Arteriovenous malformations of the transverse dural sinus

ANDREAS KÜHNER, M.D., ARNO KRÄSTEL, M.D., AND WOLFGANG STOLL, M.D.
Departments of Neurosurgery and Otorhinolaryngology, Heidelberg University, Heidelberg, West Germany

Clinical, radioanatomical, and therapeutic aspects of dural arteriovenous malformations in the region of the transverse sinus are discussed on the basis of seven personal observations and the analysis of 72 reported cases. Common symptoms are headache and troublesome tinnitus aurium. More serious neurological deficiencies may occur as a result of disturbance in cerebral hemodynamics. A complete neuroradiological investigation is essential for adequate treatment. Most frequent arterial feeders are the occipital, tentorial, and middle meningeal arteries. Ligation of the occipital artery is not sufficient in most cases. Operative isolation of the transverse sinus by craniotomy and dural section is considered by far the most successful treatment and should be performed whenever ligations fail or are not indicated.

KEY WORDS • dural angiomas • transverse sinus • tinnitus aurium • dural vascularization • arteriovenous malformation

Arteriovenous angiomas of the transverse sinus were first described by Törniss and Röttgen. To our knowledge, 72 cases have subsequently been described in the literature. At first these vascular malformations were interpreted as simple shunts between the occipital artery and the sinus. More recently, with the help of improved neuroradiological techniques it has been recognized that many other vessels are involved.

From a therapeutic viewpoint these fistulas pose problems. Three different methods of treatment are available: ligation of the occipital artery or the external carotid artery; selective transfemoral embolization; and operative isolation of the transverse sinus. We are presenting the clinical and radioanatomical features seen in seven cases of dural angioma, and therapeutic considerations are discussed.

Anatomical Characteristics

Exact knowledge of the anatomy of the dural vascularization in the region of the transverse and sigmoid sinuses is essential for adequate treatment of these malformations with the least likelihood of recurrence. Three groups of vessels may be identified (Fig. 1):

1. The external group includes the vessels of the scalp and neck which reach the dura through perforating branches, above all the occipital, superficial temporal, and posterior auricular arteries. The ascending cervical and vertebral arteries are also joined to this group by muscular anastomoses.
2. The medial group consists of the actual meningeal arteries such as the middle (posterior branch) and the posterior meningeal arteries. Smaller direct
AV malformations of transverse dural sinus

FIG. 1. Illustration of blood supply of the dura in the region of the transverse and sigmoid sinuses. A = external carotid artery; A1 = occipital artery; A2 = middle meningeal artery; A3 = posterior meningeal artery (ascending pharyngeal artery); A4 = posterior auricular artery; A5 = superficial temporal artery. B = internal carotid artery; B1 = medial tentorial artery; B2 = lateral tentorial artery. C = ascending cervical artery; C1 and C2 = muscular anastomoses to occipital artery. D = vertebral artery.

branches from the vertebral artery may also be included.1,9,12,13,17,28

3. The internal group consists of vessels of the tentorium such as the medial and lateral tentorial arteries and branches from the posterior26 and the middle8 cerebral arteries.

The manner in which the vessels named are involved in the malformation differs from case to case, and the localization of the shunts also varies: they may be global, near the torcular, or near the mastoid.

Case Reports

We have observed seven cases of arteriovenous angiomas of the transverse sinus. The common complaint of all patients was tinnitus aurium.

Case 1

After a sudden attack of vertigo 8 weeks previously, this 47-year-old woman first noticed troublesome tinnitus of the left ear. Examination revealed no neurological or ophthalmological changes of any sort. An audible bruit of the left ear could be interrupted by compression of the occipital artery. The volume of the bruit was 40 dB. Angiographically, there was an arteriovenous angioma of the left transverse sinus. Feeder vessels were identified as the occipital, tentorial, and middle meningeal arteries. The ligation of the occipital artery in the region of the mastoid resulted in complete relief, now of 6 years’ duration.

Case 2

This 57-year-old woman suddenly noticed a tinnitus of the right ear occurring after physical exertion. At examination 2 months later, there were no pathological changes discernible except the bruit. An angiogram showed a fistula near the torcular fed solely by the occipital artery. During angiography there was a fall in blood pressure. Immediately afterward, the tinnitus disappeared spontaneously, and the patient has had no further complaint at last examination 6 years later.

Case 3

For more than a year this 58-year-old woman had a tinnitus of the right ear. An audible bruit could be stopped by compression of the occipital artery. There were no other pathological findings. Angiography revealed an angioma of the transverse sinus with feeders from the occipital, middle meningeal, and tentorial arteries. Further feeders could not be recognized definitively but the angiographic investigation was not complete. Ligation of the occipital artery brought only temporary relief. Some months later the tinnitus reappeared in intensified form with a volume of 80 dB. The patient refused further surgery.

Case 4

For 3 years this 60-year-old woman suffered from an extremely troublesome tinnitus of the right ear. This could be confirmed at auscultation and interrupted by compression
FIG. 2. Case 5. Subtraction film, oblique view, shows evidence of the angioma fed by the occipital artery (crossed arrow), middle meningeal artery (double crossed arrow), and posterior meningeal artery (large arrow). Small arrow indicates the sigmoid sinus.

of the occipital artery. Clinically, there were no other changes. Angiographically, there was an arteriovenous malformation (AVM) at the transverse sinus with feeders from the occipital, posterior auricular, and middle meningeal arteries. Operative exposure of the sigmoid sinus and ligation of the occipital artery were carried out elsewhere, but 6 weeks later the patient had a recurrence. Further angiography revealed that in the region of the transverse sinus an arteriovenous fistula persisted with feeders from the middle meningeal, superficial temporal, tentorial, and occipital arteries. Multiple perforating vessels usually found here were coagulated and their channels closed with bone wax. The sinus was thus completely isolated from the vessels of the external group. The vessels of the medial group were then interrupted by parallel section of the dura about 4 mm above and below the sinus. The dural vessels were clipped. This dissection was extended from the torcular to the junction of the superior petrosal sinus which was likewise clipped and dissected. The interruption of the remaining dural bridge on the far side of the superior petrosal sinus was effected by bipolar coagulation. This is very important as numerous other perforating vessels, especially from the occipital and posterior meningeal arteries, run in this region. The last step, isolation from the internal group by dissection of the tentorium, was not carried out in either case, in order to avoid damage to the bridging veins.

Case 6. This 61-year-old woman had left-sided headache for 5 months and severe tinnitus of the left ear for 6 weeks. The bruit could be confirmed phonographically and interrupted by compressing the occipital artery. The volume was about 20 dB. There were no other clinical changes. Left carotid angiography revealed an AVM of the transverse sinus with feeders from the occipital, middle

Cases 6 and 7
Because of their special operative treatment according to the technique of Hugosson and Bergström, Cases 6 and 7 are discussed in greater detail. The operative technique was identical in both cases (Fig. 3). A large horseshoe-shaped incision was made, centered on the sinus from the mastoid to the inion, with careful coagulation of all scalp vessels. This was followed by osteoplastic craniotomy above and below the transverse sinus, revealing the latter in its whole length. The bone flap was carefully treated with bone wax. The sigmoid sinus was then exposed by means of a rongeur as close as possible to the jugular foramen and then freed from the dorsal surface of the petrous bone and the mastoid. Multiple perforating vessels usually found here were coagulated and their channels closed with bone wax. The sinus was thus completely isolated from the vessels of the external group. The vessels of the medial group were then interrupted by parallel section of the dura about 4 mm above and below the sinus. The dural vessels were clipped. This dissection was extended from the torcular to the junction of the superior petrosal sinus which was likewise clipped and dissected. The interruption of the remaining dural bridge on the far side of the superior petrosal sinus was effected by bipolar coagulation. This is very important as numerous other perforating vessels, especially from the occipital and posterior meningeal arteries, run in this region. The last step, isolation from the internal group by dissection of the tentorium, was not carried out in either case, in order to avoid damage to the bridging veins.

Case 5
This 65-year-old woman suffered for 7 years from epilepsy of the grand-mal type. For a year her sleep had been disturbed by tinnitus of the right ear. At examination there was a bruit behind the mastoid, which could be suppressed by compression of the occipital artery. There were no other pathological changes. Standard left brachial and left carotid angiography were normal. However, special oblique views with subsequent subtraction (Fig. 2) revealed a fistula with feeders from the occipital, middle meningeal, and posterior meningeal arteries. Six days after ligation of the occipital artery, the patient had recurrence of the tinnitus with a volume of 50 dB. Further surgery was refused.
AV malformations of transverse dural sinus

Fig. 3. Artist's drawing of operative isolation of transverse (TS) and sigmoid (SS) sinuses, performed in Cases 6 and 7. SPS = superior petrosal sinus.

meningeal, tentorial, and posterior auricular arteries. Left brachial angiography was normal. The operation described above also revealed an angiomatosis of the neck and the scalp. Visible vessels of the tentorium were coagulated. The postoperative course was uneventful and the patient has been free of complaint to date, 9 months after the operation.

Case 7. For 7 months this 37-year-old man had been troubled by left-sided headache and a tinnitus of the left ear. He was therefore admitted to the Ear, Nose, and Throat Department where a distinct tinnitus was confirmed clinically and phonographically. Compression of the occipital artery stopped the bruit, which was measured at 60 dB. In all other respects the patient was normal. Angiography revealed an arteriovenous angiomata of the transverse sinus with feeders from the occipital, middle meningeal, and tentorial arteries (Fig. 4 left). Ligation of the occipital artery caused the bruit to decrease, but since it was still troublesome, the patient was transferred to the neurosurgical department. Angiographic investigation revealed the persistence of the malformation with feeders from the occipital (proximal to the ligation), the middle and posterior meningeal, the posterior auricular, and the tentorial arteries (Fig. 4 right). Brachial angiography showed retrograde filling of the occipital artery distal to the ligation by muscular anastomoses from the vertebral and the ascending cervical arteries (Fig. 5 left). Surgical treatment was carried out in the manner described above. After operation the symptoms were gone, and the patient has had no relapse during 8 months of follow-up, despite the fact that there was still a shunt via the tentorial arteries at postoperative angiography (Fig. 5 right).

Discussion

Clinically, angiomas of the transverse sinus form a recognizable entity. In most published cases there are only subjective complaints such as tinnitus and headache, but these were reported to be very troublesome. Tinnitus was reported in 57 cases (79%), and in 39 of these the bruit could be heard by the physician. This symptom was the main complaint of all our patients. The incidence of neurological symptoms reported is summarized in Table 1. Among our patients there was only one case of symptomatic epilepsy. In all probability these neurological symptoms can be traced to hemodynamic changes, that is, the disturbance of venous drainage caused by the shunts. These changes

J. Neurosurg. / Volume 45 / July, 1976 15
can sometimes be confirmed angiographically. Of the cases reported in the literature, the most serious neurological symptoms were observed in those with ascertained circulatory disturbances. These malformations seem to occur predominantly in female patients: when including our cases, a ratio of 31 females to 20 males can be established from the literature.

These lesions present a typical angiographic pattern, which varies according to the number of feeders. They may be overlooked if the internal carotid artery alone is filled, and if the tentorial arteries do not participate. If an AVM is suspected, filling of the common carotid artery, or better still, selective filling of the internal and external carotid arteries should be performed. Subtraction films are an excellent aid in revealing feeders which would otherwise be difficult to detect, especially those from the posterior auricular and the posterior meningeal arteries. Selective transmural angiography of the external branches is of course ideal, but unfortunately cannot be carried out in every case. While the feeders are usually unilateral, some authors report bilateral afferent vessels. Cases of bilateral fistulas have also been described.

The hemodynamic changes demonstrable at angiography are sometimes considerable. For example, retrograde filling of the sinus rectus, the superior sagittal sinus, and cerebral veins have been reported. Indeed in some cases thromboses of the transverse sinus or even of all sinuses were observed. The case reported by Sindermann of verified thromboses of both transverse sinuses is unique. When an AVM is present in the region of the transverse sinus a complete radiological exploration is required, supplemented with oblique radiography and subtraction films, if necessary.

The most frequent and constant feeder reported is the occipital artery. In 54 cases analyzed it was present in all but two. The next most frequently observed feeders are the tentorial (22 cases), the middle meningeal (18 cases), the vertebral (11 cases), the posterior auricular (9 cases), the posterior meningeal (4 cases), and the superficial temporal (2 cases) arteries. The posterior and the middle cerebral arteries were each mentioned in one case. These figures, however, have only a relative value, because complete angiographic explorations were not always carried out.

The treatment used most often was ligation of the occipital artery, or the external carotid artery, or both. These methods were completely successful in only a few cases. Subjective improvements or long intervals without relapse were achieved in at least some cases. Ligation of the occipital artery was...
AV malformations of transverse dural sinus

Fig. 5. Case 7. Left: Left brachial angiography after ligation shows retrograde filling of distal occipital artery (double crossed arrow) via anastomoses from vertebral (arrow) and ascending cervical (crossed arrow) arteries. L indicates site of ligation. Right: Postoperative angiogram shows persistence of a fistula via the medial (arrows) and lateral (crossed arrows) tentorial arteries.

It is our opinion that complete relief can also be achieved by less mutilating methods which leave the main venous draining vessels intact. Some of the operations carried out were less extensive, such as application of a large skin flap with coagulation of the vessels, or craniectomy, but complete relief was achieved in only one case.

The method of Hugosson and Bertström, the complete operative isolation and preservation of the transverse and sigmoid sinuses, has been successfully performed in four cases. In one case, where the dural bridge between the superior petrosal and sigmoid sinuses had not been coagulated, a fistula that was filled from the posterior meningeal artery remained. In a further case the tentorium was not dissected. Nonetheless, complete relief

Through ligation of the sigmoid sinus Kosnik, et al., achieved a cure in one case, but another of their cases was successfully treated only after excision of the left transverse sinus, falx, and tentorium, and ligation of the superior and inferior sagittal and the right transverse sinuses.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>No. of Cases</th>
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<tbody>
<tr>
<td>papilledema</td>
<td>10</td>
</tr>
<tr>
<td>epilepsy</td>
<td>4</td>
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<tr>
<td>motor deficits</td>
<td>7</td>
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<tr>
<td>hemianopsia</td>
<td>5</td>
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<td>phosphene</td>
<td>3</td>
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<tr>
<td>hydrocephalus</td>
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We have compiled Table 1 below, which shows the incidence of neurological symptoms in 72 cases of AVM of the transverse sinus.

TABLE 1

Incidence of neurological symptoms in 72 cases of AVM of the transverse sinus

J. Neurosurg. / Volume 45 / July, 1976
was achieved. Relief was also achieved in both our cases treated by this method. The tentorium was not dissected in both, although in one (Case 7), a fistula filled by the tentorial arteries remained but without any symptoms. More recently, other authors have advocated, and sometimes performed with success, a selective embolization of the feeders. This method suffers from the disadvantage of being applicable only to the branches of the external carotid artery, and from a possible further development of other pathways from vessels not primarily involved.

Finally, it should be mentioned that spontaneous cures after angiography have been reported. We, too, observed such a case in which, as in Case 4 of Storr and King, cardiovascular collapse occurred during angiography. In those cases no further treatment was necessary; however, the possibility of spontaneous cure after angiography should always be verified.

Operative isolation of the transverse and sigmoid sinuses strikes us as the most promising method because it takes into consideration the special anatomical conditions of these vascular malformations and leaves the sinus intact. This operation is tolerated surprisingly well and has not led to any complications. Since cures by ligation of either the occipital artery and/or the external carotid artery may be obtained, the indication for the operative isolation of the sinuses should be considered in each particular case. When the occipital artery seems to be the only feeder, its ligation might be attempted. Ligation of the external carotid artery might be performed if angiography reveals participation of its branches. The interruption of the bruit by compression of these vessels is sometimes a useful test.

Nevertheless, as success rates of these methods are not very high, postoperative control and long-term follow-up are necessary. In case of a recurrence, the operative isolation of the transverse and the sigmoid sinuses is the treatment of choice. It should be performed primarily if there are multiple and voluminous shunts, especially if there is a large contribution of the tentorial arteries or from branches of the vertebral or the ascending cervical arteries. Finally, the persistence of the audible bruit during compression, if correctly effected, may be an aid in the therapeutic decision.

Arteriovenous fistulas of the transverse sinus should be treated whenever there is troublesome tinnitus, which may sometimes lead to insomnia or even to suicidal tendencies, or when there are signs of a disturbance in cerebral hemodynamics. Care should be taken that the contralateral transverse and sigmoid sinuses are not occluded, in which case the cerebral venous drainage might be compromised by suppression of the intradural venous collaterals.

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Address reprint requests to: Andreas Kühner, M.D., Neurochirurgische Universitätsklinik, D 6900 Heidelberg, Kirschnerstrasse 1, West Germany.