PERSISTENT CAROTID-BASILAR ANASTOMOSIS
THREE ARTERIOGRAPHICALLY DEMONSTRATED CASES WITH ONE ANATOMICAL SPECIMEN

CLINTON R. HARRISON, M.D.,* AND CHARLES LUTTRELL, M.D.
Division of Neurology, Johns Hopkins Hospital, Baltimore, Maryland

(Received for publication September 24, 1952)

The persistent carotid-basilar anastomosis is a large anomalous vessel joining the cavernous portion of the internal carotid artery to the midportion of the basilar artery. It has been called the persistent primitive trigeminal artery because of its relationship to the gasserian ganglion, especially in early fetal life.

The presence of a carotid-basilar anastomosis such as is seen in the 3 cases here presented is caused by the persistence of a vessel prominent in very early development which is ordinarily obliterated when the embryo has reached the 14 mm. stage. Our understanding of how this comes about is based on the work of Padget who first identified this “primitive trigeminal artery” as a branch of the internal carotid in a 20 somite (3 mm.) human embryo. It is in this stage the principal blood supply to the plexus of vessels which form the paired longitudinal neural arteries, precursors of the basilar artery, and is apparently instrumental in their development. The formation of the carotid-basilar anastomosis itself has been suggested by Streeter to be related to the precocity of the gasserian ganglion, to which it is constantly related as long as it exists.

As the brain develops, the origin of this anastomotic channel becomes increasingly angulated. With this distortion, with the development of the posterior communicating arteries and later of the vertebrais to supply the basilar artery, and with the eventual interposition of the basal sphenoid cartilage the carotid-basilar anastomosis disappears. Figs. 1 and 2 illustrate several phases in the history of this artery. The close relationship to the gasserian ganglion is maintained in all recorded instances of persistence of this vessel.

REVIEW OF THE LITERATURE

Since the original illustrated case report of Quain in 1844 of a “remarkable branch” between the internal carotid artery and the basilar artery, several authors have described additional cases. The literature is summarized in Table 1. It will be noted that 9 of the anastomoses occurred on the right side and 8 on the left. In 8 of the 16 anatomical specimens, the

* Present address: Department of Neurological Surgery, Vanderbilt University Hospital, Nashville, Tennessee.
Fig. 1. This illustration and Fig. 2 were assembled by Padget from her original illustrations. The artery under consideration is underlined. (a & b) A 4 mm. embryo showing how the strong trigeminal branch of the internal carotid artery supplies the bilateral longitudinal neural arteries which precede the basilar artery. By the 6 mm. stage (c), the posterior communicating arteries have usually formed to constitute the anterior supply to the neural arteries which are consolidating into the basilar artery. As a result the trigeminal arteries have dwindled.
Fig. 2. (a & b) Lateral and cross section views of two embryos approximately 14 mm. long with an unusually late retention of the trigeminal artery. Although the posterior communicating and vertebral arteries have formed, they are small in part and the trigeminal artery still supplies the basilar artery, constituting a large carotid-basilar anastomosis. Normally, as seen at 23 mm. (c), only variable remnants of this early connecting branch are found.
anomalous vessel perforated the dorsum sellae. In the other 8 it skirted this structure extradurally.

Among the articles on this subject, that of Oertel\textsuperscript{11} is notable for its review of the literature until 1922. Oertel’s case is interesting because of a co-existing persistent hypoglossal artery coursing through the hypoglossal canal and connecting the right vertebral artery to the right internal carotid artery. The carotid-basilar anastomosis in this case was also on the right side. The persistent hypoglossal artery had previously been described by Batujeff\textsuperscript{2}, but we know of no other instance of the double anomaly described by Oertel.

Sunderland’s articles\textsuperscript{19,20} are distinguished by the excellence of their illustrations. They stress the intimate relation of the abnormal vessel to the gasserian ganglion and to the sensory root of the trigeminal nerve.

The possibility of demonstrating the persistent carotid-basilar anastomosis by arteriography is mentioned by Hasenjäger.\textsuperscript{8} Sutton,\textsuperscript{21} however, is at present the only one to report a case diagnosed by this method. A reproduction of the x-ray accompanies his article.

Sutton emphasizes that the direction of blood flow within the anomaly is from carotid to basilar, as his arteriogram confirms. This is borne out by the three arteriograms here reported. Consideration of the derivation of this vessel should lead one to the same conclusion even without arteriographic confirmation. The anastomosis in earliest embryologic development must conduct blood away from the carotid, for it terminates blindly. With increased blood supply to the longitudinal arteries and later the basilar artery from the posterior communicating and vertebral artery the carotid-basilar

### Table 1

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>No. of Cases</th>
<th>Origin from Carotid</th>
<th>Course of C-B Anastomosis in Relation to the Dorsum Sellae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quain\textsuperscript{14}</td>
<td>1844</td>
<td>1</td>
<td>Right 1</td>
<td>Through 1</td>
</tr>
<tr>
<td>Tüngel\textsuperscript{23}</td>
<td>1860</td>
<td>1</td>
<td>Right 1</td>
<td>Through 1</td>
</tr>
<tr>
<td>Duret\textsuperscript{6}</td>
<td>1874</td>
<td>2</td>
<td>Left 2</td>
<td>Through 2</td>
</tr>
<tr>
<td>Tareniecki\textsuperscript{22}</td>
<td>1880</td>
<td>1</td>
<td>Right 1</td>
<td>Through 1</td>
</tr>
<tr>
<td>Flesch\textsuperscript{7}</td>
<td>1882</td>
<td>1</td>
<td>Right 1</td>
<td>Through 1</td>
</tr>
<tr>
<td>Hochstetter\textsuperscript{9}</td>
<td>1885</td>
<td>2</td>
<td>Left 2</td>
<td>Through 2</td>
</tr>
<tr>
<td>Decker\textsuperscript{6}</td>
<td>1886</td>
<td>1</td>
<td>Right 1</td>
<td>Through 1</td>
</tr>
<tr>
<td>Smith\textsuperscript{15}</td>
<td>1909</td>
<td>1</td>
<td>Right 1</td>
<td>Through 1</td>
</tr>
<tr>
<td>Oertel\textsuperscript{11}</td>
<td>1922</td>
<td>1</td>
<td>Right 1</td>
<td>Through 1</td>
</tr>
<tr>
<td>Hasenjäger\textsuperscript{8}</td>
<td>1937</td>
<td>1</td>
<td>Right 1</td>
<td>Through 1</td>
</tr>
<tr>
<td>Sunderland\textsuperscript{19,20}</td>
<td>1941</td>
<td>1</td>
<td>Right 1</td>
<td>Through 1</td>
</tr>
<tr>
<td>Sutton\textsuperscript{21*}</td>
<td>1950</td>
<td>2</td>
<td>Right 2</td>
<td>Through 2</td>
</tr>
</tbody>
</table>

* No anatomical specimen obtained with Sutton’s second case.
anastomosis becomes attenuated and finally obliterated, whereas one should expect the opposite were the blood to flow from basilar to carotid.

INCIDENCE

The incidence of this vessel among routine autopsies and cerebral angiograms is impossible to ascertain. It is probably not always seen at postmortem examination when present. It has been reported as an arteriographic finding only once, despite the large number of individuals subjected to this procedure in the past two decades. We have seen another case demonstrated arteriographically by Sugar. In a discussion of mechanisms by which the basilar artery fills during carotid angiography, and drawing from a personal experience with 1,526 cases, Lindgren failed to mention the primitive carotid-basilar anastomosis.

The literature consists largely of single case reports; incidence is usually not given. The case demonstrated arteriographically by Sutton was the only example he found in nearly 1,000 cerebral angiograms. Sunderland’s 3 cases were encountered among 210 autopsies. The 3 cases reported here were found among 582 cerebral angiograms examined personally by the authors.

CASE REPORTS

Case 1. J.H.H. 566865. J.L., a 46-year-old white married male school teacher, had been feeling listless for about 6 months. Two months before entry he had had sudden onset of headache accompanied by left-sided weakness, poor coordination and thick speech. He was hospitalized in another institution for 10 days where left hemiparesis was noted. One month before entry here he had a left-sided convulsion. Left-sided weakness persisted, and 2 weeks before entry headache recurred and persisted until admission.

Examination and Course. Significant findings were slight confusion, memory deficit, and left hemiparesis. X-ray of the skull was normal. Right carotid angiogram

Fig. 3. Case 1. Lateral and anteroposterior cerebral arteriograms. (A) Anastomosis.
revealed slight displacement of the anterior cerebral arteries to the left, and a persistent right carotid-basilar anastomosis (Fig. 3). Ventriculogram revealed a tumor mass in the right parietofrontal region.

A right frontal craniotomy and partial right frontal lobectomy were done. Pathological diagnosis: Glioblastoma multiforme.

The patient was discharged on the 14th hospital day. He died at home 2 months later. No autopsy was performed.

Case 2. J.H.H. 596598. I.S., a 54-year-old white married male janitor, was well until the day of entry. Just before noon, he noted sudden onset of severe generalized headache, worst in the region of the occiput. He felt light-headed and collapsed to the floor, but very soon was able to sit up. He vomited once. He seemed confused.

Examination and Course. Significant findings were semistupor and a stiff neck. Lumbar puncture revealed grossly bloody CSF. Emergency right carotid angiography revealed a persistent right carotid-basilar anastomosis (Fig. 4).

On the 2nd hospital day the patient became very irrational. On the 3rd day his temperature rose to 102°F. The pulse became fast. He lapsed into coma, and died shortly thereafter.

Autopsy disclosed a massive intracerebellar hematoma, and persistent carotid-basilar anastomosis.

Case 3. J.H.H. 588456. E.G., a 32-year-old white married female, had had frequent frontal headaches for as long as she could remember. A year before entry, while at work, she had a sudden, unexplained akinetic major seizure. Two months before entry a second akinetic seizure occurred following which her headache grew worse. At this time she began to experience sudden bouts of foul odor in the nostrils lasting a few seconds and not obvious to people about her. She also began to have attacks of twitching and drooping of the right side of the face.

Examination and Course. Significant findings were drooping of the left side of the
face, slight increase in the reflexes of the right arm, slight weakness of grip on the right, and right hemihypaesthesia with inattention phenomena. EEG showed a diffuse abnormality with slight suggestion of left temporal focal spiking. Left carotid arteriogram revealed a persistent carotid-basilar anastomosis (Fig. 5).

She was discharged as a case of undiagnosed disease manifest by diffuse neurological signs and syncopal attacks.

GROSS ANATOMY OF THE SPECIMEN

The death of Case 2 gave us the opportunity to obtain the portion of the base of the skull containing the anomalous vessel (Fig. 6). The origin of the artery is from the cavernous portion of the left internal carotid. At the point of its origin the caliber of this vessel is almost equal to that of the cavernous portion of the internal carotid artery. The vessel proceeds directly caudally in the cavernous sinus and lies in lateral juxtaposition to the oculomotor nerve and medial to the first division of the trigeminal nerve, the medial portion of the gasserian ganglion, and the sensory root of the trigeminal nerve. As the artery leaves the cavernous sinus it emerges through an opening formed by a groove in the posterior petrosal process whose roof is the petroclinoid ligament. At this point the abducens nerve lies directly beneath it. The course now becomes almost transverse, joining the midportion of the basilar artery over the clivus. Superior to this junction the size of the basilar artery is over twice that of the portion lying between the anastomosis and the vertebral arteries.

Both posterior communicating arteries were very small in caliber, but were patent. The circle of Willis was unfortunately destroyed when the brain was sectioned so that it cannot be reproduced here. An artist’s drawing of
Fig. 6. Case 2. (a & b) Photographs of the anatomical specimen. The relationship of the anastomosis to cranial nerves III, V and VI should be noted. Cranial nerve IV has been avulsed.
FIG. 7. Case 2. Drawing of the anatomical specimen. The position and relationship of the anastomosis are more apparent than in the photograph.

the specimen pictures more clearly than the photographs the relationships of the artery (Fig. 7).

DISCUSSION

A knowledge of variations in the circle of Willis is necessary in the interpretation of cerebral angiograms. The anomaly under consideration is an unusual one, but our experience suggests that it is not as rare as has been supposed. The arteriographic configuration of the persistent carotid-basilar
anastomosis is almost constant, and attention should be directed to the
search for this vessel in any angiogram in which the posterior cerebral and
cerebral arteries are outlined by the carotid injection of radiopaque dye.

The close anatomical relationship of the anastomosing vessel to the sen-
sory root of the 5th cranial nerve assumes salience in operations on or near
the gasserian ganglion. An encounter with the persistent carotid-basilar
anastomosis during such surgery could be hazardous.

Dandy\textsuperscript{3} suggested that pressure on the sensory root of the 5th nerve by
an S-shaped tortuosity of the basilar artery can sometimes be responsible
for trigeminal neuralgia. The carotid-basilar anastomosis creates similar
pressure on the root. Sunderland\textsuperscript{20} and Sutton \textsuperscript{21} commented on this, but in
their cases there was no record of dysfunction of the 5th nerve. It is con-
ceivable that an arteriosclerotic plaque in the vessel might compress the
nerve, but no such case has been recorded. Among the cases reported here a
review of the past histories failed to disclose any evidence of 5th nerve in-
volve ment.

As shown in our specimen the aberrant vessel also bears close relation-
ship to the oculomotor nerve, the trochlear nerve and the abducent nerve
in the cavernous sinus. In this case there was no history of extraocular pal-
sies or pupillary abnormalities.

In our specimen the posterior communicating arteries and the basilar
artery caudal to the anastomosis are small, and the principal blood supply
of the basilar artery was furnished by the anastomotic channel. Sunderland,
Altmann,\textsuperscript{3} and Oertel, observed that in the presence of a persistent tri-
geminal artery the vertebral artery on that side or both sides may be con-
siderably reduced in size. Whether failure in development of the vertebral
arteries can influence the persistence of the carotid-basilar anastomosis, or
whether the presence of the anastomosis prevents development of the verte-
bral arteries one cannot say. In any event, atresia of the vertebral arteries is
compensated for by the presence of this anomaly.

Oertel states that branching points of presegmental arteries in the em-
byro may remain as small widenings of the carotid arteries or leave a scar at
their points of obliteration. Padget\textsuperscript{12} has shown that among individuals with
cerebral aneurysms, the circle of Willis shows a primitive state of develop-
ment in about 50 per cent of cases. Dandy,\textsuperscript{3} on the basis of Padget’s work,
was of the opinion that congenital cerebral aneurysms arise from weakened
points representing the site of incompletely involuted embryonic vessels.
Sugar\textsuperscript{17} mentioned that the relatively common aneurysms of the cavernous
portion of the internal carotid artery may well arise from just such a weak
point representing the site of the obliterated carotid-basilar anastomosis.
This seems a wholly reasonable interpretation.

It is not unlikely that weakening of the wall of the carotid artery at the
site of the obliterated carotid-basilar anastomosis accounts for the predilec-
tion of the carotid to rupture within the cavernous sinus with resulting ar-
teriovenous fistula. Dandy and Folli\textsuperscript{4} demonstrated congenital weakness in
the wall of the internal carotid artery with loss of the elastic coat at the
location of the fistula in a case which was precipitated by trauma. In a spontaneous case of carotid-cavernous fistula they found two openings in the wall of an aneurysm within the sinus.

SUMMARY

The embryologic origin of the persistent carotid-basilar anastomosis is described. The literature pertaining to this vessel is cited and 3 additional cases, all demonstrated arteriographically, are presented. The gross anatomy of a specimen obtained post mortem in one of these 3 cases is described in detail. Some features of possible interest are discussed.

The authors are greatly indebted to Mrs. Dorcas Hager Padget for her help and advice, especially with reference to the embryology of the anomaly and the illustration of this specimen. They also wish to thank Dr. David Clark, who made this study possible, and Mr. Leon Schlossberg, whose drawing greatly clarifies the relationships of the vessel under discussion.

REFERENCES

5. DECKER, F. Cited by Oertel.[13]
6. DURFET, H. Cited by Oertel.[11]
7. FLESH, M. Cited by Oertel.[13]
18. SUGAR, O. Personal communication.
22. TARENIECKI-MAYZEL. Cited by Oertel.[11]
23. TÜNGEL. Cited by Oertel.[13]