THE ROENTGENOLOGICAL DIAGNOSIS OF TUMORS OF THE CORPUS CALLOSUM
WITH A CONTRIBUTION TO THE NORMAL ROENTGENOLOGICAL ANATOMY OF THE ANTERIOR CEREBRAL ARTERY

W. TÖNNIS, M.D., P. BRANDT, M.D., AND W. WALTER, M.D.
Neurosurgical Clinic, University of Cologne, and Max Planck Institute for Brain Research, Cologne, Germany

(Received for publication June 20, 1958)

The considerable difficulties in diagnosis of tumors of the corpus callosum, often met with, made a detailed roentgenological study seem desirable. In this paper we present 21 cases from the Neurosurgical Clinic of the University of Cologne in the years 1951 to 1957, and refer to another 20 cases, described in an earlier paper, from the Neurosurgical Clinic of the University of Berlin* in the years between 1937 and 1944.

In respect to the roentgenological diagnosis of these tumors most authors seem to agree that deformation of the ventricular system seen in pneumoencephalographic studies is characteristic. Following is a summary of the descriptions given by Lysholm, Dyke and Davidoff, Davidoff and Epstein, Kautzky and Zülich, Gebhardt, and Lindgren: Tumors of the corpus callosum are characterized by a separation of the lateral ventricles, usually causing a broadening of the septum pellucidum in its uppermost part, this deformation being best observed in the sagittal (anteroposterior) view. Usually the separation of the ventricular system is accompanied by a more or less pronounced lowering and bowl-like impression in the roof of both ventricles. On the lateral view one meets with a similar aspect, there usually being an impression in the roof of the anterior horn of both sides, usually with an irregular contour, and sometimes a deformation of the roof of the third ventricle. According to the size of the tumor and the possible obstruction of one or both interventricular foramina, there may exist a concomitant dilatation of the lateral ventricles. Tumors involving the corpus callosum do not always have a perfectly symmetrical growth and consequently the roentgenological aspect may vary. If the tumor has grown mainly to one side there will still be a deformation of the ventricles, but one of them will be more deformed than the other. This applies to expanding lesions of the rostrum and middle third of the corpus callosum. The separation of ventricles is very difficult to appreciate closer to the splenium of the corpus callosum, as similar pictures may be obtained when there is an insufficient quantity of air in the ventricles. As the ventricular cavities tend to separate from the midline in their posterior aspect, a chance of appreciating the deformity in

* At that time Prof. W. Tönnis was Director.
the lateral view becomes increasingly smaller. A descended pineal gland, combined with obliteration of the suprapineal recess and deformity of the posterior part of the roof of the third ventricle are considered to be diagnostic of tumors of the splenium. With a symmetrical growth of the tumor the ventricular system remains in the sagittal plane but suffers a shift when the distribution of the tumor mass becomes irregular. In this case one lateral ventricle may fail to fill with air because of an obstruction of the interventricular foramen, or only its posterior aspects may show, according to the procedure employed (pneumoencephalography, ventriculography). On the other hand the view of the ventricular system obtained may be exceedingly confusing, as it may cause the impression of a big frontomedial tumor that has displaced the ventricular system to the opposite side. Only the separation of the ventricles by a broadened septum pellucidum may induce the correct diagnosis.

As for the angiographic signs very little is mentioned in the literature. Except for a few casuistic data we found this aspect referred to only by Gebhardt,15 Johanson,17 and Lindgren,22 who concluded that arteries suffer little or no displacement. There may be a separation greater than usual of the cingular and pericallosal arteries, or these vessels may have a pathological course. Greater stress is laid on the displacement of the inner veins (lowering of the septal vein, caudal displacement and/or stretching of the thalamostriate vein, both vessels sometimes forming an arch delimiting the tumor). On the other hand the thalamostriate vein may form an acute angle with the internal cerebral vein, the latter being displaced dorsally. This applies to tumors situated anteriorly, the more posterior ones displacing the end portion of the internal cerebral vein caudally and stretching it. A similar description is given by Johanson,17 who added that in these cases there is usually no lateral shift of the inner veins. Gebhardt15 examined the angiograms of 12 cases of tumor of the corpus callosum and described for most of them a normal course of the anterior cerebral artery although sometimes combined with a parallel displacement to the contralateral side. In some of her cases the pericallosal artery was displaced upwards and described a greater arch than usual. She also observed a rostral displacement of the bend of the anterior cerebral artery around the genu of the corpus callosum, or a flattening of this portion. Sometimes the pericallosal artery formed a right angle with the anterior cerebral artery and had a rigid course. Obliteration or widening of the anterior cerebral artery, or of one of its main branches, was found occasionally.

As we were not able to find a detailed description of the course of the anterior cerebral artery2,4,6,8,10,11–14,16,20,20 we found it exceedingly difficult to state whether in doubtful cases the arteriographic picture was normal or not. The first step then would be to establish a standard for normality of its course so as to be able to say when and why in pathological angiograms this artery seems to indicate the presence of an expanding lesion.
MATERIAL AND METHODS

In this study 50 normal angiograms were used. The term “normal” is not used in the conventional sense, but means that roentgenograms of the skull showed no signs of pathological lesions, and neither case history nor course gave any reason for suspecting a tumor. Of each of these 50 angiograms a drawing was made of the lateral aspect showing the course and branches of the anterior cerebral artery. The age of the patients ranged from 16 to 40 years, 10 angiograms being taken per age group of 5 years (16 to 20 years, 21 to 25 years, etc.). These angiograms came from the Neurosurgical Clinic of the University of Cologne and were selected out of a total of nearly 4,200 serial angiograms.

Further we examined the angiograms of 21 cases of tumor of the corpus callosum. These were selected out of a greater group of cases, diagnosis being based on operative, ventriculographic or postmortem evidence. Only angiographic material of good quality, consisting of serial angiograms of 4 lateral and 4 anteroposterior films each, was taken into account. The age of these patients ranged from 19 to 51 years (mean age 39 years). In 16 of these cases the corresponding ventriculograms were revised and subjected to detailed study. Diagnosis was established on grounds of operative findings in 10, and on postmortem findings in 7 cases; in the remaining cases the encephalographic evidence was considered to be conclusive.

RESULTS

In order to appreciate pathological alterations of the course of the anterior cerebral artery we compared its course in 50 normal arteriograms and established three groups and their transitional forms according to the topography of this vessel.

The anterior cerebral artery of Type I (Fig. 1) had a straight or nearly straight course until reaching the rostrum of the corpus callosum, where it generally turned dorsally in a close arch. The angle formed with the floor of the anterior fossa varied from $15^\circ$ to $45^\circ$ and according to the steepness of

Fig. 1. See text.
this angle the bend around the rostrum was more or less wide. Transitional
forms included a concavity towards the floor of the anterior fossa (Fig. 1a)
or the insinuation of a Z-shaped curve, elements characteristic for Type II
and III respectively (Fig. 1b).

Type II showed a more or less pronounced concavity of the portion of the
anterior cerebral artery running to the rostrum of the corpus callosum
towards the floor of the anterior fossa (Fig. 2). Here the bend was usually
quite wide and varied less than in the preceding group (25° to 45° angle with
the floor of the anterior fossa). Transitional forms resembled Type III, i.e.,
a more pronounced Z-shaped bend (Fig. 2a), or a convexity towards the
floor of the anterior fossa (Fig. 2b).

Type III showed a clear-cut Z-shaped bend, the descending branch
usually nearly vertical to the floor of the anterior fossa. The bend around the
rostrum of the corpus callosum took the form of a U, sometimes with nearly
right angles (Fig. 3). Transitional forms had shapes similar to Type II
(Fig. 3a), or a pronounced Z-shape, with rounded angles, the ascending
branch tending towards an obtuse angle with the floor of the anterior
fossa (Fig. 3b).

The differences between the mean ages of Type I and II were not sig-
nificant, but became so between the latter and Type III (mean ages of 27
and 25 years respectively, and 32 years). Type I was found 11 times, Type II in 21 cases and Type III in the remaining 18 cases, the frequency of Type I plus Type II being predominant (64 per cent of all cases).

This classification is based only on the topography of the anterior cerebral artery, because of its diagnostic significance. Another criterion would be an anatomical and descriptive one, allowing establishment of three forms.

**Group 1** comprises 7 cases in which the anterior cerebral artery dichotomized at its beginning or very near the carotid fork. In this group two varieties occurred, one characterized by a rather thick cingular artery and a meager pericallosal, in the other both vessels having about the same diameter (Fig. 4). The cingular artery normally runs in a wide arch, the pericallosal nearly straight, or slightly concave, towards the base of the skull.

**Group 2.** The branching of the anterior cerebral artery at the rostrum of the corpus callosum is subdivided into two groups: (i) the anterior cerebral artery bends in an arch (Fig. 5a) — 11 cases; or (ii) it is angulated at the genu (Fig. 5b) — 9 cases. In these two groups the anterior cerebral artery usually forms an angle of about 40° with the floor of the anterior fossa and after turning around the rostrum continues nearly straight or slightly arched at an angle of 60° to 70°.

In Group 1 the frontopolar artery usually took off independently and gave rise to the cingular artery. This may occur also in Group 2 or it may arise from the main trunk of the anterior cerebral artery, there sometimes being two vessels. This second vessel may be of small diameter, giving off several branches, and probably represents the orbital artery of Foix and Hillemand.13

**Group 3** comprises 23 cases in which the anterior cerebral artery branches into cingular and pericallosal arteries after having gone around the rostrum of the corpus callosum (Fig. 6). It may give off one or two branches, the orbital and frontopolar arteries. Usually at the main branching there form several smaller rami besides the cingular and pericallosal arteries, some of them running on the mesial surface of the brain to the parasagittal cortex,
others accompanying the pericallosal artery and ending on the cingular gyrus.

Groups 2 and 3 occur most frequently, comprising 86 per cent of all cases. Lazorthes and coworkers' scheme proved very useful in dividing the branches of the anterior cerebral artery into two main groups: the frontopolar group is composed of the inferior frontal artery (orbital artery of Foix and Hillemand) and the antero-internal frontal artery (prefrontal or frontopolar artery). The frontoparietal arteries consist of the medial internal frontal artery (branch of the cingular [callosomarginal] artery), the postero-internal frontal artery (branch of the cingular artery), the internal parietal artery (paracentral artery) with its parieto-occipital and precuneal branches. The cingular artery is not constant, but often there are a medial internal and a postero-internal frontal artery, and these branches, whenever a cingular artery exists, come off the latter.

It appears that the topographical classification is more useful and might serve as a standard for comparison with pathological cases. No two anterior cerebral arteries are exactly alike, especially since the site of branching varies enormously. Only the course of the main vessel and its two most important branches, cingular and pericallosal arteries, appears to be fairly constant.

THE ANGIOGRAM IN CASES OF TUMOR OF THE CORPUS CALLOSUM

We may divide our angiographical findings into three groups. In the first group, the diagnosis of tumor of the corpus callosum could readily be made. In 7 out of 8 cases we found a tumor stain situated on the lateral projection in the region corresponding to the corpus callosum, embraced by the anterior cerebral and pericallosal arteries, and on the anteroposterior view usually in the midline or slightly paramedian (Fig. 7 A,B,C). The remaining case, a lipoma of the corpus callosum, showed a characteristic calcification. In 4 of these cases the anterior cerebral was seen on the anteroposterior view sometimes slightly arched first to one, then to the other side in the sagittal plane of the skull. In the remaining 4 cases, 2 showed a marked separation of the cingular and pericallosal arteries, with the tumor stain between them, the anterior cerebral artery being slightly displaced towards the contralateral side (maximal 15 mm.). In 7 cases the deep veins had suffered a marked shift on the lateral view, usually the internal cerebral vein being compressed, its anterior third either displaced dorsally or caudally and dorsally. On the other hand, a lateral shift of the deep veins in the anteroposterior view appeared in only 1 case. Operative findings or postmortem examination revealed that among these 8 cases there were 6 bilateral frontal gliomas
Fig. 7A. Case history 6264/57. E.E., aged 49 years. Oligodendroglioma. Angiogram, anteroposterior view. Note very slight displacement of anterior cerebral artery and tumor stain in sagittal plane. (See also Figs. 7 B and C.)

Fig. 7B. Angiogram, lateral view. Anterior cerebral artery runs parallel to floor of anterior fossa. Tumor stain lies between cingular and pericallosal arteries. Slight basal displacement of middle cerebral artery.
The remaining patient was not operated upon.

The second group is composed of 8 cases in which the presumptive diagnosis of a bilateral frontal glioma could have been made on angiographic
findings indicative of a large frontal tumor, with little or no displacement of the anterior cerebral artery in the anteroposterior view (Fig. 8 A, B, C). The maximum displacement of the anterior cerebral artery was 12 mm. in 2, 8 mm. in 1, and 6 mm. in 2 cases, while it remained in the sagittal plane in 3.
This disagreed with other angiographic findings, namely a tumor stain the size of a small apple in 1 case, and caudal displacement and stretching of the middle cerebral artery or its insular rami in 4 cases. In the remaining 3 cases there were phlebographic signs strongly suggestive of a big frontal tumor (Fig. 9 A,B,C), combined with slight displacements in the sagittal plane of...
the anterior cerebral artery. Retrospectively the diagnosis of tumor of the corpus callosum could easily be made on the basis of the above findings. In practice the diagnosis was made in 6 cases through ventriculography, and in 2 at operation, the tumor having a frontal position in all of them. Histological examination revealed an astrocytoma in 3 cases. The rest of the patients either refused operation or underwent radiological treatment.

The third group, composed of 5 cases, either showed no angiographic signs of an expanding lesion (4 cases) or those of a large frontal tumor. However a retrospective analysis showed the following: again, as already noted in the second group, there were signs suggestive of a frontal tumor, with the difference that in 1 case they were arterial and venous, coupled with a shift of the anterior cerebral artery in the anteroposterior view, but not giving any hint of callosal involvement. In 4 cases there were no arteriographic signs of a tumor, but there was phlebographic evidence of a frontal tumor in 2 cases and of a parietal expanding lesion in 2 others. These signs, paired with the lack of displacement of the anterior cerebral artery and some minimal stretching or displacement of the middle cerebral artery might have suggested callosal involvement. In 1 case of frontal tumor extending through the corpus callosum to the other hemisphere the anterior cerebral artery failed to fill, but, as we did not have the contralateral angiogram, the significance of this finding is rather insecure.\textsuperscript{28,29} Of these latter 4 tumors 2 were located in the rostrum and 2 in the middle third of the corpus callosum. Diagnosis was based on ventriculography in all cases. Two patients died, necropsy being performed. Of the remaining 3 patients, 2 had astrocytomas and 1 a glioblastoma.

In summarizing our findings we may say that there are two groups, one
diagnostic and another suggestive, the former giving the clues for the latter. Angiographic diagnostic signs of a tumor of the corpus callosum are the median position of, or slight displacement of, the anterior cerebral artery, combined with a tumor stain taking the position of the corpus callosum, or a few millimeters lateral to it. Complementary signs are the marked separation of the cingular artery from the pericallosal artery. In all cases the inner cerebral veins had suffered a displacement that is characteristic of frontal tumors, usually without a lateral shift. The angiographic findings suggestive of a tumor of the corpus callosum or involving it are essentially the same, with the difference that in these cases there is no tumor stain, but signs of a large frontal expanding lesion are evident, the anterior cerebral artery being only slightly displaced in comparison to the apparent size of the tumor. Venographic clues are the same as mentioned above. A rather insecure clue is given by the lowering of the internal cerebral vein, as this also occurs with temporal tumors. There were probably sufficient angiographic clues present in 17 cases out of 21 to enable us to make the diagnosis of tumor of the corpus callosum. Comparing the course of the anterior cerebral artery in these cases with our previously established topographical standards it appears further that only 2 cases could be classified without doubt as being pathological. In the first case the anterior cerebral artery ascended steeply, forming an arch slightly convex rostrally. The pericallosal artery after having a straight course for 15 mm. suddenly became very irregular, descending in a wavy form. In the second angiogram the course of the anterior cerebral artery was very irregular from the beginning. In the remaining 19 cases it was quite impossible to ascertain whether the vessel in question was pathological, as its course remained within the range of "normal" variation.

THE ENCEPHALOGRAM IN CASES OF TUMOR OF THE CORPUS CALLOSUM

Our encephalographic findings were concordant with those mentioned in the literature. However, the septum pellucidum seemed thicker than normal in only 11 out of 16 cases. As thickening of the septum pellucidum is considered an essential criterion for the differential diagnosis between meningioma of the falx and tumor of the corpus callosum, these findings point to the fact that broadening of the septum pellucidum may occur with tumors of the corpus callosum, but it is by no means pathognomonic. Examination of gross specimens showed a thickened septum pellucidum in a higher percentage than our approximate 2 out of 3. When analyzing the 20 cases of tumor of the corpus callosum published previously from our clinic, we find that in only 7 cases was the septum thicker than normal, judged by encephalography. Necropsy revealed that in another 5 cases the septum had been invaded by the tumor and appeared broadened. Therefore, out of a total of 36 cases, there were only 18 cases in which invasion of the septum was evident encephalographically.

A further statistical analysis might yield more nearly exact data concerning the thickening of the septum pellucidum with tumors of the corpus
callosum. Encephalographic differential diagnosis concerns meningiomas of the falx,\textsuperscript{35} frontomedial gliomas, and pinealoma. Another condition similar to tumor of the corpus callosum is the impression caused by the radiatio corporis callosi in the roof of the frontal horns of the ventricles. This can be recognized by its clearly outlined borders and its U-like form. It will never cause a separation nor a ventricular shift. Diagnosis is difficult when it is unilateral, but in these cases encephalography and clinical criteria, based on case history and course, may decide the question. Angiographically we would have to differentiate frontal gliomas which cause a bulging shift of the anterior cerebral artery to the contralateral side always in accordance with the size of the tumor. If there is a tumor stain, decision will be easy enough, as its position will be characteristic. The shift of the internal cerebral vein may or may not be present, depending on the size of the tumor. If there is a shift in the lateral view, there should be a displacement in the sagittal plane, otherwise suspicion of invasion of the corpus callosum should arise.

Meningiomas of the falx usually have a characteristic angiographic aspect. Cingular and pericallosal arteries have a normal course and may never become separated as occurs with gliomas of the corpus callosum. There might be a depression of the pericallosal artery as the tumor presses on the corpus callosum.

In spite of the findings mentioned above, the diagnosis of tumors of the corpus callosum remains difficult. The sagittal position of the anterior cerebral artery in an angiogram showing evident signs of a frontal tumor is conclusive. Early diagnosis is exceedingly difficult and probably can only be made by encephalography, but here we meet with the difficulty that infiltration of the septum pellucidum occurs only when the tumor has grown to an inoperable size.

SUMMARY

Twenty-one cases of tumor of the corpus callosum are presented and the roentgenological diagnosis by means of encephalography and angiography is discussed. To be able to ascertain when the anterior cerebral artery has a pathological course, 50 normal angiograms were reviewed and classified into three groups according to the course of this vessel. No essential differences between the normal and pathological course of the anterior cerebral artery could be established, except in 2 cases out of 21. Besides the well known encephalographic alterations, angiographical signs, some of them conclusive, others inducing diagnosis, are presented. Retrospectively an angiographic diagnosis would have been possible in 17 out of 21 cases. Differential diagnosis is briefly discussed.

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