Microsurgical anatomy of the supraclinoid portion of the internal carotid artery

HIROHIKO GIBO, M.D., CARLA LENKEY, M.S., AND ALBERT L. RHOTON, JR., M.D.

Department of Neurosurgery, University of Florida Health Center, Gainesville, Florida

The microsurgical anatomy of the supraclinoid portion of the internal carotid artery (ICA) was studied in 50 adult cadaver cerebral hemispheres using × 3 to × 40 magnification. The ICA was divided into four parts: the C1 or cervical portion; the C2 or petrous portion; the C3 or cavernous portion; and the C4 or supraclinoid portion. The C4 portion was divided into three segments based on the origin of its major branches: the ophthalmic segment extended from the origin of the ophthalmic artery to the origin of the posterior communicating artery (PCoA); the communicating segment extended from the origin of the PCoA to the origin of the anterior choroidal artery (AChA); and the choroidal segment extended from the origin of the AChA to the bifurcation of the carotid artery. Each segment gave off a series of perforating branches with a relatively constant site of termination. The perforating branches arising from the ophthalmic segment passed to the optic nerve and chiasm, infundibulum, and the floor of the third ventricle. The perforating branches arising from the communicating segment passed to the optic tract and the floor of the third ventricle. The perforating branches arising from the choroidal segment passed upward and entered the brain through the anterior perforated substance. The anatomy of the ophthalmic, posterior communicating, anterior choroidal, and superior hypophyseal branches of the C4 portion was also examined.

KEY WORDS • internal carotid artery • microneurosurgery • microsurgical anatomy • intracranial aneurysm • cerebrovascular disease

The supraclinoid portion of the internal carotid artery (ICA) is a common site of intracranial aneurysms, and its branches are frequently stretched or displaced by intracranial tumors. It is exposed during most operations on aneurysms of the circle of Willis, and tumors of the sphenoid ridge, anterior and middle cranial fossae, and sellar region. The increased use of the operating microscope for these operations has created a need for a detailed study of the supraclinoid portion of the ICA.

Materials and Methods

Fifty adult, formalin-fixed cerebral hemispheres (25 brains) removed at autopsy provided the material for this study. The arteries were perfused with colored latex or acrylic to facilitate dissection. The supraclinoid portion of the ICA was examined under × 3 to × 40 magnification, with special attention being directed to the ophthalmic, posterior communicating, and anterior choroidal arteries, and the perforating branches arising from the supraclinoid segment of the ICA.

Results

Segments of the Internal Carotid Artery

The ICA was divided into four parts (Fig. 1): the C1 or cervical portion extended from its junction with the common carotid artery to the external orifice of the carotid canal; the C2 or petrous portion coursed within the carotid canal, and ended where the artery entered the cavernous sinus; the C3 or cavernous portion coursed within the cavernous sinus, and ended where the artery passes through the dura mater, forming the roof of the cavernous sinus; and the C4 or supraclinoid portion began where the artery passed above the anterior clinoid process to enter the subarachnoid space and terminated at the bifurcation into the anterior and middle cerebral arteries. The
Supraclinoid portion of internal carotid artery

**Fig. 1.** Lateral (left) and anterior views (right) of the left internal carotid artery (ICA) and A and B segments of the supraclinoid (C4) portion. A: Lateral view of the C1 portion. B: Anterior view of the C1 portion. The ICA is divided into four parts. These parts, from proximal to distal, are the C1 through the C4 portions. The cervical portion (C1, red) extends from the origin of the ICA to the external orifice of the carotid canal in the petrous temporal bone. The petrous portion (C2, orange) extends from the external orifice of the carotid canal to where the artery exits the carotid canal to enter the cavernous sinus. The cavernous portion (C3, yellow) begins where the artery enters the cavernous sinus and terminates where it emerges from the dura mater on the medial side of the anterior clinoid process to enter the intracranial cavity. The intracranial (supraclinoid) portion (C4, beige) begins where the artery enters the cranial cavity medial to the anterior clinoid process and terminates below the anterior perforated substance where the artery bifurcates into the anterior and middle cerebral arteries. The ICA gives rise to the ophthalmic (Ophth.A.), posterior communicating (P.Co.A.), anterior choroidal (A.Ch.A.), anterior cerebral (A.C.A.), and the middle cerebral (M.C.A.) arteries. The supraclinoid portion of the ICA is divided into three segments based on the origin of these branches: the ophthalmic segment (C4-Op., dark blue) extends from the origin of the ophthalmic artery to the origin of the posterior communicating artery; the communicating segment (C4-Co., light green) extends from the origin of the posterior communicating artery to the origin of the anterior choroidal artery; and the choroidal segment (C4-Ch., dark green) extends from the origin of the anterior choroidal artery to the bifurcation of the internal carotid artery into the anterior and middle cerebral arteries.

Cavernous (C3) and intracranial (C4) portions have several curves that form an S-shape, and together these portions are called the carotid siphon.\(^1\) Fischer\(^4\) divided the carotid artery into five numbered segments, beginning intracranially and proceeding toward the cranial base.\(^1\)

**Basic Anatomical Relationships**

The supraclinoid (C4) portion of the ICA began where the artery emerged from the dura mater, forming the roof of the cavernous sinus (Fig. 2). It entered the cranial cavity on the medial side of the anterior clinoid process below the optic nerve and coursed posterior, superior, and slightly lateral to reach the lateral side of the optic chiasm. It bifurcated in the area below the anterior perforated substance at the medial end of the Sylvian fissure to give rise to the anterior and middle cerebral arteries. In its course, it gave rise to the ophthalmic, anterior choroidal, and posterior communicating arteries, and to other small perforating branches including the superior hypothalamic arteries.

The C4 portion was present in each of the 50 hemispheres examined. Agenesis or aplasia of this artery, although rare, has been reported.\(^2\) Its average diameter at the level of the origin of the ophthalmic artery was 5.0 mm, and at the terminal bifurcation 4.1 mm.

**Segments of the C4 Portion**

The C4 portion of the ICA was divided into three segments based on the site of origin of the ophthalmic,
FIG. 2. Perforating branches of the internal carotid artery (ICA). A: Inferior view. The internal carotid artery gives rise to the ophthalmic (Ophth.A.), posterior communicating (P.Co.A.), anterior choroidal (A.Ch.A.), anterior cerebral (A.C.A.), and the middle cerebral (M.C.A.) arteries. The supraclinoid portion of the ICA is divided into three segments based on the origin of these branches: an ophthalmic segment (C4-Op., blue) that extends from the origin of the ophthalmic artery to the origin of the PCoA; a communicating segment (C4-Co., light green) that extends from the origin of the PCoA to the origin of the AChA; and a choroidal segment (C4-Ch., dark green) that extends from the origin of the AChA to the bifurcation of the ICA into the anterior and middle cerebral arteries. The perforating branches arising from the ophthalmic segment extend to the optic nerve (O.N.), optic chiasm (O.Ch.) and the optic tracts (O.Tr.) and the floor of the third ventricle around the infundibulum (Infund.) and tuber cinereum (Tuber Cin.). The superior hypophyseal arteries (Sup.Hyp.A.) arise from the ophthalmic segment and extend to the infundibulum of the pituitary gland. The branches arising from the communicating segment reach the optic tracts.

FIG. 2 (continued→)
floor of the third ventricle and the area around the mamillary bodies (Mam.Bodies). The perforating branches of the choroidal segment pass upward and enter the anterior perforated substance (Ant.Perf.Subst.). The posterior cerebral arteries (P.C.A.) arise from the basilar artery (B.A.) and pass backward below the optic tracts. The anterior cerebral and anterior communicating (A.Co.A.) arteries course above the optic chiasm and pass between the frontal lobes (Fr.Lobe). The olfactory nerves (Olf.N.) are lateral to the gyrus rectus (Gyr.Rectus).

B: Anterior view. The left optic nerve has been divided near its entrance into the optic canal and elevated to give a clearer view of the perforating branches. The ophthalmic artery arises above the cavernous sinus. The carotid artery courses through the cavernous sinus and then laterally and produces a prominence in the wall of the sphenoid sinus before giving rise to the ophthalmic artery. The oculomotor (III), trochlear (IV), abducens (VI), and the ophthalmic (V1), maxillary (V2), and mandibular (V3) divisions of the trigeminal nerve pass lateral to the sphenoid sinus in the walls of the cavernous sinus. The superior hypophyseal arteries arise from the ophthalmic segment.

C: Anterior view with both optic nerves divided and elevated to show the lower surface of the floor of the third ventricle and the perforating branches passing to it. The infundibulum has been divided above the diaphragma sellae (Diaph.).

Perforating Branches of the C4 Portion

Each segment of the C4 portion gave off a series of perforating branches with a relatively constant site of termination (Figs. 2 to 7). The number of perforating arteries (excluding the ophthalmic, posterior communicating, and anterior choroidal arteries) arising from C4 ranged from three to 16 (average 8.2).

Ophthalmic Segment. The number of perforating arteries arising from the ophthalmic segment ranged from one to seven (average 3.6). Of the perforating arteries found in 50 hemispheres, 40% arose from the posterior aspect of the C4 portion, 31% arose from the posteromedial aspect, 26% arose from the medial aspect, and the remaining 3% arose from the other surfaces. These branches were most commonly distributed to the infundibulum (stalk) of the pituitary.
FIG. 3. Inferior views of the perforating branches of the supraclinoid portion of the internal carotid artery (ICA). A: The supraclinoid portion of the ICA gives rise to the ophthalmic (Ophth.A.), posterior communicating (P.Co.A.), and the anterior choroidal (A.Ch.A.) arteries. The supraclinoid portion of the artery is divided into three segments based on the site of origin of these three branches: the ophthalmic segment (C4-Op.) extends from the origin of the ophthalmic artery to the origin of the PCoA; the communicating segment (C4-Co.) extends from the origin of the PCoA to the origin of the AChA; and the choroidal segment (C4-Ch.) extends from the origin of the AChA to the bifurcation of the carotid artery into the anterior and middle cerebral arteries. The optic nerves (O.N.) are above the ophthalmic arteries. The optic chiasm and optic tracts (O.Tr.) are above the anterior (Ant.Lobe) and posterior (Post.Lobe) lobes of the pituitary gland. The tuber cinereum (Tuber Cin.) is anterior to the apex of the basilar artery (B.A.). The posterior cerebral arteries (P.C.A.) pass around the cerebral peduncles (Cer.Ped.) above the oculomotor nerves (III). The perforating branches arising from the ophthalmic segment pass superior to the anterior lobe to the optic nerve and chiasm and to the anterior part of the tuber cinereum. A single perforating branch arises from the communicating segment on each side and passes upward to the optic tract and the floor of the third ventricle. B: The anterior lobe of the pituitary gland has been reflected backward to show the superior hypophyseal arteries (Sup.Hyp.A.) passing from the ophthalmic segment to the infundibulum (Infund.). The anterior cerebral (A.C.A.) and the anterior communicating (A.Co.A.) arteries are seen above the optic chiasm (O.Ch.). C: The pituitary gland has been removed to show the superior hypophyseal and infundibular arteries (Infund.A.) passing to the infundibulum of the hypophysis. The branches from the ophthalmic segment pass to the optic nerve, optic chiasm, optic tract, and the infundibulum and tuber cinereum. The AChA's pass posteriorly below the optic tracts as do the posterior cerebral arteries. A single perforating branch arises from the communicating segment on the right. The communicating segment on the left is very short and does not give rise to any perforating branches.

FIG. 4. Inferior views of the perforating branches of the supraclinoid portion of the internal carotid artery (ICA). A: The supraclinoid portion of the artery gives rise to the posterior communicating (P.Co.A.), anterior choroidal (A.Ch.A.), middle cerebral (M.C.A.), and anterior cerebral arteries (A.C.A.). The supraclinoid portion of the artery is divided into three segments based on the site of origin of these branches. An ophthalmic segment (C4-Op.) that extends from the origin of the ophthalmic artery (not shown because the ICA was divided above the level of origin of the ophthalmic artery) to the origin of the PCoA; a communicating segment (C4-Co.) that extends from the origin of the PCoA to the origin of the AChA; and a choroidal segment (C4-Ch.) that extends from the origin of the AChA to the level of the bifurcation of the ICA into the anterior cerebral and middle cerebral arteries. The ophthalmic segment sends perforating branches to the optic nerves (O.N.), and optic chiasm (O.Ch.), and the tuber cinereum (Tuber Cin.). The superior hypophyseal arteries (Sup.Hyp.A.) pass to the infundibulum of the hypophysis (Infund.). The communicating segment sends one perforating branch on each side to the optic tracts (O.Tr.) and the region around the mamillary bodies (Mam.Body). The choroidal segment sends its perforating branches into the anterior perforated substance (Ant.Perf.Subst.). The posterior cerebral arteries (P.C.A.) arise from the...
Supraclinoid portion of internal carotid artery

Fig. 4 (continued)
basilar artery (B.A.) and pass laterally around the cerebral peduncles (Cer.Ped.). The temporal lobe (Temp.Lobe) is lateral to the carotid artery. The middle cerebral arteries pass laterally into the Sylvian fissure below the anterior perforated substance. The frontal lobes (Fr.Lobe), gyrus rectus (Gyr.Rectus), and olfactory nerves (Olf.N.) are above the optic nerves. The thalamoperforating arteries (Thal.Perf. A.) pass posteriorly between the oculomotor nerves (III). B: Inferior view of another specimen. The ophthalmic segment gives rise to perforating branches that pass to the optic nerves, chiasm, and tracts, and to the infundibulum and tuber cinereum. No perforating branches arise from the communicating segment on either side in this specimen. The perforating branches from the choroidal segment pass into the anterior perforated substance (A.Co.A.) arteries. The basilar and the proximal parts of the posterior cerebral arteries have been removed. The superior hypophyseal arteries arise from the ophthalmic segment and the infundibular arteries (Infund.A.) arise from the PCoA, and both pass to the infundibulum. One perforating branch arises from the communicating segment on each side and passes to the optic tract and floor of the third ventricle. The choroidal segment gives rise to multiple perforating branches that pass into the anterior perforated substance lateral to the optic tracts.

J. Neurosurg. / Volume 55 / October, 1981
Fig. 5. Anterior and anterior inferior views of the supraclinoid portion of the internal carotid artery (ICA). A: Anterior view. The optic nerves (O.N.) enter the optic canals medial to the anterior clinoid processes (Ant.Clinoid). The infundibulum (Infund.) passes inferiorly below the optic chiasm (O.Ch.) to the pituitary gland. The carotid arteries (C.A.) are posterior to the optic nerves. The planum sphenoidal (Planum) is anterior to the chiasmatic sulcus (Ch.Sulc.) and the tuberculum sellae (Tuberculum). The perforating branches of the carotid artery pass medially in the subchiasmatic space. The superior hypophyseal arteries (Sup.Hyp.A.) arise from the carotid artery and pass to the infundibulum. The falxform process (Falc.Process) is a fold of dura mater that passes above the optic nerve proximal to the optic foramen. B: The right optic nerve has been divided at the optic foramen and elevated to show the perforating branches of the supraclinoid portion of the carotid arteries. The right anterior cerebral artery (A.C.A.) was divided at its origin so that the optic nerve and chiasm could be elevated. The carotid artery gives rise to multiple perforating branches as well as the ophthalmic (Ophth.A.), posterior communicating (P.Co.A.), anterior choroidal (A.Ch.A.), and the middle cerebral arteries (M.C.A.). The supraclinoid portion of the ICA is divided into three segments based on the origin of its major branches: the ophthalmic segment (C4-Op.) extends from the origin of the ophthalmic artery to the origin of the PCoA, the communicating segment (C4-Co.) extends from the origin of the PCoA to the origin of the AChA, and the choroidal segment (C4-Ch.) extends from the origin of the AChA to the bifurcation of the carotid artery. The perforating branches arising from the ophthalmic segment pass to the optic nerve, chiasm, infundibulum, and the floor of the third ventricle. The perforating branches arising from the communicating segment pass to the optic tract and the floor of the third ventricle. The perforating branches arising from the choroidal segment pass upward and enter the brain through the anterior perforated substance (Ant.Perf.Subst.). The diaphragma sellae (Diaph.) surrounds the infundibulum above the pituitary gland. The temporal lobe (Temp.Lobe) is below the middle cerebral artery.
Supraclinoid portion of internal carotid artery

FIG. 5. C: The left optic nerve has been divided at the optic foramen and the anterior cerebral artery divided near its origin so that both optic nerves, and the chiasm and tract could be elevated to show the perforating branches of the carotid artery. The Liliequist membrane (Lilieq.Memb.) is posterior to the infundibulum, and hides the basilar artery but not the posterior cerebral artery (P.C.A.). The perforating branches of the ophthalmic segment pass upward to the infundibulum and the optic nerve, chiasm, and tract. D: Both optic nerves and both anterior cerebral arteries and the infundibulum have been divided to permit the optic nerves and chiasm to be elevated with a forceps for this view under the optic chiasm and across the diaphragma sellae and dorsum to the upper part of the basilar artery (B.A.) and the oculomotor nerves (III). The oculomotor nerves pass forward below the posterior cerebral arteries. The perforating branches of the supraclinoid segment of the carotid artery pass upward to supply the infundibulum, the optic chiasm and tracts, and the floor of the third ventricle; some enter the brain through the anterior perforated substance. The right AChA is very large.

Communicating Segment. No perforating branches arose from the communicating segment in 60% of hemispheres. One perforating branch arose from this segment in 24% of hemispheres, and two arose here in 16%. In a previous study in this laboratory, no perforating branches were found on this segment in 68% of hemispheres, one was found in 14%, two were found in 12%, and three in 6%. These branches arose from the posterior one-half of the arterial wall. These branches terminated in descending order of frequency in the optic tract, premamillary part of the floor of the third ventricle, the optic chiasm, infundibulum,
and the anterior and posterior perforated substance.

**Choroidal Segment.** The choroidal segment was the most frequent site of perforating branches. The number of perforating branches varied from one to nine (average four). Of the perforating branches found in 50 hemispheres, 76% arose from the posterior surface of the C3 portion, 10% arose from the posteromedial surface, 11% arose from the posterolateral surface, and the remaining 3% arose from the other surfaces. These branches terminated in descending order of frequency at the anterior perforated substance, optic tract, and the uncus.

**Superior Hypophyseal and Infundibular Arteries**

The superior hypophyseal arteries were a group of small branches that arose from the C4 segment and terminated on the pituitary stalk and gland, but also sent branches to the optic nerves and chiasm and the floor of the third ventricle (Figs. 2 to 7). The infundibular arteries are a group of arteries that originated from the PCoA and were distributed to the infundibulum (Figs. 3C and 4C).2

The superior hypophyseal arteries usually arose from the ophthalmic segment. The number of superior hypophyseal arteries arising from a C4 portion ranged from one to five (average 2.2). Stanfield and Taveras and Wood found two or more superior hypophyseal arteries arising from the ICA. Of the total number found in 50 hemispheres in this study, 39% arose from the posteromedial aspect of the C4 portion, 35% arose on the medial aspect, 24% arose on the posterior aspect, and 2% arose from the other surfaces. There were fewer infundibular arteries than there were superior hypophyseal arteries. There was one infundibular artery in 14% of hemispheres, two in 10%, and none in 76%.

The superior hypophyseal and infundibular arteries passed medially across the ventral surface of the chiasm to reach the tuber cinereum. They intermingled and formed a fine anastomotic plexus around the pituitary stalk called the "circuminfundibular anastomosis" that can be seen on most angiograms using magnification and subtraction.1,20

The superior hypophyseal and infundibular arteries and the circuminfundibular plexus were distributed to the pituitary stalk and anterior lobe. The inferior hypophyseal branch of the meningo-hypophyseal branch of the C3 segment perfused the posterior lobe. The capsular arteries of McConnell also arose from the C3 segment and supplied the capsule of the pituitary gland.8,14

This circuminfundibular plexus gives rise to ascending and descending arteries.14,23,24 The descending arteries include short-stalk and superficial arteries. The short-stalk arteries are reported to penetrate the infundibulum directly and form capillaries that lead into sinusoids running down the stalk. The superficial arteries course inferiorly on the outside of the stalk in the subarachnoid space and penetrate the anterior lobe. The ascending arteries supply the tuber cinereum, median eminence, and the inferior surface of the optic chiasm. The superior hypophyseal arteries also send branches to the chiasm and proximal portions of the optic nerves.

**Prebifurcating Branches of the C4 Portion**

The major prebifurcation branches of the C4 portion are the ophthalmic, posterior communicating, and anterior choroidal arteries. These arteries give rise to perforating branches that supply areas that overlap with the perforating branches of the C4 portion (Figs. 2 to 7).

**Ophthalmic Artery.** The ophthalmic artery arose from the C4 portion below the optic nerve, and passed anterolaterally below the optic nerve to enter the optic canal and orbit (Figs. 2, 3, and 5 to 7). In this study, all of the ophthalmic arteries arose from the C4 portion except one that arose from the C3 segment. In a previous study from this laboratory, the ophthalmic artery was found to originate from the ICA above the cavernous sinus in 89% of hemispheres and within the cavernous sinus in 8%; it was absent in 3%.8,17 The ophthalmic artery usually arose from the medial one-third of the superior surface of the C4 portion immediately distal to the cavernous sinus in the area below the optic nerve and medial to the anterior clinoid process. It arose above the medial one-third of the superior surface of the C4 portion in 78% of hemispheres and above the middle one-third of the superior surface in 22%. None arose from the lateral one-third of the superior surface. The origin of the ophthalmic artery may vary from as far as 5 mm anterior to 7 mm posterior to the tip of the anterior clinoid process and between 2 and 10 mm medial to the clinoid process.8 Most ophthalmic arteries arise anterior to the tip of the anterior clinoid process approximately 5 mm medial to the clinoid process.

The intracranial segment of the ophthalmic artery is usually very short. In a previous study from this laboratory,8 14% of the segments were found to exit the ICA and immediately enter the optic canal; in the remaining 86%, the maximum length of the preforaminal segment was 7.0 mm, and the mean length 3.0 mm. The diameter of the origin of the ophthalmic artery ranged from 0.4 to 2.0 mm (average 1.4 mm).

Only two of the 50 ophthalmic arteries examined...

H. Gibo, C. Lenkey and A. L. Rhoton, Jr.
Supraclinoid portion of internal carotid artery

Fig. 6. Right and left lateral views of the perforating branches of the supraclinoid portion of the internal carotid artery (ICA). A: Right lateral view. The optic nerves (O.N.) pass posteriorly from the optic foramen to join the optic chiasm (O.Ch.) and optic tracts (O.Tr.). The anterior clinoid process (Ant. Clinoid), posterior communicating (P.Co.A.), anterior choroidal (A.Ch.A.), middle cerebral (M.C.A.), and anterior cerebral (A.C.A.) arteries. The supraclinoid portion of the ICA is divided into three segments on the basis of the origin of its branches: the ophthalmic segment (C4-Op.) extends from the origin of the ophthalmic artery to the origin of the PCoA; the communicating segment (C4-Co.) extends from the origin of the PCoA to the origin of the AChA; and the choroidal segment (C4-Ch.) extends from the origin of the AChA to the bifurcation of the carotid artery. The perforating branches arising from the ophthalmic segment pass to the undersurface of the optic nerve and chiasm. The perforating branches arising from the choroidal segment enter the anterior perforated substance (Ant.Perf.Subst.) near where the branches from the anterior cerebral artery enter it. B: Left lateral view. The proximal part of the supraclinoid segment of the left carotid artery (C.A.) has been reflected inferiorly to show the perforating branches arising from the carotid artery. The superior hypophyseal artery (Sup.Hyp.A.) passes to the infundibulum (Infund.). The dorsum sellae (Dorsum) and posterior clinoid process (Post.Clinoid) are posterior to the diaphragma sellae (Diaph.).

gave rise to intracranial perforating branches. These branches ran posteriorly, and were distributed to the ventral aspect of the optic nerve and chiasm and the pituitary stalk. These vessels have been called “prechiasmal branches” by Dawson.210

Posterior Communicating Artery. The PCoA arose from the midportion of the C4 segment. The length of the C4 portion between the origins of the ophthalmic artery and PCoA ranged from 6.0 to 15.0 mm (average 9.6 mm) and between the origin of the PCoA and the terminal bifurcation ranged from 4.0 to 18.0 mm (average 9.7 mm). The PCoA passed posteromedially below the tuber cinereum and above the sella turcica and oculomotor nerve to join the posterior cerebral artery. In the embryo, the PCoA continues as the posterior cerebral artery, but in the adult the latter artery is annexed by the basilar system. If the PCoA remains the major origin of the posterior cerebral artery, the configuration is termed “fetal.” If the PCoA was of small or normal size, it coursed posteromedially to join the posterior cerebral artery medial to the oculomotor nerve, but if it was of a fetal type it coursed posterolaterally above or lateral to the oculomotor nerve. The PCoA arose from the posteromedial aspect of the C4 portion in 44% of hemispheres, the posterior surface in 30%, the posterolateral surface in 22%, and the medial surface in 4%. Its diameter varied from 0.4 to 4.0 mm (average 1.4 mm) and its length ranged from 5.0 to 18.0 mm (average 12.0 mm).

The number of perforating arteries arising from the PCoA ranged from four to 14 (average 7.8). These branches coursed superiorly and terminated in decreasing order of frequency in the premamillary part of the floor of the third ventricle, the posterior perforated substance and interpeduncular fossa, the optic tract, the pituitary stalk, and the optic chiasm. They then reached the thalamus, hypothalamus, subthalamus, and internal capsule.21,25,24 The largest branch that arose from the PCoA and entered the floor of the third ventricle in front of or beside the mamillary body has been named either the “premamillary” or “anterior thalamoperforating” artery.21
FIG. 7. Posterior views of the perforating branches of the supraclinoid portion of the internal carotid artery (ICA). A: The basilar artery (B.A.) and brain stem have been divided and the floor of the third ventricle has been elevated to provide this posterior view of the supraclinoid portion of the ICA. The optic nerves (O.N.) can be followed back to the optic chiasm and the optic tracts (O.Tr.). The infundibulum of the pituitary gland (Infund.) arises from the tuber cinereum (Tuber Cin.). The mamillary bodies (Mam.Bodies) lie posterior to the tuber cinereum. The supraclinoid portion of the ICA gives rise to the posterior communicating (P.Co.A.), anterior choroidal (A.Ch.A.), middle cerebral (M.C.A.), and anterior cerebral (A.C.A.) arteries. The PCoA can be followed backward to its junction with its posterior cerebral arteries (P.C.A.). The supraclinoid portion of the ICA is divided into three segments on the basis of the origin of its major branches: the ophthalmic segment (C4-Op.) extends from the origin of the ophthalmic artery to the origin of the PCoA, the communicating segment (C4-Co.) extends from the origin of the PCoA to the origin of the AChA, and the choroidal segment (C4-Ch.) extends from the origin of the AChA to the bifurcation into the anterior and middle cerebral arteries. The perforating branches arising from the ophthalmic segment in this specimen enter the optic tract, the floor of the third ventricle, and the infundibulum. The superior hypophyseal arteries (Sup.Hyp.A.) pass to the infundibulum. A single perforating artery arises from the communicating segment on each side. The posterior wall of the choroidal segment is the source of numerous perforating branches. The pituitary stalk passes through the diaphragma sellae (Diaph.) anterior to the dorum sellae (Dorsum). B: The right half of the dorum sellae and the right posterior clinoid process (Post.Clinoid) have been removed to expose the pituitary gland and its anterior (Ant.Lobe) and posterior (Post.Lobe) lobes. The infracavernous segment of the carotid artery (C.A.) is exposed to the right of the pituitary gland. The apex of the basilar artery and the proximal parts of the posterior cerebral and the superior cerebellar (S.C.A.) arteries have been elevated to expose the pituitary stalk and floor of the third ventricle. The intracavernous portion of the carotid artery gives rise to the inferior hypophyseal (Inf.Hyp.A.) and the tentorial (Tent.A.) arteries. The posterior half of the right PCoA is duplicated. The ophthalmic segments give rise to the superior hypophyseal arteries. The left carotid artery has been divided just distal to the origin of the PCoA. C: Posterior views of the anterior part of the circle of Willis. The optic chiasm has been divided posterior to its junction with the optic nerves and anterior to where the infundibulum arises from the floor of the third ventricle. The superior hypophyseal arteries pass medially from the carotid artery to the infundibulum and also give rise to branches coursing to the lower surface of the optic chiasm. The communicating segment gives rise to one perforating branch on the right and two on the left. The choroidal segment gives rise to more perforating branches than the other segments, but they have been divided near their origin. The anterior cerebral artery gives rise to perforating branches coursing to the upper surface of the optic chiasm and nerves. The anterior communicating artery (A.Co.A.) is seen above the optic chiasm.
Supraclinoid portion of internal carotid artery

Dilations of the origin of the PCoA from the C₄ portion, known as "junctional dilatation" or "infundibular widening," were found in three hemispheres in this study. Such dilation may be difficult to distinguish from an aneurysm. Hassler and Saltzman found this change in 6.5% of normal angiograms and regarded it as an early stage of aneurysm formation because of the histological appearances, which were identical with those of aneurysms. On the other hand, Epstein, et al., using histological techniques, examined these junctional dilations obtained from autopsy specimens, and concluded that they were neither aneurysmal or preaneurysmal.

Anterior Choroidal Artery. The AChA’s were present in each hemisphere examined, and all arose from the C₄ portion (Figs. 2 to 7). Their origin was located between 2.5 and 10.0 mm (average 5.6 mm) proximal to the terminal bifurcation of the ICA. The site of origin was on the posterolateral aspect of the C₄ portion in 66% of hemispheres, on the posterior aspect in 28%, and on the lateral side in 6%. The AChA arose as a duplicate or two arteries in two hemispheres. The diameter of the AChA varied from 0.5 to 2.1 mm (mean 1.0 mm).

From its origin, the AChA coursed posteriorly below the optic tract and above the PCoA. It terminated by passing through the choroidal fissure and joining the choroid plexus in the temporal horn and atrium. The AChA sent branches in decreasing order of frequency to the optic tract, cerebral peduncle, lateral geniculate body, uncus, and temporal lobe. These branches supplied the optic radiations, globus pallidus, midbrain, thalamus, and the retrolenticular and posterior portion of the posterior limb of the internal capsule.

Discussion

The C₄ segment of the ICA and its major and perforating branches are frequently exposed in operations on tumors of the sphenoid ridge, anterior, and middle cranial fossae, and the suprasellar region. Only infrequently should any of these branches be sacrificed in removing a tumor. Any vessel that stands above the surface of the tumor capsule should be dealt with initially as if it were a vessel supplying the brain. An attempt should be made to displace the vessel off the tumor capsule using a small dissector after the tumor has been removed from within the capsule. The perforating branches from the ophthalmic segment arise from the medial wall of the C₄ segment and are commonly stretched over the dome of sellar tumors. The perforating branches from the communicating and choroidal segments arise from the posterior wall of the C₄ portion and are frequently stretched around tumors arising behind C₄ in the parasellar region or along the sphenoid ridge.

The intradural exposure of the C₄ portion and the anterior portion of the circle of Willis is along the ipsilateral sphenoid ridge or orbital roof to the anterior clinoid process. In exposing the ICA, the approach is usually from proximal to distal, beginning with the ophthalmic segment and working distally toward the bifurcation. The ophthalmic artery, the first C₄ branch, is difficult to expose because of its short intradural length and its location under the optic nerve. It usually arises from the medial third of the superior surface of the ophthalmic segment under the optic nerve and commonly enters the optic foramen within 1 to 2 mm of its origin. The origin may be as far as 1 cm medial to the anterior clinoid process. The exposure of the ophthalmic artery may be facilitated by removing the anterior clinoid process and incising the falciiform process (Fig. 5A), a thin fold of dura mater that extends medially from the anterior clinoid process and covers the 0.5- to 11-mm (average 3.5 mm) segment of the optic nerve immediately proximal to the optic foramen.

In exposing the C₄ portion beyond the origin of the ophthalmic artery, the surgeon often sees the AChA before the PCoA, although the AChA arises distal to the PCoA. This occurs because of three sets of anatomic circumstances. First, the C₄ segment passes upward in a posterolateral direction, placing the origin of the AChA further lateral to the midline than the origin of the PCoA. Second, the AChA commonly arises further lateral on the posterior wall of the C₄ portion than the PCoA. The site of origin of the AChA from the posterior wall of the C₄ portion was found to be lateral to the site of origin of the PCoA in 94% of hemispheres. Third, the AChA pursues a more lateral course than the PCoA; the former passes laterally around the cerebral peduncle and into the temporal horn, whereas the latter is most commonly directed in its initial course in a posteromedial direction above the oculomotor nerve toward the interpeduncular fossa.

It may be easier to inspect the PCoA through the triangular space (opticocarotid triangle) between the optic nerve and the internal carotid and anterior cerebral arteries than in the space posterior to the C₄ portion, between C₄ and the oculomotor nerve. The perforating branches arising from the C₄ portion pass across, and may prove to be an obstacle to, the operative approaches directed through the space between C₄ and the optic nerve. Opening the medial part of the Sylvian fissure below the anterior perforated substance facilitates the exposure of the choroi-
H. Gibo, C. Lenkey and A. L. Rhoton, Jr.

FIG. 8. Lateral and superior views of common aneurysm sites on the C4 portion of the internal carotid artery. A: Lateral view of the right C4 portion. B: Superior view of the C4 portion with the right optic nerve and right half of the optic chiasm reflected forward to expose the origin of the ophthalmic artery. The aneurysms arise on curves in the artery at the site of origin of its branches. The aneurysms point in the direction of the maximum hemodynamic force immediately proximal to the aneurysm site and in the direction the blood would have flowed if there were no curve at the aneurysm site. The aneurysm sites on the C4 portions are usually located immediately distal to the origin of its branches. Aneurysms occurring at the origin of the ophthalmic artery (Ophth.A.) arise from the ophthalmic segment (C4-Op.) and point upward into the optic nerve (O.N.). The perforating branches arising from the ophthalmic segment are on the medial side of this aneurysm. Aneurysms occurring near the origin of the posterior communicating artery (P.Co.A.) arise from the communicating segment (C4-Co.) and point posteriorly toward the oculomotor nerve (III); they are usually located superolateral to the posterior communicating artery. The perforating branches arising from the communicating segment are often stretched around the neck of these aneurysms. Aneurysms occurring near the origin of the anterior choroidal artery (A.Ch.A.) arise from the choroidal segment (C4-Ch.) and point posterolaterally. They are usually located superior or superolateral to the origin of the AChA. Aneurysms arising at the bifurcation of the C4 portion into the anterior (A.C.A.) and middle (M.C.A.) cerebral arteries point upward lateral to the optic chiasm (O.Ch.) and tract (O.Tr.) toward the anterior perforated substance. The perforating branches arising from the choroidal segment are usually stretched along the posterior wall of the aneurysm arising at the bifurcation of the C4 portion.
Supraclinoid portion of internal carotid artery

dal segment and the area above the bifurcation of the C4 portion.

If all sites on the C4 portion are included, this portion is the most common site of intracranial aneurysms (Fig. 8). Approximately 35% of intracranial aneurysms occur here. These aneurysms arise at four sites: the upper surface at the origin of the ophthalmic artery, the posterior wall at the origin of the PCoA, the posterior wall at the origin of the AChA, and at the apex of the bifurcation.

Carotid-ophthalmic aneurysms usually have their neck on the superior wall of the C4 portion just distal to the origin of the ophthalmic artery. They arise above the roof of the cavernous sinus, where the superiorly directed C3 segment turns posteriorly to become the C4 segment. At this turn, the maximum hemodynamic thrust is against the superior wall of the carotid artery just distal to the ophthalmic artery, and the aneurysm points upward against the optic nerve. Exposure of the neck of this aneurysm may be facilitated by the removal of the anterior clinoid process, by incision of the falciform process of the dura mater, and possibly by unroofing the optic foramen to allow some mobilization of the optic nerve. The perforating branches of the ophthalmic segment arise from the medial and posterior side of the C4 portion. These aneurysms typically point upward, away from these perforating branches. The perforating arteries and the hypophyseal vascular supply may be compromised if the aneurysm expands medially. Diabetes insipidus and amenorrhea have been reported following occlusion of these branches.

The most common aneurysm site on the C4 portion is on the posterior wall of the communicating segment immediately above the level of origin of the PCoA. The initial part of the C4 portion is directed posterolaterally, but distally it curves gently forward to complete the upper half of the S-shaped curve comprising the carotid siphon. The carotid-posterior communicating aneurysm arises from the posterior wall of the communicating segment near the apex of the curve forming the upper one-half of the siphon. The PCoA is found on the inferomedial side of the aneurysm, and the AChA is superior or superolateral to it. These aneurysms expand posteriorly and compress the oculomotor nerve near the point where it enters the dura. The oculomotor nerve enters the dura lateral to the posterior clinoid process between 2 and 7 mm (average 5 mm) posterior to the ICA. Fortunately, fewer perforating branches arise from the communicating segment than from the ophthalmic or choroidal segments. As the aneurysm enlarges, it may stretch the perforating branches arising from the PCoA, AChA, and ICA around its neck and fundus. Some authors suggest that the PCoA could be clipped with the neck of the aneurysm, especially if the artery is hypoplastic. However, we have found that hypoplastic segments of the circle of Willis gave rise to the same number and size of perforating branches as did normal or large segments. Occlusion of these perforating branches may cause sequelae similar to those ascribed to vasospasm.

Aneurysms of the AChA arise from the C4 portion at the level of, or just distal to, the AChA between the AChA and the bifurcation. They point posteriorly or posterolaterally. Aneurysms arising below the choroidal artery from the communicating segment are referred to as posterior communicating aneurysms. Aneurysms arising at the level of the AChA are usually located superior or superolateral to the origin of the AChA. Aneurysms arising from the choroidal segment have a greater tendency to have perforating branches stretched around their neck than those arising from the communicating or ophthalmic segment because the choroidal segment has a greater number of perforating branches arising from it. The perforating branches arising from the choroidal segment pass superiorly behind the choroidal segment and the bifurcation of the C4 portion to enter the anterior perforated substance adjacent to where the perforating branches of the anterior cerebral, recurrent, and middle cerebral arteries enter the anterior perforated substance.

The fourth common site for aneurysms on the C4 portion is at its bifurcation. These aneurysms arise at the apex of the T-shaped bifurcation formed by the origin of the anterior and middle cerebral arteries. They point upward in the direction of the long axis of the prebifurcation segment of the ICA toward the anterior perforated substance. The perforating branches arising from the choroidal segment and the proximal part of the anterior and middle cerebral arteries are stretched around the posterior side of the neck and wall of the aneurysm. The operative approach to AChA and bifurcation aneurysms may be improved by opening the arachnoid over the medial half of the Sylvian fissure. It is often helpful to work above the carotid bifurcation in order to expose all or a portion of the neck of these aneurysms.

References

Manuscript received March 16, 1981.
This work was supported in part by the R.D. Keene Family Endowment and by the National Institutes of Health, Grant NS10978-03.
Address reprint requests to: Albert L. Rhoton, Jr., M.D., Department of Neurosurgery, University of Florida Health Center, Gainesville, Florida 32610.