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The Cerebellopontile Angle, The Blood Supply of the Brain Stem and the Reticular Formation: Anatomical and Functional Correlations Relevant to Surgery of Acoustic Tumors

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The cerebellopontile angle and the vascular supply of the adjacent brain stem and cerebellum are susceptible to compression and damage by tumor and may be injured, directly or indirectly, during surgery. Awareness of the normal anatomical features of the region is valuable to the neuropathologist, the neurosurgeon and the neuro-otologist. Following is the first of a two-part presentation which describes the anatomy of the cerebellopontile angle, the vascular supply of the brain stem and its pathophysiology.—Ed.

The Cerebellopontile Angle, The Blood Supply of the Brain Stem and the Reticular Formation

Anatomical and Functional Correlations Relevant to Surgery of Acoustic Tumors*

Jose Bebin, M.D., Ph.D.**

I. THE CEREBELLOPONTILE ANGLE

According to Cushing (1917), Henneberg and Koch (1902) introduced the term *"cerebellopontile angle tumor"* ("Kleinhirnbruckenwinkel-tumor"). Even though it refers to an anatomical region, the point of origin of the lesion, the term has been used for all tumors of the region. It has almost superseded the designation of acoustic tumor. Ziehen (1905) attempted to introduce the term "angulo pontis", and the French prefer the designation of "tumerus cerebello-protuberantielles" for the neoplasms occupying this region. The fact remains, as Cushing so aptly stated, "by the time a tumor is present, the so-called angle has disappeared and its confines disordered beyond recognition." Because of this, Dandy (1925) prefers to describe them as cerebellopontile tumors.

The relationships of this region may be described as potential rather than actual space. The pons and the medulla fit snugly into a gently sloping depression in the basilar portion of the occipital bone. When the flocculus of the cerebellum is prominent, it fits into a small depression in the posterior surface of the petrous pyramid caudal to the internal auditory meatus.

The space between the brain stem, cerebellum and dura mater covering the posterior surface of the petrous bone consists of (1) a groove between the pons and the cerebellum, (2) a groove between the medulla and the cerebellar tonsil, and (3) an irregular cuboidal space between the two. This space is bounded medially by

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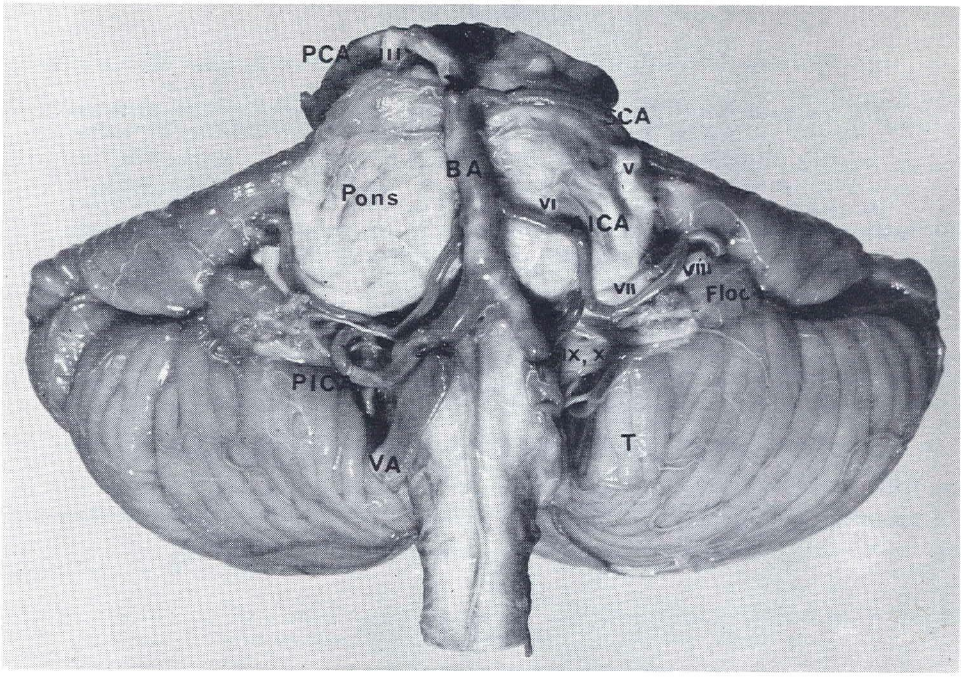

Figure 1

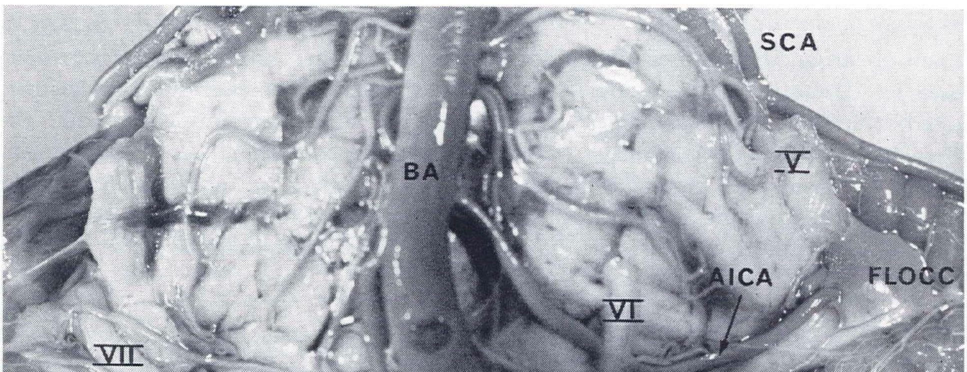

Figure 2

the inferior olive, rostrally by the caudal border of the pons, and caudally by the cerebellar tonsil. Its floor, *in situ,* is formed by the arachnoid crossed by the anterior inferior cerebellar artery (AICA), and other small arteries. Its roof is formed by the substance of the cerebellum and middle cerebellar peduncle. Its lateral wall is formed by the cortex of the cerebellar tonsil and flocculus, and is covered by the root fibers of vagus and glossopharyngeal nerves. In the outer rostral angle of this space are the roots of the facial and acoustic nerves. (Fig. 1-4) The arachnoidal floor is prolonged laterally into a cone surrounding the roots of these nerves and enters the internal auditory canal. Thus, instead of an "angle" this irregular cisternal space resembles a tent in which the facial and acoustic nerves provide a curving central support. (Fig. 5)

Loculated CSF accounts for the superimposed cysts which often cover cerebellopontile tumors. Release and accumulation of fluid may cause fluctuation of symptoms from tumors occurring in this region.

The facial and acoustic nerves are closely related during their course through the subarachnoid space and into the internal auditory meatus. The eighth nerve (acoustico-vestibular) usually lies posterior and slightly caudal to the seventh nerve (facial). From the cerebellar approach in posterior fossa craniotomy, the facial nerve may be hidden by the eighth nerve.

As these nerves leave the brain stem, they lie closely against the cerebellum, in contact with the lateral recessus of the fourth ventricle and its fold of choroid plexus. The eighth nerve consists of two portions, the cochlear (auditory) and the vestibular divisions. These may or may not be grossly identifiable since they frequently form a single nerve bundle. The cochlear division is the more dorsal and caudal portion of the nerve and passes over the restiforme body (inferior cerebellar peduncle), while the vestibular division forms the more superior and anterior portion of the nerve and passes into the side of the medulla below the restiforme body. (Fig. 2, 4-6)

The facial nerve also consists of two roots where it attaches itself to the lateral surface of the brain stem, close to the caudal border of the pons. The motor root is large and anterior to the mixed sensory and parasympathetic root (N, intermedius) which is a rather small filament lying between the eighth and seventh motor nerves.

The eighth and seventh nerves pass laterally and slightly upward to enter the internal auditory meatus. As they pass across the subarachnoid space and enter the internal auditory meatus, the facial nerve lies more anteriorly and the acoustic more posteriorly with the nervus intermedius between the two. The fundus of the meatus is divided into upper and lower portion by the transverse crest. In the upper portion there is an anterior depression with an opening for the seventh nerve, and a posterior funnel-shaped depression which contains numerous openings for the branches of the superior vestibular nerve. In the anterior lower portion below the transverse crest, there is a rounded depression, the cochlear area, with a series of small openings (tractus spiralis foraminosus) which transmit the bundles of the cochlear nerve directly to

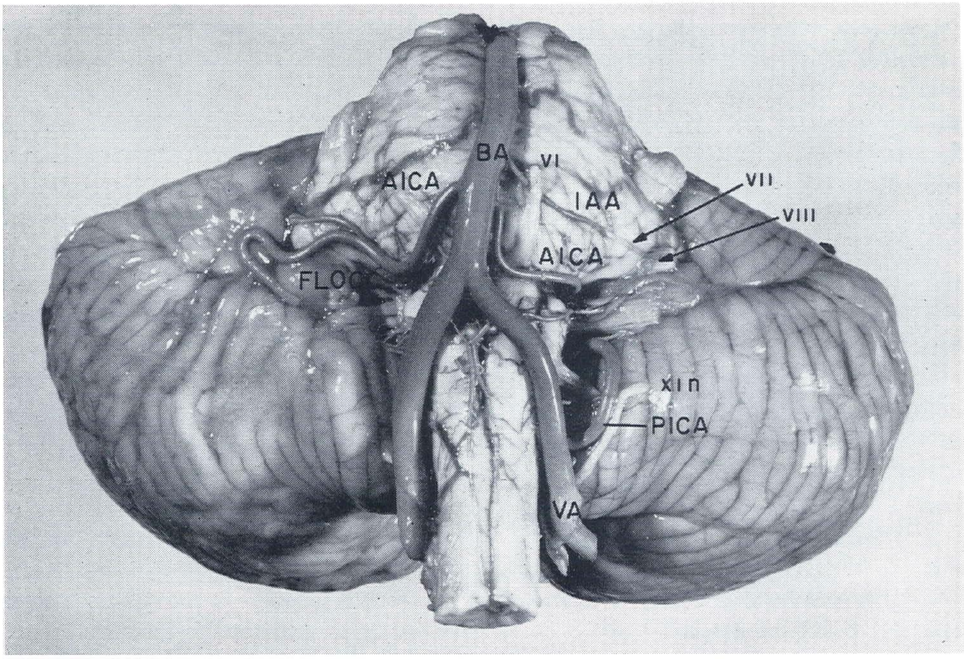

Figure 3

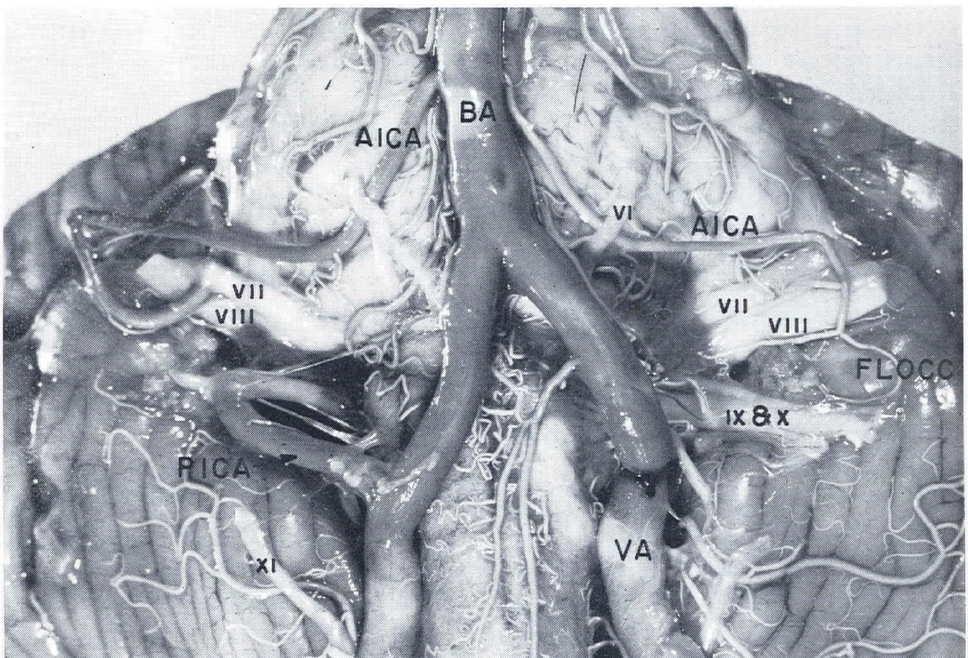

Figure 4

the cochlea. In the posterior portion of the same area, close to the transverse crest, lies the area containing small openings for the transmission of the inferior vestibular nerve fibers.

These relationships are well known to otologic and neurological surgeons. They are of the utmost significance when considering the removal of small intracanicular acoustic tumors while preserving non-involved nerves.

As the seventh and the eighth nerves pass laterally from the brain stem toward the internal auditory meatus, they are closely related to the AICA. This relationship is of considerable practical significance in surgical explorations of such confined spaces as the cerebellopontile angle and, in particular, in the surgical treatment of acoustic tumors. (Fig. 1-5, 7, 8)

According to Sunderland (1945) in 39% of 132 subjects, the AICA passed outwards anterior to the facial and acoustic nerves to enter the internal auditory meatus where it looped for a variable distance. (Our own observation confirms this finding). Stopford (1915) found the artery lying more commonly ventral to the nerves, between them and the pons. Before passing to the cerebellum, the recurrent loop of the AICA courses between, above or below the nerves, either in the meatus or soon after leaving it. According to Sunderland, in 25% of the specimens, the loop of the AICA just reached the enrance of the meatus ventral to the nerves, and the distal limb of the loop passed to the cerebellum below or between the nerves. In several specimens, complicated looping at the entrance to the meatus increased the complexity of the neurovascular relations at that site. In 13% of specimens, the AICA did not extend as far as the IAM but passed above (1%), between (15%) or below (7%) the facial and acoustic nerves. In 23% of specimens the artery was not related significantly to the nerves. Watt and McKillop (1935) have noted passage of the artery over, under, and in-between the nerves in the cerebellopontile angle. They noted that the AICA was constantly related to the roots of the facial and acoustic nerves. (Fig. 1-5, 7, 8)

The facial and the acoustic nerves are accompanied into the internal auditory meatus by the *internal auditory artery* (IAA) which frequently insinuates itself between them. This artery is often considered a branch of the basilar artery but most evidence favors its origin from the AICA. Stopford found that the IAA arises from the AICA in 63% of cases (64% right and 63% left) and Sunderland reported a similar origin in 83% of 264 subjects. The IAA arises from the basilar artery in 17% of specimens according to Sunderland and in 36% and 28%, right and left sides, respectively, according to Stopford. Watt and McKillop found the IAA to be double in 6% of 63 cases. These findings are in agreement with our observation of 60 brains with post-mortem injections. (Fig. 2, 3, 9, 10)

The IAA originated at a variable site in the AICA, usually at the point where it leaves the brachium pontis and extends on to the cerebellum. Here the artery is closely related with the eighth and seventh nerves and it accompanies these nerves through

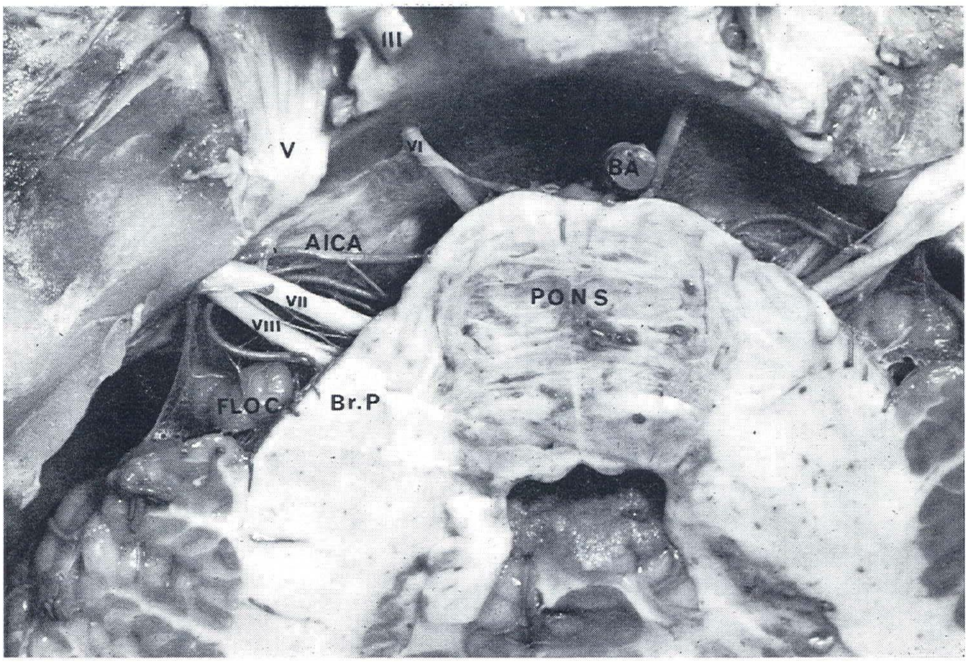

Figure 5

Figure 6

the internal auditory meatus, dividing at the end of the internal auditory canal into terminal branches, the cochlear and the vestibular arteries. When the AICA loops into the internal auditory meatus or well down into the internal auditory canal, the IAA arises from the apex of the loop, or occasionally from the proximal limb at points between the pons and the apex. (Fig. 2, 7, 8) The IAA divides into three branches. The first of these, *the vestibular artery,* supplies the vestibular nerve and part of the saccule, utricle and semicircular canals. The second branch, the *vestibulo-cochlear artery,* supplies the basal turn of the cochlea, the greater part of the saccule, the body of the utricle, the posterior semicircular canal. The third, or terminal branch, is the *cochlear artery,* which, after entering the modiolus, separates into the spiral arteries. The essential features of the IAA are its small size and its lack of support aside from attachment to the acoustic nerve itself.

The venous drainage of the labyrinth is accomplished by three main veins and their tributaries. The *internal auditory vein,* which drains the apical and middle turn of the cochlea, leaves the temporal bone by the internal auditory meatus. The *vein of the cochlear aqueduct* drains the basal turn of the cochlea, the saccule and part of the utricle. It terminates in the inferior petrosal sinus. The *vein of the vestibular aqueduct* drains the semicircular canals and part of the utricle. This vein reaches the dural sinuses through the bony vestibular aqueduct. The vena auditiva interna accompanies the IAA and terminates in the posterior part of the superior petrosal sinus or in the lateral sinus. *These vessels may be easily torn in the exploration of the cerebellopontine angle.*

II. VASCULAR SUPPLY OF THE BRAIN STEM AND CEREBELLUM

The brain stem and the cerebellum receive its arterial blood supply exclusively from the vertebral basilar system. The basilar artery is a single vessel which supplies both sides of the neural tube. The basal portion of the pons receives its blood supply from the basilar artery through six to eight branches on each side. The large vessels, superior cerebellar and anterior inferior cerebellar arteries give off small branches which enter the pons before continuing over the cerebellum.

Among the important contributions to this subject are the papers of Foix, et al (1925), Krayenbühl and Yasargil (1957), Lazorthes, et al (1961) and Kaplan (1958). Foix, et al, mentioned the difficulties encountered in their study of the arteries of the brain stem. These small and delicate arteries are difficult to dissect and follow. They wrote "nothing is more impressive than to see the thinnest of these arteries and arterioles and one can only wonder how the supply of blood of such important regions of the brain stem is assured by these remarkable thin blood vessels". Their work was based on the study of fixed postmortem material and on radiopaque studies of sections previously injected.

Improvements in injection techniques permitted Lazorthes, Kaplan and others to confirm and correct the original descriptions. All authors writing on this subject recognize the very numerous variations of the vertebrobasilar arterial system and its branches, and of the vascular pedicles which enter the brain stem. These variations

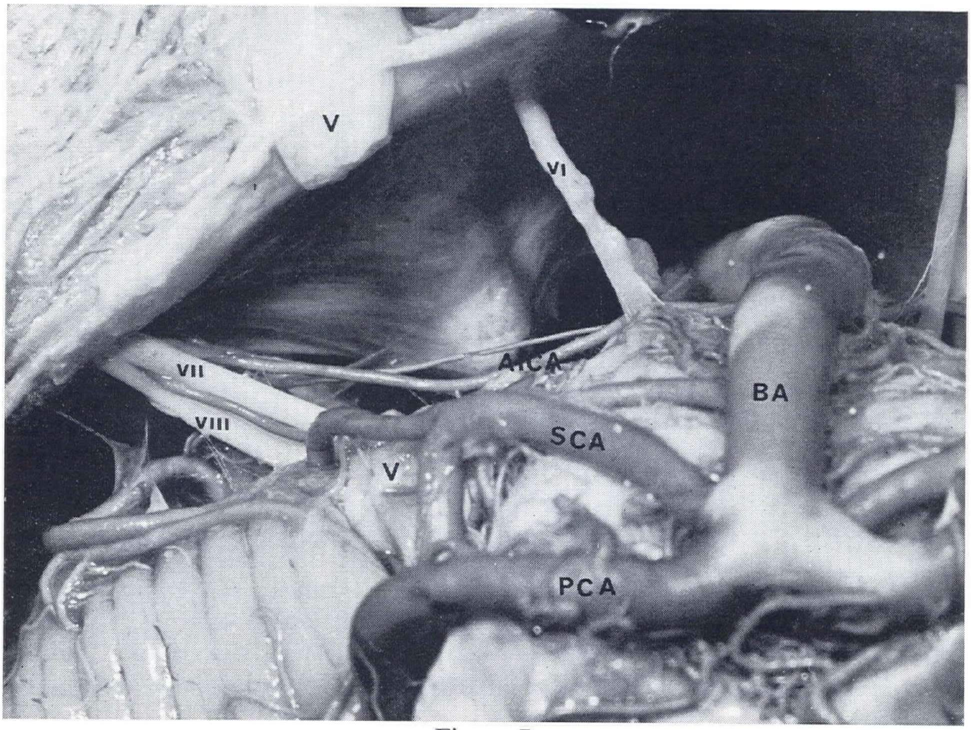

Figure 7

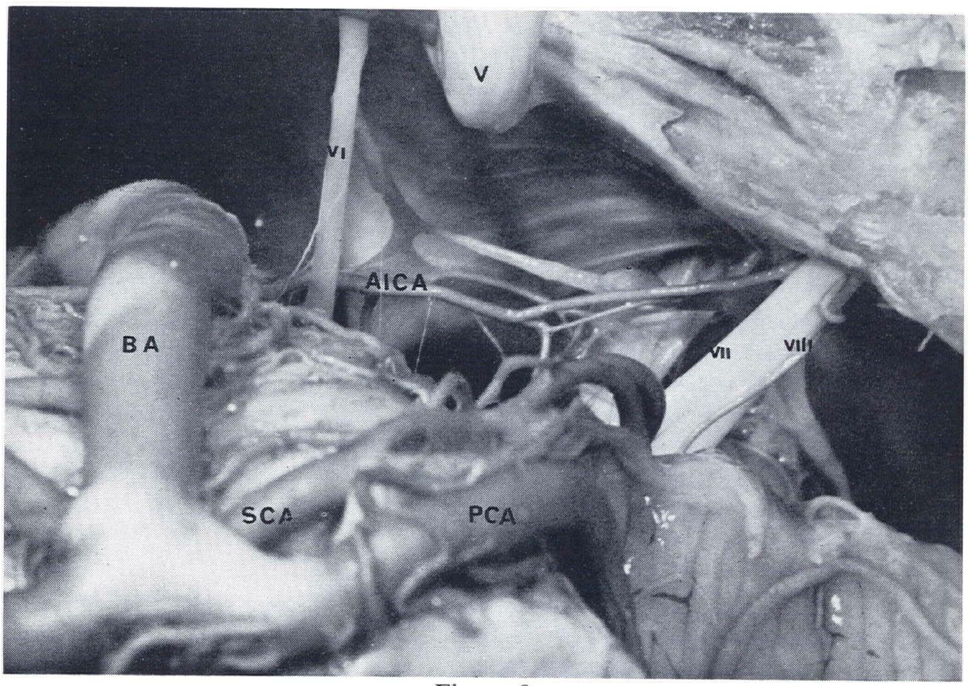

Figure 8

prevent description of a single pattern of superficial distribution; however, their central distribution seems to be relatively fixed and more amenable to a diagramatic presentation.

The most rostral vessels, the *superior cerebellar arteries* (SCA) arise from the basilar artery close to is bifurcation (94%). It is found double in 12% unilaterally and in 4% bilaterally. The artery usually divides immediately distal to its origin. From its origin, the SCA courses laterally and caudally to the third nerve and curves around the basis peduncle to gain the dorsal surface of the cerebellar hemispheres of the ipsilateral side. On the surface of the cerebellum, it divides into numerous branches which freely anastomose with other cerebellar arteries. Injections and arteriograms prove that there is a free communication between the cerebellar arteries of the two sides. These anastomoses must be an important factor in preventing cerebellar infarcts in many cases of vascular occlusion of one or more of these arteries. (Fig. 11-15)

In 33% the SCA of the two sides were equal; in 31% the right was larger, and in 33% the left was larger. Reduction in size or the absence of one cerebellar artery are invariably accompanied by an increase in caliber of one of the others. Thus there seems to be a compensatory supply of blood to the cerebellum (Stopford).

Dandy described a branch of SCA as lying either beneath the trigeminal root (that is, between the root and the stem) or along its lateral surface. In 30% of 215 cases of trigeminal neuralgia operated by Dandy, this artery had affected the fifth nerve, by lifting or bending the sensory root or leaving an impression upon it.

The *anterior inferior cerebellar artery* (AICA), middle cerebellar artery of the French anatomists, is the second of the largest branches of the basilar artery to reach the cerebellum. The size, course of the vessel and the level of origin from the basilar artery are variable even in the two sides. Variation in the caliber of the vessel depends largely upon the size and distribution of the posterior inferior cerebellar artery (PICA). Stopford, Atkinson, etc., have also observed that variation in size of the AICA usually is in inverse proportion to the size of the PICA. (Fig. 1-4, 10-12, 14, 15)

According to Stopford, whose findings correspond with ours, the AICA of the two sides were equal in 15%, the right was larger in 48% and the left in 37%. As to origin, in 85% the two arteries arise at same level; of these, 78% arose from the lower third, 17% from the middle and 5% from the lower limit of the basilar artery. In one case, the AICA had a common origin with the PICA and in one case was single on the left and in one case double (Stopford).

From its origin, the AICA courses over the ventral surface of the pons toward the anterior surface of the ipsilateral cerebellar hemisphere where it anastomoses extensively with the PICA and SCA. The AICA has an important relationship with the sixth nerve. According to Sunderland (1948), the artery is anterior (ventral) to the sixth nerve, 84% on the right and 73% on the left. These figures are closely parallel to those of Stopford (1915) 86% on the right and 81% on the left, and ours.

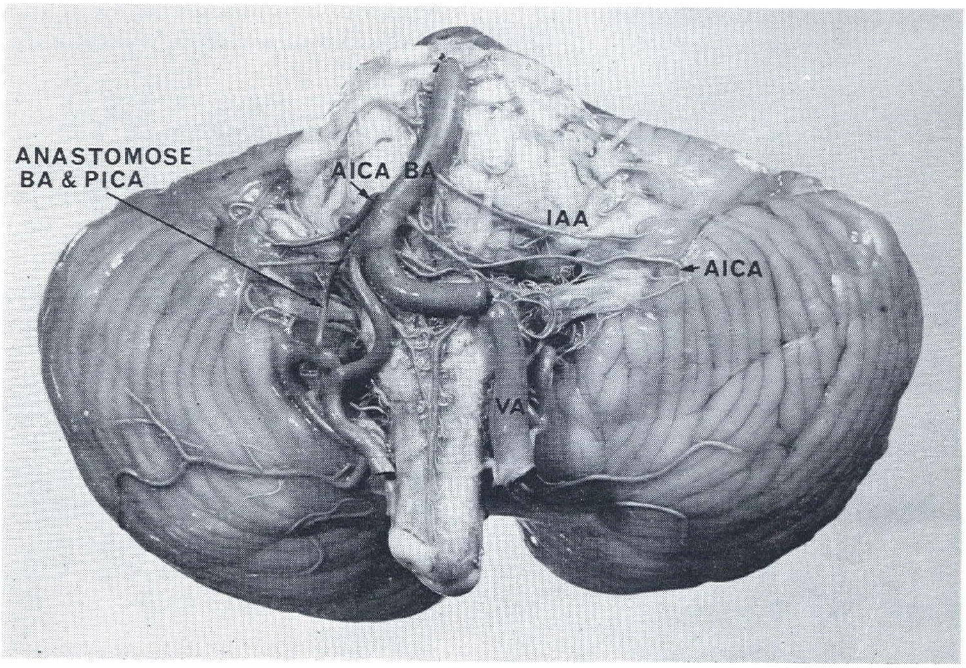

Figure 9

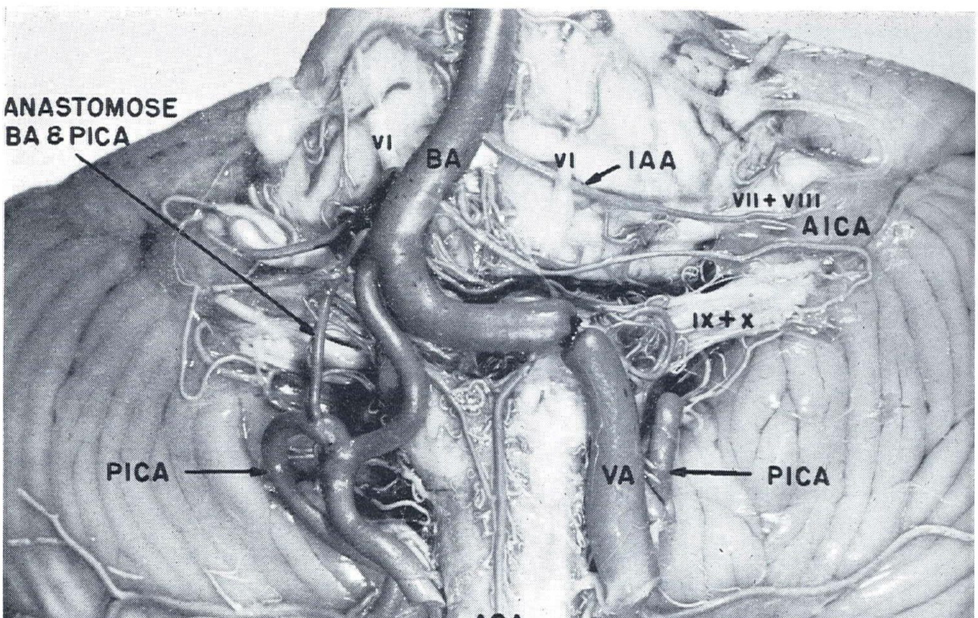

Figure 10

In some specimens, the artery passed through the nerve. Cushing reported this anomaly in three specimens, Stopford in two and we found it in one.

Cushing advanced the idea that obscure sixth nerve palsies, accompanying expanding intracranial lesions, could be explained on the basis of strangulation of the sixth nerve by the AICA. This concept is supported when the arteries overlie the nerves. In cases of brain tumors, the vessel which normally encircles the brain stem produces a more or less deep grooving of nervous tissue. The abducentes in many of these cases are deeply constricted, and a large percentage of cases which show post-mortem pontine grooving implicating these nerves, record either subjective diplopia or a convergent strabism. Sunderland's and Stopford's findings confirm Cushing's observations that the sixth nerve is more likely to be compressed when the AICA is running anterior to it.

Collier (1904) attributed these palsies of the abducent nerves to "backwards" displacement of the brain stem, from supratentorial pressure, producing traction in the nerves, stretching them between their origin, in the pontomedullary junction, and its entrance into the cavernous sinus.

A rare anomaly of PICA is perforation of the sixth nerve by the artery. This phenomenon usually occurs on the left. The reasons advanced are that the abducent nerve originally arises from several rootlets arranged segmentally. In man, the intermediate ones persist but others may remain as aberrant roots. In case of perforation of the sixth nerve it would appear that the AICA passes between the true nerve and an aberrant one.

Immediately before or immediately after crossing the eight nerve, the AICA divides into two branches (Atkinson, 1949), one passing laterally and downward on the medial and anterior border of the cerebellar hemisphere. After a short tortuous (1 cm.) course, it gives off a rather constant branch of variable size along the medial surface of the hemisphere to anastomose with a cerebellar branch of the PICA. The other branch passes laterally and curls around the upper edge of the flocculus, where it lies on the surface of the brachium pontis and then passes on to the cerebellar hemispheres and anastomoses with the other two main cerebellar arteries. During its course the AICA also gives off a series of small arteries, variable in number and size, to the region of the pontomedullary sulcus, the lateral medullary fossa, (these include the artery of the lateral medullary fossa), and to the brachium pontis. In many specimens, these small arteries arise directly from the lower part of the basilar artery.

The AICA has two regions of distribution (Atkinson). The proximal portion of this vessel supplies the lateral region of the lower pons. The lateral branches, after crossing the eighth nerve, supply the brachium pontis and an area of variable size in the lateral tegmental regions of the lower two-thirds of the pons. According to Atkinson, a clip on the artery (AICA) as it crosses the eighth nerve, will immediately deprive the lateral part of the tegmentum of blood supply if no anastomoses exist via the PICA or SCA. Alexander and Suh (1937) extend the territory of the AICA to the upper third of the lateral medullary region.

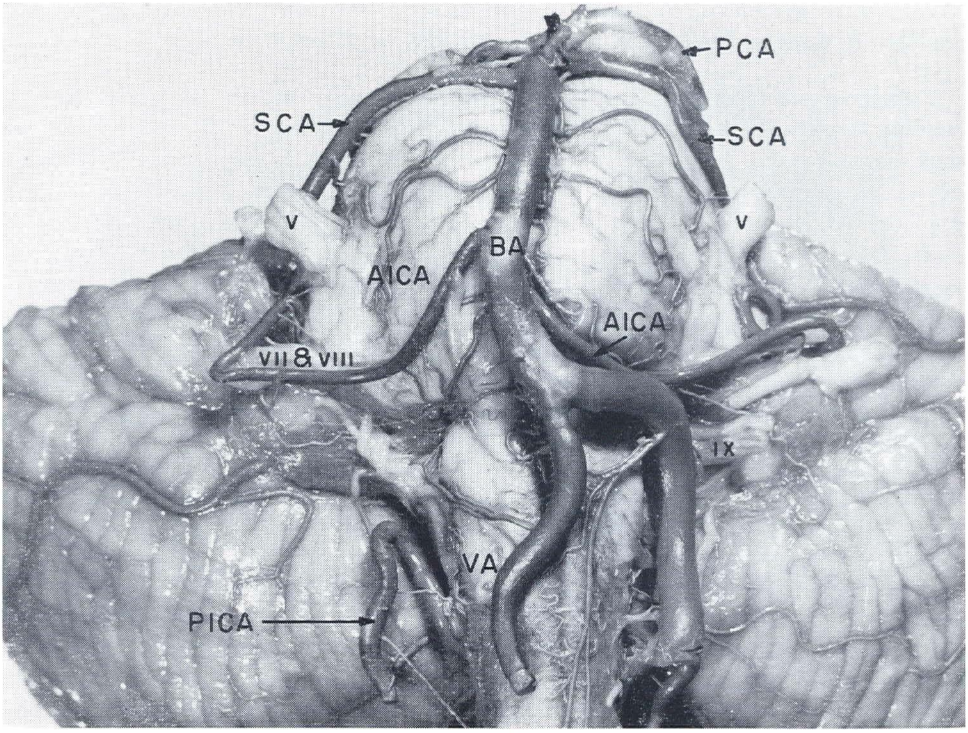

Figure 11

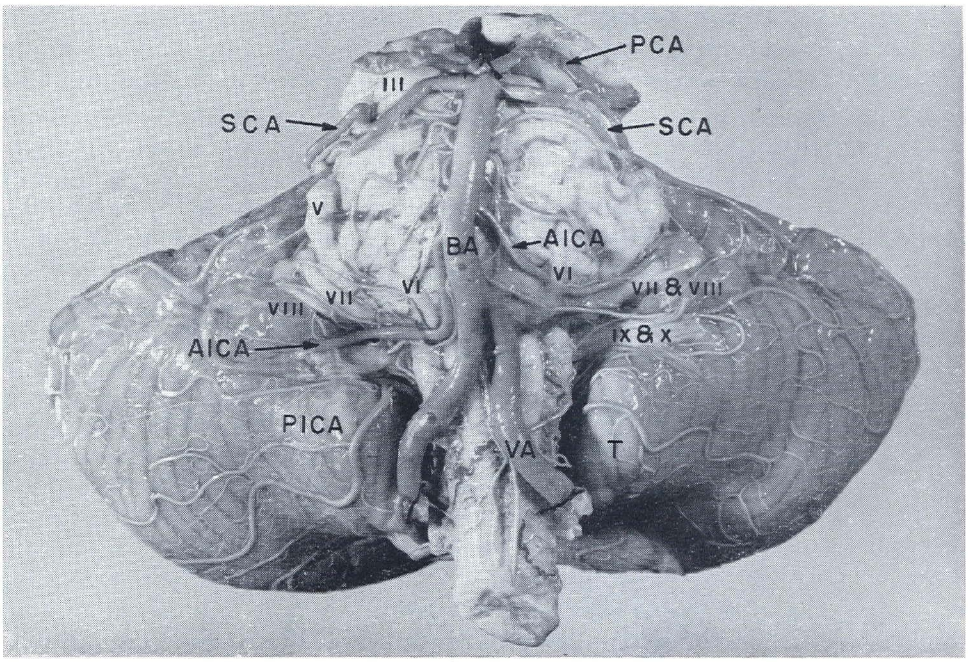

Figure 12

The Blood Supply of the Brain Stem

The *posterior inferior cerebellar artery* (PICA) (Fig. 1, 3, 4, 9, 11-15) usually arises from the vertebral artery (VA) but varies in the level of its origin and may even arise from the basilar artery. After its origin it courses cranially to loop dorsally and caudally and thus becomes closely related to the roots of the ninth, tenth and eleventh nerves. Sometimes this upward loop of the artery is ventral to the facial and acoustic nerves at their site of origin, where it may compress them against the pons or the brachium pontis. According to Sunderland, the two PICA were equal in size in 22%, the right and the left were each larger in 39%. This artery is not infrequently absent. It was missing on the right in 15%, on the left in 6%, and bilaterally in 3% of cases.

During its course the PICA at first lies anterior to the roots of the ninth, tenth and eleventh nerves. The extent of this relationship varies, however, with the level of origin of the artery. The PICA may arise from the vertebral artery soon after this vessel has entered the foramen magnum. Or it may arise near the formation of the basilar artery, close to the caudal border of the pons.

In the first ascending portion of its course, the PICA may lie posterior to or upon the roots of the ninth, tenth and eleventh nerves, or it may lie ventral to these nerves. At the end of its ascending course, the artery loops dorsally and caudally to descend along the side of the medulla and anterior surface of the cerebellar tonsil. This loop may lie above the origin of the ninth, tenth and eleventh nerves. It passes between these nerves or between the rootlets of the tenth, eleventh and twelfth nerves to reach the interval between the restiforme body and the cerebellum. The relationship between the PICA and these structures is variable but is always intimate, causing the deforming and stretching of the nerve rootlets. Finally, the descending loop of the artery passes on the cerebellum where it forms a rich plexus of small arteries which anastomose freely with branches of the SCA and AICA. The AICA give collateral branches to the choroid plexus of the fourth ventricle and lateral recesses as well as important branches to the lateral medullary region.

The pattern of distribution of the arteries within the pons is similar to that of other regions of the brain stem. Foix, et al, divided the vessels into three groups: (1) paramedian arteries, (2) short circumferential arteries, and (3) long circumferential arteries. The central perforating vessels (paramedian or median) curve laterally and the lateral perforating vessels (short circumferential) curve medially. A vessel supplies only the side of the brain stem it enters, never crossing the middle line. Because of the open dorsal aspect of the pons, some of the lateral perforating vessels traverse the pontine substance vertically to its dorsal aspect. (Fig. 15, 16)

The division by Foix, et al, of the arterial supply of the brain stem in paramedian, short and long circumferential arteries has wide acceptance. It is based on a pedicular distribution and does not correspond exactly to the distribution in depth nor to the limits of each vascular territory. Based on a study using angiographic techniques, Lazorthes proposed a more precise delineation of the arterial distribution throughout the length of the brain stem into three territories: the anterior or median, the lateral and the posterior territories. (Fig. 17)

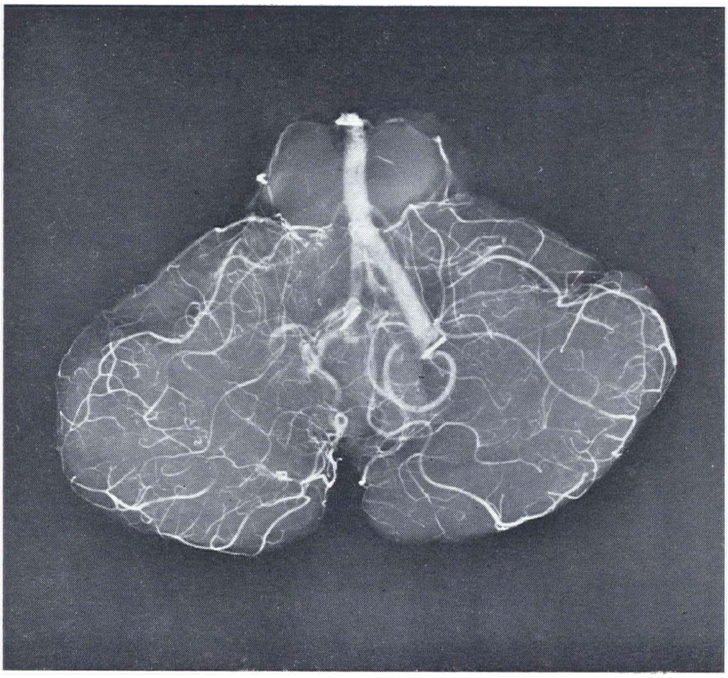

Figure 13

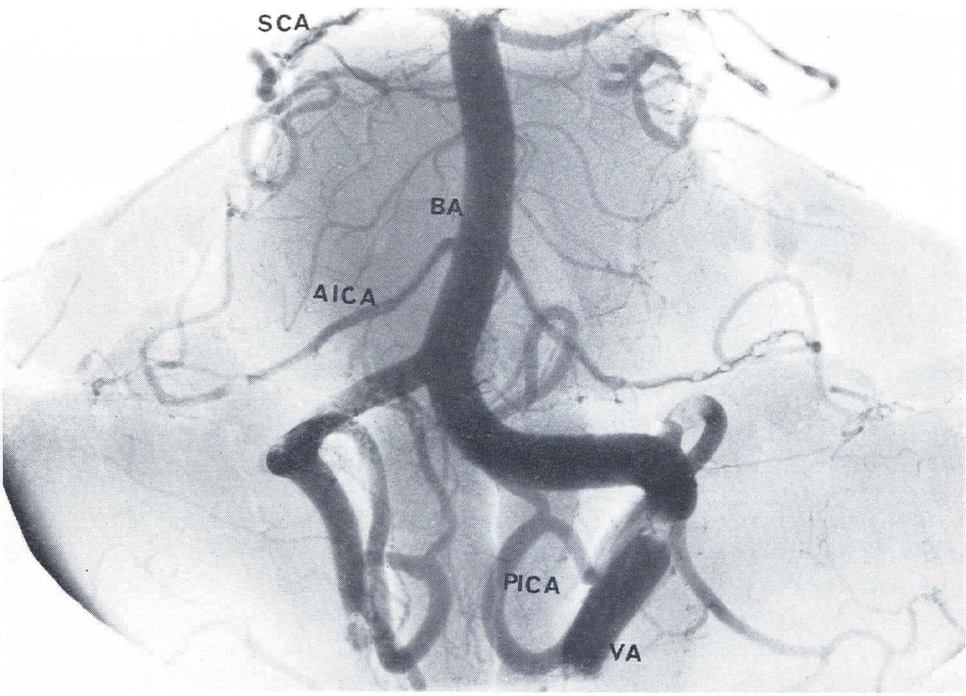

Figure 14

The Blood Supply of the Brain Stem

Knowledge of this vascular distribution in the brain stem permits a better understanding of the symptomatology and diversity of the numerous vascular syndromes in this region. It also provides a more simple classification into anteromedian syndrome, lateral syndrome, and posterior syndrome.

Medulla Oblongata

At lower medullary levels, the arterial vascularization resembles that of the spinal cord. A central and a peripheral territory can be described.

At middle and upper medullary levels, the arrangement of the arterial distribution changes just as the organization of the medulla changes. The central system always remains in central and median position and the peripheral system is subdivided into lateral and posterior.

The *anteromedian arteries* run between the pyramid. Their course is straight to reach the ependymal surface. They give off several collaterals often at right angles passing through the corticospinal tracts, the medial lemniscus, and the twelfth nucleus to ramify in the medial portion of the reticular formation. They end in a paramedian distribution. (Fig. 17)

The *anteromedullary syndrome* is characterized by an ipsilateral twelfth nerve palsy, and a contralateral hemiplegia or hemiparesis, sometimes associated with a contralateral hemihypoesthesia (for tactile and deep sensibilities).

The *lateral arterial group* (short circumferential) at this level consists of two groups of arteries. The first supplies mainly the inferior olive and sends curved branches forward to its center. A second *retro-olivary group* consists of a large number of these arteries which penetrate deeply and supply in particular the nucleus ambiguus, the nucleus and fascilus solitarius, trigeminal nucleus and tract, and the lateral reticular formation. This vascular territory is wedge shaped with a laterally situated base. (Fig. 17). The *lateral medullary syndrome* is perhaps the best known of the syndromes of the brain stem. It has been considered to be due to thrombosis of the PICA (Wallemberg, 1895), the artery of the lateral medullary fossa (Foix, et al, 1925) and vertebral artery (Fisher, et al, 1961, and Krayenbühl, 1957). The extreme variation of vessels involved makes it difficult to attribute this syndrome to any specific artery. It seems more practical to consider it to be due to an occlusion of the arteries of the lateral medullary group. This syndrome is characterized by ipsilateral paralysis of ninth, tenth and eleventh nerves (dysphonia, dysphagia, paralysis of palate and pharynx), hemianesthesia of the face, vertigo, nystagmus, and Horner's syndrome, associated with a contralateral hemianesthesia for superficial modalities (pain and temperature). Respiratory and cardiac symptoms may be present, but are rare. The variations in this syndrome are related to the variations on the arterial supply of this area.

The *posterior arterial group* loses its significance above the nucleus gracilis and soon disappears. This group of arteries supplies the gracilis and cuneate nuclei, part of the vestibular and cochlear nuclei and the restiforme body.

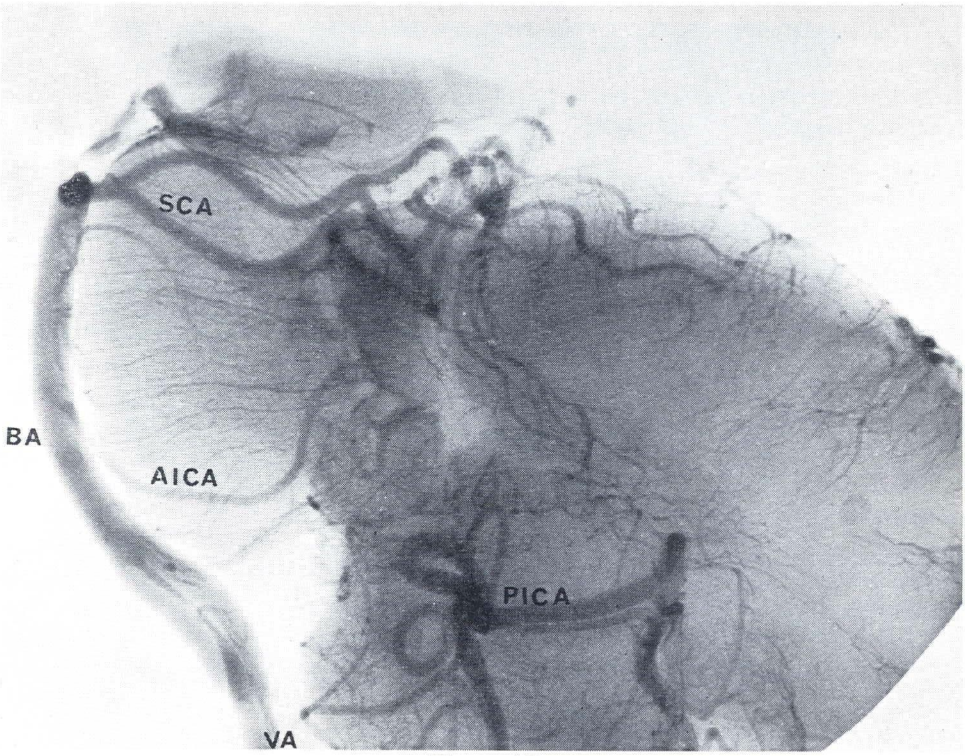

Figure 15

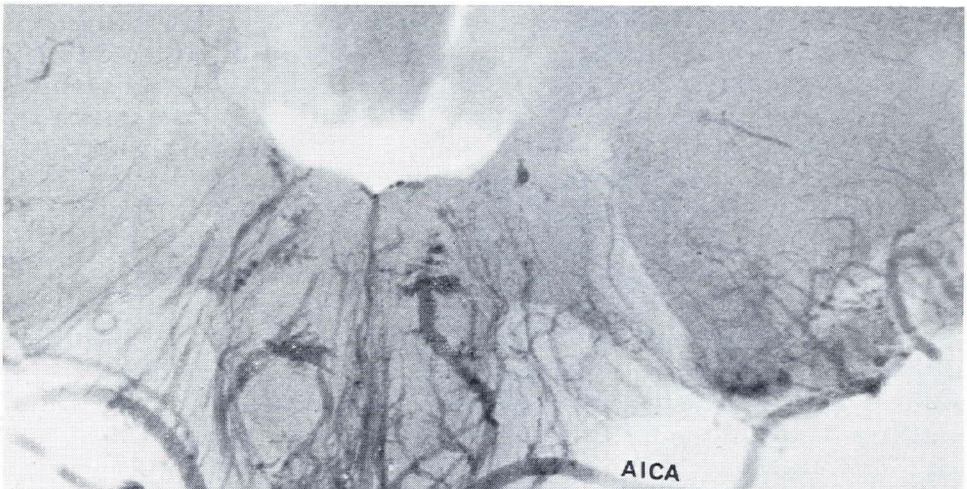

Figure 16

The Blood Supply of the Brain Stem

The *posterior medullary syndrome* consists of ipsilateral ataxia and asynergia (involvement of ICP). It is rarely present isolated. Often it is part of the lateral medullary syndrome.

Rons

The *anterior and median arteries* (paramedian arteries) no longer penetrate along the same paramedian line as in the spinal cord and medulla; their course is often oblique. The median arteries give off numerous collateral branches which pass between the bundles of the corticospinal tract and pontine fibers to extend, in the tegmentum, to the reticular formation and pontine nuclei. The median arteries then end in the subependymal gray matter, in the nuclei of the sixth nerve and other tegmental nuclei. (Fig. 17)

The *anteropontine syndrome* is characterized by ipsilateral sixth nerve palsy, and contralateral hemiplegia or hemiparesis. The face and the tongue may be affected if the lesion is above these nuclei (involvement of corticonuclear fibers), and sometimes, a contralateral hemihypoesthesia for tactile and deep sensibilities.

The *lateral arterial group* (short circumferential arteries) retains its importance but spreads out over the lateral surface of the pons. The arteries of this group penetrate deeply into the tegmentum to supply the nuclei of fifth, seventh and eighth cranial nerves; arterioles reach the cochlear nuclei. The brachium pontis is only slightly vascularized. (Fig. 17) The *lateral pontine syndrome* is characterized by ipsilateral involvement of the fifth and sometimes eighth nuclei, middle cerebellar peduncle (hemiasynergia) and contralateral hemianesthesia for pain and temperature.

Between the anterior and lateral vascular groups, there is an anterolateral region, rather poorly vascularized, which corresponds to the corticospinal bundles. Posteriorly, these zones disappear as the medial and lateral group of arteries meet one another and supply the tegmental pontine nuclei and the reticular formation. The posterior lateral group reappears in the upper pontine levels, to include the superior cerebellar peduncle and dorsolateral part of the tegmentum.

Midbrain

At lower mesencephalic levels the *median and anterior group* is reassembled again. It is made up of a number of thin arteries, which penetrate the posterior perforated space and give off many collaterals to supply the medial portion of substantia nigra, the reticular formation, the medial lemniscus and the medial longitudinal fasciculus including the fourth nucleus and the locus coeruleus.

The *lateral arterial group* consists of numerous arteries running closely together. They enter through the lateral mesencephalic sulcus and supply the lateral portion of the substantia nigra and neighboring tegmental region and part of the sensory pathways. The anterior and lateral groups are widely separated by the cerebral peduncles. Behind the substantia nigra, the posterior arterial group reappears and is well-developed. It consists of short, thin arteries which penetrate the collicular region. At upper mesen-

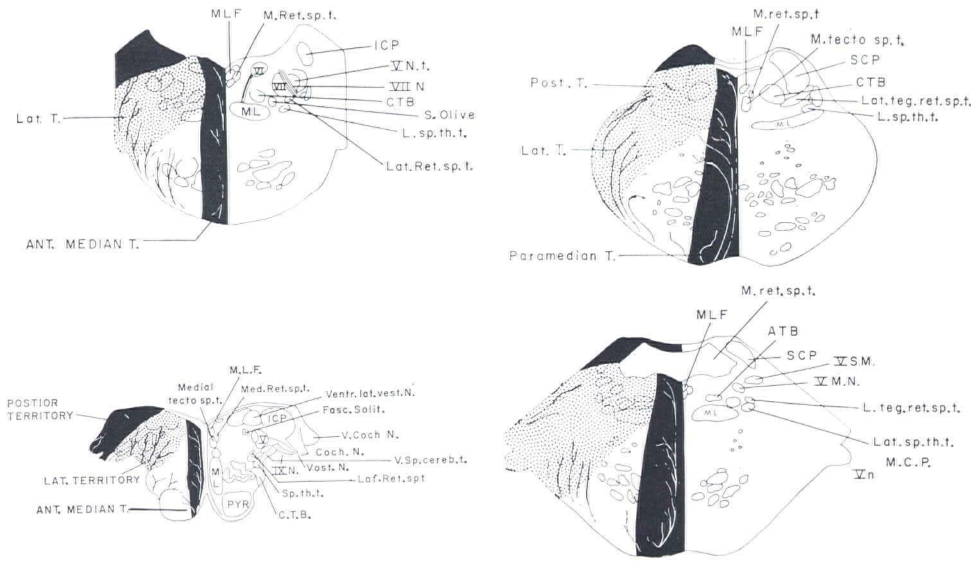

Figure 17

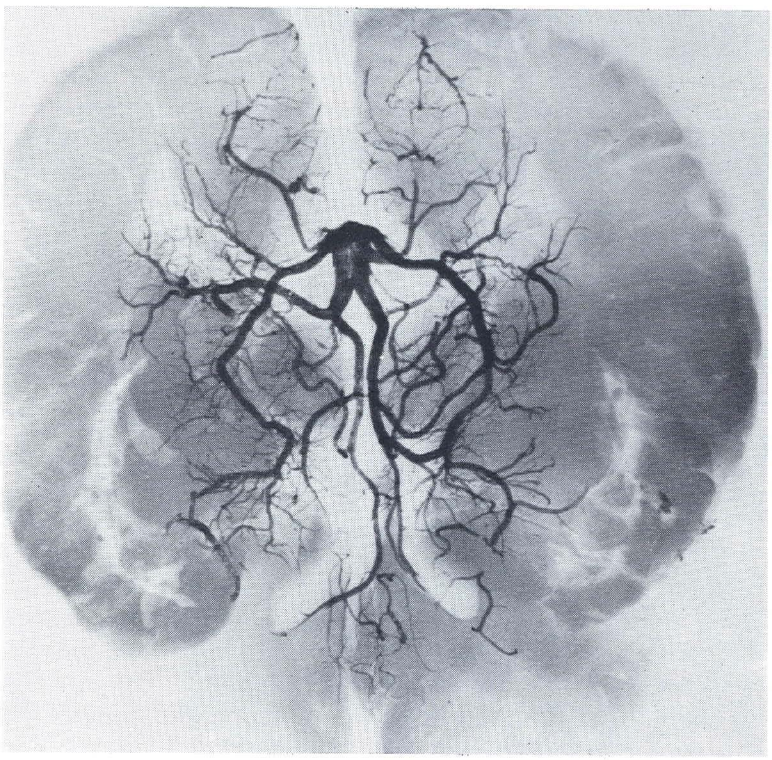

Figure 18

cephalic levels, the median and anterior vessels are compact and near the midline. They pass between the red nuclei and supply the third nuclei, the red nuclei and medial portion of substantia nigra.

The lateral and posterior arterial groups and the lower segments show similar distribution.

The *antero-median mesencephalic syndrome* is characterized by ipsilateral third nerve and/or fourth nerve palsy, associated with contralateral hemianesthesia. The involvement of MLF may produce internuclear ophthalmoplegia. If the lesion is at a higher level, it may produce the syndrome of Benedickt (ipsilateral third nerve palsy with contralateral hemiasynergia and choreoathetosis). The anteromedian syndrome may be bilateral. The *lateral mesencephalic syndrome* consists of ipsilateral hemiataxia associated with contralateral hemianesthesia for pain and temperature and sometimes ipsilateral hypoacusia.

Arterial Territories of the Cerebellum

The cerebellum is supplied with blood by the three cerebellar arteries: SCA, AICA, and PICA. The arterial supply may be divided into cortical distribution and central distribution.

The flocculus is supplied almost exclusively by the AICA and in only 3.5% of cases is supplied by the PICA (Lazorthes).

The dorsal aspect of the cerebellum, both vermis and hemispheres, is supplied by the SCA. The anterior inferior aspect of the cerebellum, including the vermis, is supplied by the PICA. Between these arteries there is an extensive network of anastomoses and consequently they overlap in their cortical distribution.

Central distribution depends on the SCA branches which penetrate the hilum of the cerebellum to subdivide and supply the cerebellar white matter, the dentate nuclei and other cerebellar nuclei.

Venous System of the Brain Stem and the Cerebellum

The veins of the brain stem develop from a venous plexus. This explains the multiple variants that occur in their distribution. In general, the veins of the brain stem do not reach the dural sinuses directly beneath. They must empty into veins reaching the dorsal aspect of the brain stem and the cerebellum.

The pattern for the venous drainage of the posterior fossa, on the basis of the direction of its major channels, can be described as: (1) *superior group,* those veins draining into the system of the vein of Galen, (2) *anterior group,* those veins draining into the petrosal sinus, and (3) *posterior group,* those veins draining into the torcula and straight sinus. (Fig. 18)

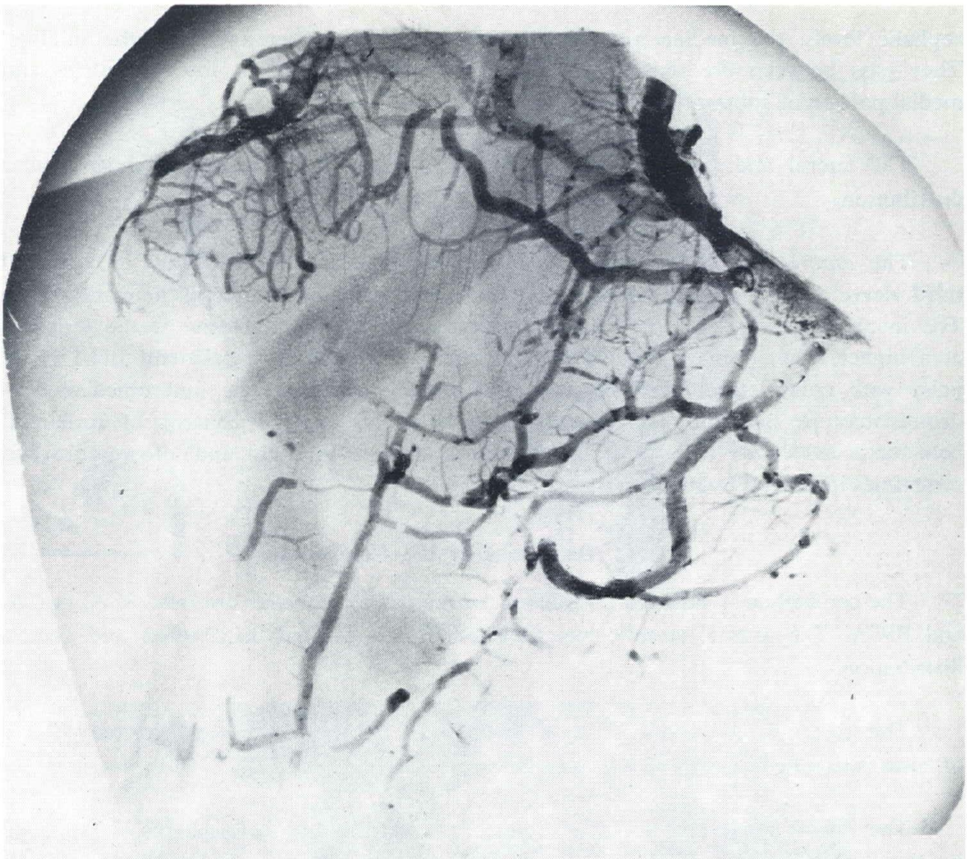

Figure 19

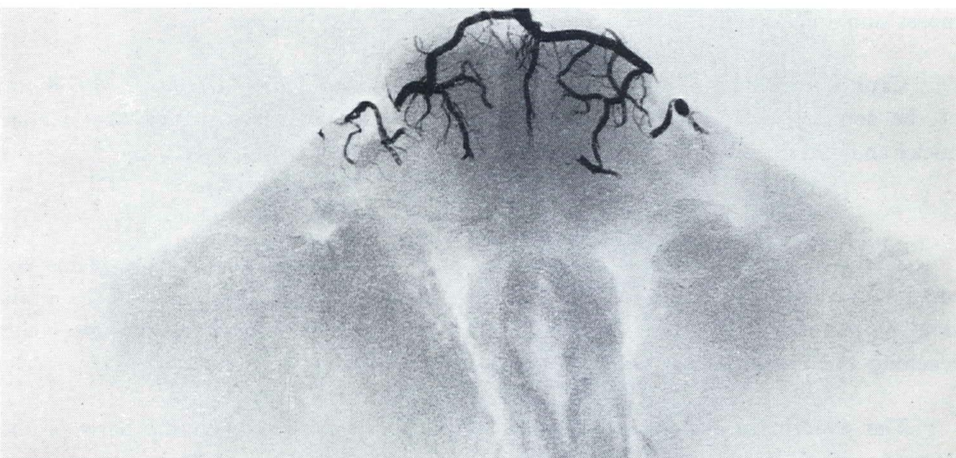

Figure 20

The Blood Supply of the Brain Stem

Veins from the caudal brain stem connect with those of the spinal cord. The anterior median vein, posterior median vein and radicular veins can be identified in the medulla. The anterior median vein continues with the pontine veins and it drains also by a radicular vein running with the twelfth nerve. The posterior median vein terminates in the occipital sinus. (Fig. 19)

In the pons, the anterior median vein forms an anastomotic network with the lateral veins. The veins of the lower half of the pons empty into the cerebellar veins and with them into the petrosal sinuses. One of the most important of the radicular pontine veins is the one associated with the fifth nerve (Dandy's vein) which reaches the superior petrosal sinus. The veins of the superior half of the pons empty into the superior group and, with the encephalic veins, reach the Galen system. (Fig. 20)

The cerebellar veins form "des amarres" which maintain the cerebellum against the walls of the posterior fossa. Lazorthes (Fig. 21) described three systems of "amarres": (1) *Anterior,* at the cerebellopontile angle which consists of one vein (80%) or two veins (20%) which travel from the dorsal aspect of the cerebellum below and lateral to the fifth nerve, the superior petrosal vein (Dandy) to enter the superior petrosal sinus. Sometimes there are also present two inferior cerebellar veins emptying either into the superior petrosal sinus or into the inferior petrosal sinus. (2) Dorsal or verniam system, usually consisting of two to four veins running parallel in the dorsal aspect of the vermis, slightly lateral to the midline and emptying into the confluent sinus. (3) *Lateral* or hemispheric systems consisting of one to three veins emptying the venous network of the surface of the cerebellar hemispheres into the lateral sinuses.

In addition, there is a constant group of cerebellar veins which run from the dorsal aspect of the cerebellum through the tentorium draining either into the lacunar system of this membrane or into the straight sinus or lateral sinus.

Experience With Acoustic Tumors

In 1948, the Society of British Neurological Surgeons held a Symposium on the results of operations on acoustic tumors. At that meeting, Olivecrona gave an analysis of 305 patients he had treated. In this series, there were 51 deaths (23.5%). In the cases with complete removal the causes of death were pulmonary complications: 5, lesion of the basilar artery, subdural hematomas, injury to the vagus nerve, shock and hemorrhage, 1 each. In the remaining 34 cases, death was caused by a postoperative clot in the tumor bed or hemorrhagic softening of the pons. In about half of the cases, the clot was held to be the dominant factor; in others, it was the brain stem injury. The hemorrhagic softening of the pons was considered to be due to interruption by clip or electrocoagulation of the petrous and other veins in the lateral surface of the pons. It could be seen in cases when it was known that injury to the brain stem had been minimal at operation.

At the same meeting, Northfield reported his personal experience with 49 patients with acoustic tumors on whom 57 operations were performed, with 18 deaths. A post-

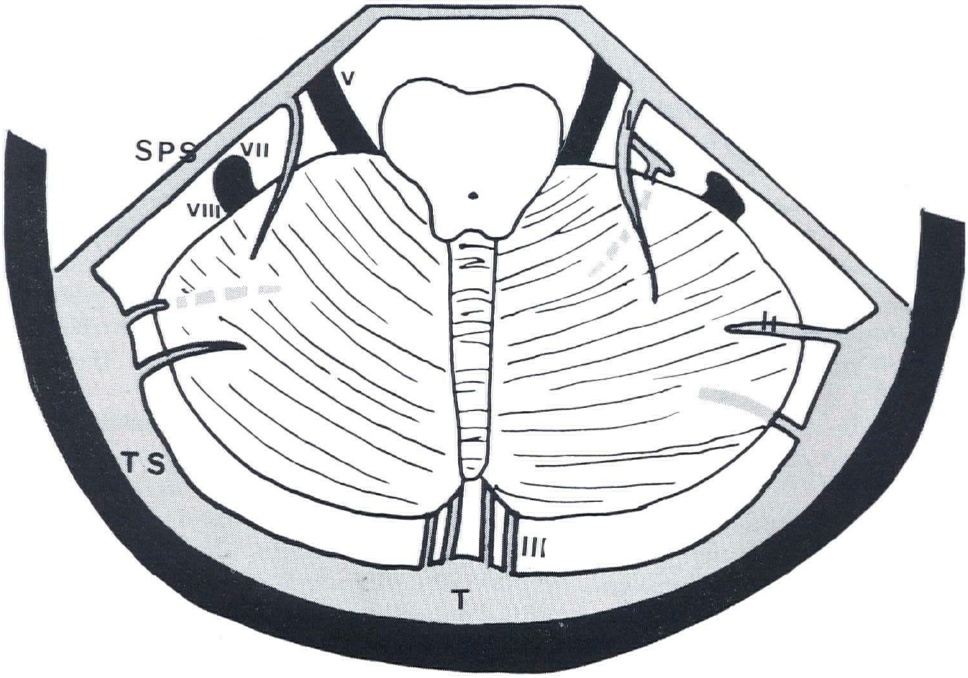

Figure 21

Table I.

FINDINGS IN 7 DEATHS FOLLOWING REMOVAL OF ACOUSTIC TUMORS
(Atkinson's Series)

Cases	Consciousness Po.	Temp.	Pulse/M.	Resp. /M.	Blood Press.	Death & P. M. Findings
1. 45 ♀	Coma 4 h.	104°F	150	N	?	10 d., inf. lat. pons, AICA ?
2. ? ♀	Coma	102.4° 104°	140 176 200	28 40	150/95	48 h., ext. hem. inf., r. lat. pons. & med., cereb., AICA clipp.
3. 47 ♀	Awake, coma	?	120 110 140		120/90, 160/110, 110/85, 80/60	24 h., hem. inf. r. pons, AICA clipp.
4. 57 ♂	Coma	102°	72 150	N 30	150/80	23 h., pontine inf., AICA ?
5. 58 ♀	Coma		120	22	100/60	24 h., l. hem. inf. pons & upper med., AICA clipp.
6. 56 ♀	Coma 4 h. drowsy	102°	78		94/70, 110/72, 120/78, 98/70, 150/100	24 h., l. pons hem. inf., AICA clipp.
7. 62 ♀	Drowsy 3 d., coma				160/100	7 d., l. pons teg. isch. inf., AICA thromb.

mortem examination was performed in 16 cases. In seven, damage to the pons was noted either as "bruising" or "softening". He considered these to be examples of infarction and the chief cause of death.

Atkinson (1949) wrote on the significance of the AICA in the surgery of the cerebellopontine angle tumors. At Queen Square, London, he gathered seven patients with acoustic neurinoma who died soon after operation. At necropsy there was found an infarction of the lateral tegmental region of the pons, in the area corresponding to the distribution of the AICA.

The operative procedure, postoperative course and postmortem findings are described in each case. All seven cases (six women and one man) died following the complete or partial removal of acoustic tumors (see Table I). In four cases (1, 3, 5, 6) the AICA was clipped during operation; in two cases (1 and 4), the condition of the vessels is not stated, and in one case (7) the artery thrombosed without being clipped at operation. The operative and postoperative records revealed a series of autonomic disturbances in the pulse rate, respiration, temperature, blood pressure and level of consciousness. Most of the patients were in coma in the postoperative period and did not regain consciousness. In many of them there were signs of increased intracranial pressure. Atkinson considered that clipping or injury of the AICA during the operation may be associated with many of these disturbances. The area of infarction in these cases "coincides almost exactly" with the distribution of AICA. As far as the patient's life is concerned, the region of primary importance is the tegmental area.

Atkinson gave a detailed anatomical description of the autopsy findings in Cases 3 and 5 and briefly described extent of the lesions in the others. From these and the paper's illustrations, one must necessarily conclude that the extension of the lesions described goes beyond the confines of the distribution of the AICA to include adjacent and even distant territories which depend on their blood supply from other arteries. These require participation of other blood vessels in the lesion or the presence of "other factors" in the causality of these extensive lesions. Nevertheless, an extensive involvement of tegmental regions is a constant feature of the postmortem findings. We will consider later the significance of this involvement.

Poppen (1958) successfully ligated the AICA proximally in three patients with aneurysms of the vessel. The three patients are presently living.

The first patient was a man of 35, with episodes of dizziness and deafness of the left ear. An aneurysm 1.5 cm was found at the AICA and the artery ligated. The second was a man aged 27, with headache, blurred vision, vertigo and right ataxia of sudden onset. At operation, an aneurysm of AICA was found and the artery clipped. The third case was a man, 54 years old, with frequent attacks of dizziness and loss of hearing in the left ear. At operation an aneurysm of a branch of AICA was found; the artery proximal to the aneurysm was clipped.

All three patients have been able to return to work full or part time.

The Syndrome of the AICA

Atkinson attributed to Wallemburg (1901) the first description of the syndrome. The case was reported as a hemorrhage from the *ramus centralis arteriae radicularis nervis fasciae dextri,* a branch of the anterior inferior cerebellar artery. The patient lived seven years. At the postmortem examination the right side of the pons appeared smaller than the left. Sections revealed a hemorrhagic cyst in the tegmentum of the pons extending to the floor of the fourth ventricle. Caudally, it reached the rostral part of the inferior olive, and rostrally the lingula of the cerebellum. The lesion destroyed the motor nucleus, as well as part of the sensory nucleus and some of the roots of the fifth nerve. The nuclei of the sixth and seventh nerves on the right were destroyed, as were the superior and lateral vestibular nuclei, parts of the restiforme body and medial longitudinal fascicules, the dorsal fibers of the cochlear nucleus as they passed to the trapezoid body, and part of the spinothalamic tracts on the same side. Judging from Atkinson's summary of Wallemburg's case, the lesions described and the territories damaged include more extensive areas than the usual distribution of the AICA if only this artery would have been affected.

Goodhardt and Davison (1936) described a case with a partial occlusion of the right AICA in a 47-year-old woman with sudden weakness of right extremities, ataxia and Hoffman sign, and without sensory disturbances. The postmortem examination revealed advanced arteriosclerosis of the vertebrobasilar system with occlusion of the right AICA. On sectioning the brain there were several small areas of softening in the thalamus and putamen on each side, an area of infarction in the upper third and inferior surface of the paramedian and ansiforme lobules on the right. The right AICA was occluded by a thrombus. No mention is made of pontine lesions.

Adams (1943) reported a clinicopathological study of a man, aged 48, with sudden vertigo, tinnitus, nausea and vomiting. Two hours later, he developed right facial paralysis. On examination he was lethargic but conscious, with facial paralysis, Horner's syndrome, deafness, impairment of pain and temperature sensation on side of the face and ataxia of limbs on the right. No muscle weakness, no abnormal reflexes were present. The patient died four weeks later from cardiac failure and pneumonia.

The postmortem examination showed a thrombosis of the right anterior inferior cerebellar artery with infarction of the lateral part of the medulla oblongata and cerebellum, thrombosis of the lateral branch of the left posterior inferior cerebellar artery with infarction of the cerebellum and multiple small infarcts in basis pontis, the mid-brain and the lenticular nuclei.

The onset of the syndrome of AICA is usually sudden and unaccompanied by loss of consciousness. Vertigo is the first symptom, often associated with nausea and vomiting. Facial paralysis, deafness, sensory disturbances, and cerebellar ataxia appear in a few hours. The clinical course is one of gradual improvement. Notably absent are signs of involvement of corticospinal tracts and medial lemniscus.

In view of the variability of the arterial supply of the brain stem and of the anterior inferior cerebellar artery, it cannot be assumed with certainty that all the syndromes caused by occlusion of this vessel will be identical with the case described by Adams.

When surgical obliteration of the AICA is required for the removal of an angle tumor in which it is entwined, one must remember that the AICA is a variable vessel in origin, size and distribution. It has extensive collaterals with the distal branches of the SCA and PICA and, not infrequently, it has a direct large anastomosis with the proximal portion of the PICA in the lateral aspect of the medulla. Any surgical occlusion of this vessel (AICA) ought to be made as far lateral as possible from its origin.

The circuitous course in the cerebellopontile angle and the presence of numerous other significant vessels and nerves in this region (mentioned before) would indicate a very careful dissection of this vessel before occluding it if it cannot be saved. The internal auditory artery arising from the AICA, when occluded during the removal of acoustic tumor, poses no problem if the hearing loss is total.

The PICA is also a variable vessel. It varies in size and significance, depending on its anastomoses and the size of the AICA. Occluding of this vessel should be done after it divides into its medial and lateral branches. If the medial branches are to be ligated, they should be occluded as distantly as possible. The lateral branches of the PICA are severed in removing part of the cerebellar hemisphere for excision of acoustic tumors. But because of the cerebellar tissue excision and compression of the brain stem by the tumor, the resulting complications cannot be accurately assessed.

The veins which exit from the brain stem, other than the Dandy's vein, pose no special problem by surgical occlusion. The acoustic tumors that grow out of the internal auditory meatus, in the cerebellopontine angle, push the lateral branch of the AICA upward and as the artery continues over the flocculus and brachium pontis, it comes to lie posteriorly and inferiorly on the surface of the tumor. However, because of the variable course of the artery, it may lie over the ventral aspect of the tumor as some of the Cushing and Dandy cases seem to demonstrate.

In the suboccipital approach to the cerebellopontine angle tumors, the artery is usually seen lying directly on the posterior inferior surface of the tumor as soon as the cerebellar hemisphere is retracted (Knighton's personal communication). Hamby wrote that because the arteries running over the capsule of the tumor are distorted and cannot be identified until the tumor is out, one should avoid clipping any artery on the tumor.

When the translabyrinthine approach is used, the AICA is in medial and inferior position and not in direct vicinity of the operative field (House). If the tumor is small, the artery can be separated from the tumor.

The following case is the only one of acoustic tumor with postmortem examination at Henry Ford Hospital in the last 10 years. This case illustrates very well some of the problems of this type of surgery:

CASE OF ACOUSTIC TUMOR (HFH #047 88 64)

A 57-year-old housewife with intermittent headaches for nine months had had occasional dizziness, sometimes nausea but without vomiting for three or four months. She had noted ringing in her left ear for about six months and diminished hearing in the same ear for three months.

General and neurological examinations were normal. X-ray of the skull revealed erosion of the posterior clinoid processes and an EEG indicated a lesion of the left temporal region. Ventriculograms showed moderate enlargement of lateral ventricles but the fourth ventricle and aqueduct was not seen. An otologic examination revealed Rinne test positive bilaterally, and the Weber test referred to the right ear. Audiograms showed a severe sensorial deafness in the left ear with incomplete recruitment and good discrimination. Auditory test on the right ear was normal. The caloric responses were diminished on the left ear and normal on the right.

A posterior craniotomy revealed a tumor in the cerebellopontine angle (acoustic neurinoma). The ninth, tenth, eleventh and fifth cranial nerves were intact. Subtotal intracapsular removal of the tumor was performed. Part of the medial aspect of the tumor capsule, where it was attached to the brain stem, was left in place and two "fairly good arteries" entering the capsule were coagulated and divided. Hemostasis and cleaning completed, the operation was concluded. During the entire operation (five hours) the patient's vital signs remained constant. Her blood pressure of 120/70 remained stable. At the end of surgery, her condition was good. Postoperatively, she remained unresponsive, vital signs stable, blood pressure 140/80, pulse 60 xm, normal respirations. Twenty-four hours later, she was more responsive but remained somewhat lethargic; 48 hours postoperatively, she was again unresponsive with a blood pressure of 140/80, pulse 64 xm, with a skew deviation of the eyes, the left eye deviated laterally. Later the same day, she seemed more responsive and with stable vital signs. She expired suddenly on the third postoperative day.

The postmortem examination revealed edema of the brain with left temporal pressure cone and marked tonsillar herniation bilaterally. The cerebellum was edematous with infarction and necrosis of the anterior inferior aspect of the left hemisphere. The brain stem was markedly distorted and displaced toward the right. Sectioning of the brain revealed an extensive hemorrhagic infarction of the left cerebellar hemisphere and brachium pontis with extension into the lateral and tegmental region of the pons and into the fourth ventricle. At the left cerebellopontine angle, a small remnant of the acoustic tumor was found. Examination of the left temporal bone revealed a tumor located within and destroying the bony walls of the internal auditory meatus. The tumor had invaded the facial canal and both the superior and inferior divisions of the vestibular nerve.

A postmortem injection of radiopaque material was made. X-ray of sections of the brain stem and cerebellum showed displacement of the brain stem from left to right, a large avascular area in the left cerebellum and brachium pontis extending toward the fourth ventricle. Most of the injected vessels on the left hemisphere and left half of the brain stem appeared displaced and distorted. Several silver clips were present but we could not identify the vessels occluded by them.

To conclude this topic, I would suggest that if more careful considerations were given to the details of the vascular system in the operative site, less vague and unexpected complications would be encountered. *A detailed knowledge of the vascular anatomy is of the utmost importance when large vessels must be occluded during the operative procedure.*

Statistical percentages are of only relative significance in surgery. Each operation for tumor removal is a problem within itself. The size of the vessel, its origin single or multiple, its location in relation to supplying branches to important structures and the extent of collaterals, all would determine the possibilities of a safe occlusion of a vessel.

Except in the case of vascular malformation and aneurysms that require occlusions of large feeding blood vessels, "the greater the number of vessels that can be avoided in an operation, the better off the patient will be". (Kaplan)

To be concluded in the next issue of HENRY FORD HOSPITAL MEDICAL JOURNAL. Bibliography in next issue. Complete reprints will be available after publication of Part II.