsequently did not inject the posterior cerebral artery; we wished to be sure that we were not dealing with an anomaly. The vertebral angiogram made a week later showed the same image. The condition, therefore, was not a spasm but a thrombosis.

Case 11. In the course of a typical vascular syndrome of the anterior cerebral artery, a carotid injection was made on the right side. The injection stopped at the base of the cranium—the characteristic aspect of a thrombosis. The injection of the other carotid artery showed that it did not have a functional anastomosis. We then performed vertebral angiography (Fig. 11) which explained the mystery of this syndrome, showing that the Sylvian system was almost totally supplied by the vertebral and the posterior communicating artery, whereas nothing passed into the territory of the anterior cerebral.

Fig. 11

Comment. It is not possible here to multiply these examples indefinitely. However, it may be added that vertebral angiography permitted us to localize an occipital abscess and to demonstrate the posterior development of a large hypophysial adenoma; and to discover one of those cases of abnormal communication between the vertebral and the carotid at the base of the skull, which is an embryological rarity.

ACCIDENTS

To practice vertebral angiography does not seem to us to be a dangerous method if one follows the proper indications and observes certain rules. In making 160 angiographies, however, we have observed 4 serious accidents, of which 2 were mortal. A fatal accident occurred in 1949. The operator, having demonstrated that there was a spasm with the first plate, injected 5 cc. of novocain, 1-100, in the artery. Immediately there appeared a paleness of the face, profuse sweating, vomiting, and irregularity of the pulse and of respiration. Finally a profound coma developed which after a few hours resulted in death. Autopsy did not show any appreciable lesion.
We must attribute the fatal accident to the intra-arterial injection of novocain. Therefore we have never repeated this procedure.

The second accident occurred after an arterial angiography in a young man with a left hemianopsia, with no vascular hypertension. A few minutes after the injection the patient entered into a coma and remained so for several hours. There was a left hemiparesis which later disappeared entirely. Angiography did not show any vascular displacement. The opposite vertebral artery was injected in retrograde fashion, showing that there had been an excessive pressure in the course of the injection. For this reason we have made it a dogma not to inject with any great pressure.

The third case concerned a left hemiparesis. It was found in the morning following a vertebral angiography made in an attempt to determine the cause of a meningeal hemorrhage which had developed a month before, the carotid angiography having shown nothing. Hemiparesis disappeared rapidly in the following days. The genesis of this accident is mysterious. There seems to have been no fault in technique and the vertebral angiography did not show any lesion.

The fourth case concerned an elderly subject, arteriosclerotic, with a right hemiparesis and hemianopsia. The procedure passed without any untoward incident. Three days later, there appeared a state of shock, anxiety, precordial pain, air hunger and lowering of the arterial tension. We thought of a myocardial infarction but the autopsy did not confirm this diagnosis. Necropsy showed retraction of the mitral valve with calcification and old softening of the left cuneus. Whatever may have been the part of the angiography in the mechanism of this late fatal accident, it is unquestionable that the cardiovascular state of this patient should have made us renounce such a test. So we believe that, of these four grave accidents, three could have been avoided, the first one by correcting an error of technique, the last one by avoiding an error of indication.

CONTRAINDICATIONS

These are the same as for carotid angiography on which Petit-Dutaillis, Pertuiset and Rougerie have insisted in a former article. Certain of them are formal: hypertension, renal insufficiency, and diffuse vascular sclerosis of those with coronary disease. Also asthma should make one fear allergic reactions to iodized products.

CONCLUSIONS

The author believes that percutaneous vertebral arteriography is not simply a feat of technical prowess but that it can render numerous real services, sometimes irreplaceable, and that it is relatively benign, if one makes the injections gently. It is certain that we can hope for more important information as we accumulate a larger series. So it is believed, in spite of the prejudices of certain persons concerning this method, that it must figure from now on in the arsenal of every neurosurgical service among the complementary methods of investigation.
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SUMMARY

In the light of 162 percutaneous vertebral angiographies made since 1948 in the neurosurgical clinic of the Pitié, the author describes a personal procedure of percutaneous approach at the base of the skull and lays down the bases for a normal radiological anatomy, showing what there is that is fixed and certain in the relations of this artery, which is so variable. With the aid of several examples he describes the most characteristic pathological aspects, insisting notably on the value of vertebral arteriography in the diagnosis of tumors in the region of the cerebellopontine angle and of the clivus. He insists on the relative benignity of this examination, if one observes certain precautions that are the rule in surgical circles.

REFERENCES