THE ARTERIES OF THE PONS AND MEDULLA OBLONGATA: PART II. By J. S. B. STOPFORD, M.D., *Lecturer in Anatomy, University of Manchester.*

PART II.

THE PRECISE DISTRIBUTION OF THE ARTERIES SUPPLYING THE MEDULLA OBLONGATA AND PONS.

ALTHOUGH our knowledge of the gross anatomy of the bulbar branches of the vessels of the hind brain has hitherto been far from complete, it is vastly superior to the information we possess of the regions of the medulla oblongata and pons which these arteries supply.

Heubner (73), Duret (54), Kolisko (85), and particularly Beevor (19), have provided us with a considerable amount of information of the cortical and basal distribution of the cerebral arteries; and almost every anatomical text-book describes, in great detail, the precise blood supply of the fore brain. Alezais and d'Astros (5) have studied most carefully the vessels which supply the mid brain. As previously stated, the blood-vessels of the spinal cord have been fully considered by Marie (95), Obersteiner (102), Kadyi (82), Adamkiewicz (2), and Ross (115).

Yet the exact blood supply of the hind brain, by comparison, has been left in obscurity to this day; and no English manual of anatomy even attempts to unravel its mysteries, although its importance to the modern neurologist cannot be overestimated. This work, however, has not been wholly neglected, but within recent years it has become increasingly evident that the subject requires reinvestigation to elucidate the problems of clinical medicine. Enormous advances in our knowledge of the structure and functions as well as in the pathology of the central nervous system have been made since the arterial supply of the medulla oblongata and pons was last studied, and the importance and urgent desirability of further information are becoming more and more obtrusive. Our present knowledge is wholly due to the researches of Duret (55) and Adamkiewicz (2).

Duret's memoir was published more than forty years ago, when histological methods were very imperfect and the localisation of tracts was quite in its infancy. He made only twenty injections, and his attention was directed primarily to the radicular arteries. No attempt was made to define the areas of the medulla and pons supplied by the individual vessels. Adamkiewicz, over twenty years ago, covered the same ground as Duret in his researches, but only advanced our knowledge by supplying a more detailed account of the course of the minute nutrient arteries within the bulb.

Both of these observers examined most carefully the small vessels supplying the cranial nerves, and traced their ramifications peripherally and centrally; but their work was essentially descriptive, for the knowledge of the structure and functions of the brain was not sufficiently extensive at that time to suggest the clinical significance such researches might have. This is another reason why it has failed to satisfy the demands of present-day neurology.

These two published accounts create the impression that the distribution of the arteries of the hind brain is extremely constant, and almost completely ignore the question of variation in supply.

The unsatisfactory state of our knowledge is manifest in almost every treatise or memoir on vascular lesions of the pons and medulla, and is the explanation of much of the vagueness in references to the subject when attempts have been made to explain the obscure etiology of so many bulbar diseases. Even if a greater knowledge did not prove of very great assistance in determining the etiology, it would at any rate prevent irrelevant allusions by which the physician and pathologist are able to throw the responsibility for their ignorance upon the unfortunate anatomist.

TECHNIQUE.

About fifty injections in all have been made; but some of the earlier ones were not very satisfactory owing to defects in technique, which were remedied as the work progressed. At first it was intended to adopt completely Beevor's (20) method, in which he used a system of pressure bottles, and injected simultaneously several vessels. But this was not found to be feasible, owing to the small calibre and delicacy of many of the arteries in this region; instead, it became necessary to make the injections with a record syringe.

Beevor adversely criticises this method for the cerebral arteries, but it has been repeatedly proved, in the case of the arteries of the hind brain, that the resultant varying pressure did not cause any material inaccuracy in the field of injection. Even when two neighbouring vessels were injected, there was never the slightest confusion of the two colours along their line of contact. This fact lends support to the accepted opinion that the nutrient vessels to the pons and medulla oblongata are true "end-arteries."

Valenti and d'Alundo (146) studied the terminal branches of the cerebral arteries in mammals, especially the cat and the rabbit, and found that they anastomosed during intrauterine life, but after birth

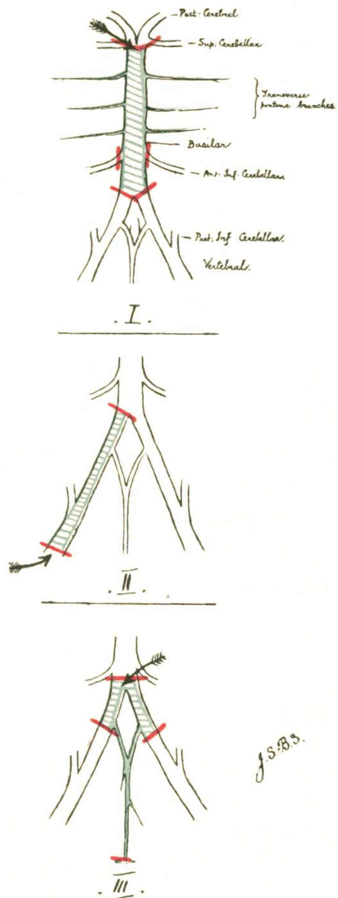

FIG. 6.—Method used for injection of I. basilar artery, II. vertebral artery, III. anterior spinal artery.

the communications were obliterated. Duret found that similar communications existed in the human fœtus during the third and fourth months of fœtal life.

As an essential preliminary to injection, the arteries were washed free from blood with saline solution. After the necessary ligatures had been applied, to prevent error from anastomoses or too widespread diffusion of the stain, the needle was tied into the vessel and the brain placed in hot water in order to prevent the injection-fluid setting. In making the injection considerable pressure had to be exerted, and maintained for some time, if a complete and successful result was to be obtained. This was especially necessary in the case of the basilar artery, which proved to be much the most difficult to inject.

After withdrawal of the needle, the ligature fixing it was immediately tied to prevent escape of the stain, and the brain fixed in formalin for at least forty-eight hours.

After fixation, the bulbar or pontine branches were carefully studied and noted, as well as the anatomical disposition of the other vessels as described in Part I.

When the cerebellum had been removed, the stained portion of the floor of the fourth ventricle was accurately mapped out in diagrammatic form; and then serial sections of the medulla and pons were cut, figured, and mounted in order.

The sections were cut about one-sixteenth to one-eighth of an inch thick, and were fixed on sheets of glass.

Soluble colours in gelatine, as described by Beevor (20), were used for the injections.

Red and blue were chosen because they exhibit such a marked contrast, and the latter colour proved to be particularly satisfactory in the case of small areas, as its definition was so very clear.

Red.	Carmine, ½ drachm.	*Blue.*	Nicholson's blue, 15 grains.
	Ammonia, ½ ,,		Alcohol (90 per cent.), ½ ounce.
	Glycerine, ½ ounce.		

In both cases dissolve, and then add to 2 ounces of gelatine dissolved in 1 pint of hot water.

Beevor (in 1907) was the first to employ soluble colours in his investigation of the cerebral vessels, but this method has never been adopted for the arteries of the pons and medulla; the greater accuracy obtained by using soluble colours, in preference to suspended insoluble powders, is quite obvious, and is referred to in Beevor's classical paper. Beevor claimed that all the colours, except the yellow (which has not been used in this work), were absolutely fixed by the formalin. My own specimens, although mounted in formalin, tend to fade slightly and lose their sharp definition at the periphery of the injected area; and I hear that the same difficulty is at present being experienced with Beevor's magnificent specimens in the Museum of the Royal College of Surgeons.

The Anterior Spinal Artery.

The bulbar distribution of this vessel is confined to the anterior and median parts of the medulla oblongata, and, owing to its remarkable constancy, it has been found preferable to consider it first, in order to simplify the descriptions of the less regular inconstant ones.

From the results of the seven experiments quoted by Moxon (100), there is good reason to conclude that the anterior spinal fills from above downward—a fact of considerable significance when clinically determining the result of its occlusion. The only variations in its distribution depended upon either an unusually low origin from the vertebrals (20 per cent. on the right and 13 per cent. on the left), or extreme caudal fusion of these two vessels, which was noted in 19 per cent. These two factors only influence the level of the upper limit of the area supplied, and in both cases cause the distribution to be less extensive when traced in a cephalic direction. In either instance the vertebral is found to compensate for the deficiency and to supply the region normally vascularised by the anterior spinal as the pons is approached.

In consequence of the diminutive size of the anterior spinal some difficulty was found in injecting it, which rendered it necessary to insert the needle at the junction of the two vertebrals, after applying ligatures below the origin of the artery under investigation. Thus the upper part of each vertebral was injected in addition to the anterior spinal. After ascertaining the area supplied by the vertebral in subsequent experiments, it was possible to eliminate that part of the medulla it supplied, and in that way obtain the exact distribution of the anterior spinal alone (see fig. 6).

Floor of the Fourth Ventricle.

Invariably the trigonum hypoglossi was accurately defined by the stain of the injection.

Spinal Cord.

In a number of injections it was possible to see the distribution to the first cervical segment of the spinal cord.

The grey matter of the anterior cornua and around the central canal was deeply stained; whereas the white matter of the ventral columns and the region of the anterior roots was stained a much paler colour. In addition, in about 50 per cent. the base of the posterior cornua was also injected. The median branches (set B) appeared to supply the grey matter, whilst the transverse rami (set C) provided smaller branches which ramified in the white matter and terminated in the grey matter; but their precise anatomical arrangement and course within the cord have been admirably studied previously by others.

The more intense staining of the anterior cornua indicates its rich blood supply, which has been demonstrated by Ross (115) and subsequent observers.

The above description is in perfect agreement with the opinion of Kadyi (82), Adamkiewicz (3), Obersteiner (102), and Marie (95), but, in addition to the support it lends to their work, it also gives a clearer and probably more accurate conception of the region supplied by the anterior

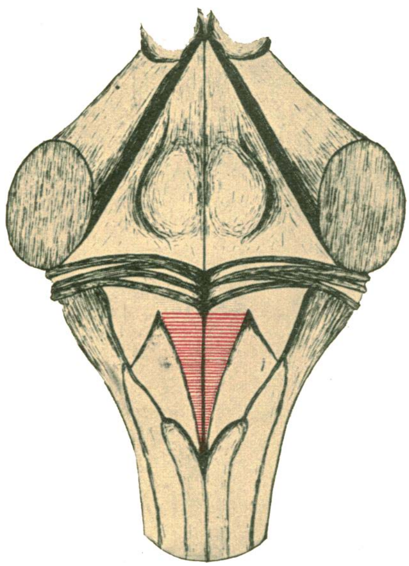

FIG. 7.—Floor of fourth ventricle.

system of spinal arteries; because the observations are made before it becomes obscured by the anastomoses between the anterior and posterior systems, which occur below this level. In the investigation of the distribution of the anterior spinal to the cord, this vessel has never been injected as far as the point where it communicates with the posterior spinal, and consequently the stained area must strictly represent the district supplied by the former vessel alone.

This subject is somewhat controversial, and often rendered obscure by many writers in their endeavour to divide the cord into three districts—first the part supplied by the anterior system, secondly the part supplied by the posterior, and lastly the area supplied by both. The latter, according to Kadyi, approximately amounts to one-third of the transverse area of the cord.

Level of Pyramidal Decussation.

The median set of bulbar branches can be seen with a lens to turn obliquely in a dorsal direction amongst the decussating fibres, which they supply as far back as the crossed pyramidal tract, where they terminate. The detached head of each anterior cornu and the grey matter surrounding the central canal, as well as the ventro-lateral ground bundles, the nucleus

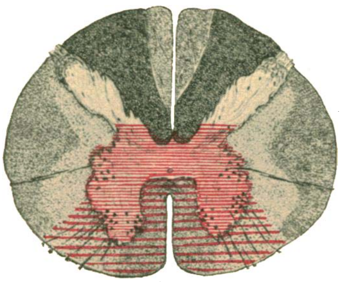

FIG. 8.—Cervical spinal cord.

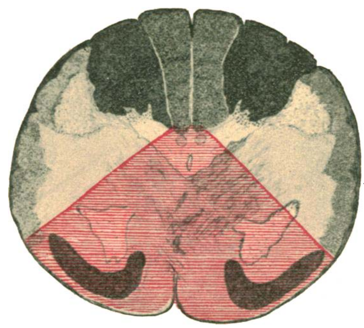

FIG. 9.—Decussation of pyramids.

and tractus solitarius, Gower's tract, and (of course) the remains of the pyramid were also supplied. The latter two were chiefly dependent upon the smaller perforating branches of the transverse rami.

Level of Sensory Decussation.

The area of distribution at this level was very similar to the previous one; the only additional structures supplied were the internal arcuate fibres as they cross the middle line to form the medial lemniscus, and the nucleus of the hypoglossal nerve.

Calamus Region.

Here the district supplied by the anterior spinal was limited laterally by the fila of the hypoglossal nerve as they passed to their superficial origin, and dorsally by the nuclei of the posterior columns, which were never included. At this level the dorsal nucleus of the vagus, in addition to the hypoglossal nucleus, pyramid, medial lemniscus, tecto-spinal tract, and medial longitudinal bundle, was within the injected area, but the tractus solitarius was usually situated laterally to it.

Mid-Olivary Region.

In this section the ventral part of the inferior olive with the olivo-cerebellar fibres, as they passed out of the hilum to reach the opposite

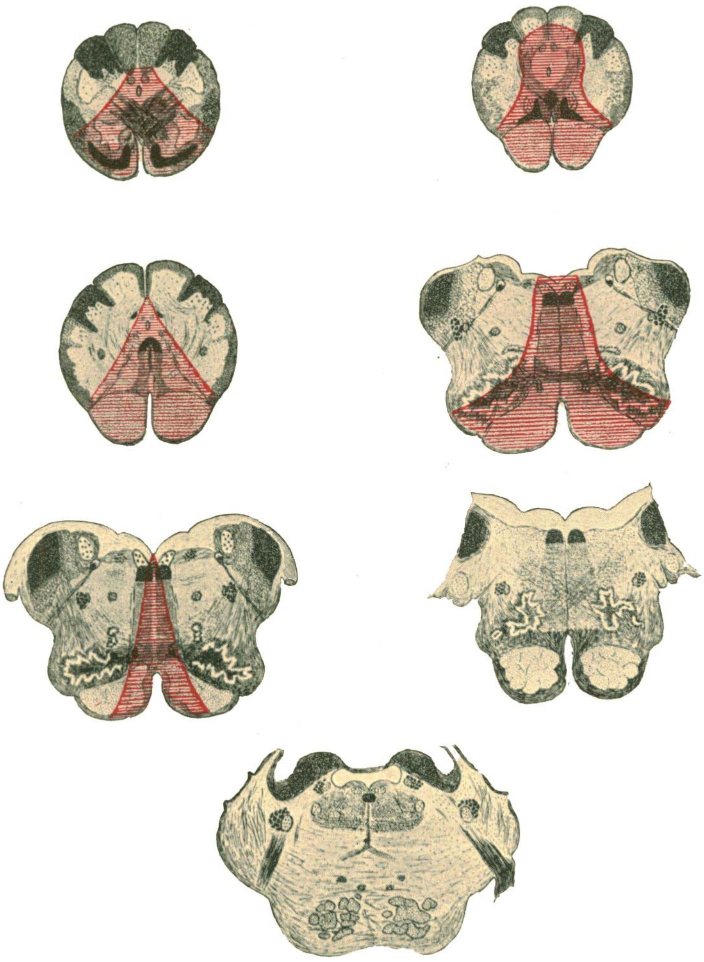

Fig. 10.—Normal distribution of anterior spinal artery.

inferior cerebellar peduncle, and the medial accessory olive were supplied, as well as the structures supplied in the calamus region. That is to say, at this level the pyramid, hypoglossal nucleus, ventral part of the inferior olive, and the whole of the formatio reticularis alba on each side are supplied by the anterior spinal.

There was every indication that the median branches formed a network and richly supplied the hypoglossal nucleus, as described by Duret. The majority passed dorsally, through the lemniscus, to this nucleus, but a certain number turned into the hilum of the inferior olive, the ventral

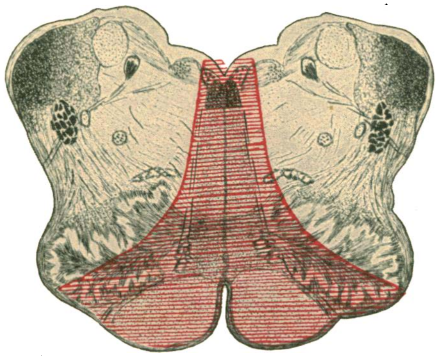

FIG. 11.—Normal distribution. Mid-olivary region.

part of which they were found to supply. The transverse set provided shorter branches, which penetrated the pyramids and the ventral external arcuate fibres, even to a point just dorsal to the antero-lateral sulcus.

The upper group of branches (set A), as described in Part I., formed a plexus on the upper part of the pyramids, and supplied a similar area to the parent vessel, above its origin from the vertebrals.

Upper Olivary Region.

Hitherto it has been found unnecessary to refer to the variations signified at the outset of the description of the distribution of this artery. Normally the anterior spinal continued to supply the same region as described in the previous section as far, in a cephalic direction, as the level of the entrance of the auditory nerve, at which point it was replaced by the vertebral. In cases of low origin of the anterior spinal, or where the site of junction of the two vertebrals was considerably below the inferior border of the pons, the former artery was found to supply the bulb only as far as a point somewhere between the lower border of the pons, and the upper third of the olivary eminence. The exact level of this point obviously depended upon the extent of the variation in the two factors which have been stated to affect its distribution.

Under no circumstances was the anterior spinal found to supply any region above the level of the lower border of the pons, or, in other words, no injection is to be seen in a transverse section displaying the striæ medullares; but their position is so liable to variation that it is preferable to adopt the first method of description.

Normally, in the cephalic direction, the distribution of the anterior spinal became slightly reduced, and was gradually replaced by bulbar branches of the vertebral (set A) and the basilar.

It is instructive to note that the hypoglossal nucleus, the origin of nerves, primarily spinal, which later became cranial, is supplied by the anterior spinal artery.

The Vertebral Artery.

In the early part of the work this vessel was injected from above, but, owing to the imperfect injection of the most cephalic set of bulbar branches by this method, it was found advantageous to insert the needle of the syringe below, immediately above the place where the artery had pierced the dura.

The distribution of this artery was subject to very considerable variation, which has been found to depend upon three factors:—

1. *Variation in the distribution of the posterior inferior cerebellar artery.*—Attention has already been drawn to the fact that the vertebral replaces the bulbar branches of this vessel when it is absent or fails to provide any nutrient twigs for the supply of the medulla, and compensates almost invariably for their insufficiency. The effect of this will be shown to be most obvious in the olivary region.
2. *The origin of the anterior spinal artery.*—When this vessel arises at the level of the lower extremity of the olive, or below that point (20 per cent. on the right and 13 per cent. on the left), the vertebral has to compensate for its deficient supply to the most cephalic part of the medulla.
3. *The level of the junction of the two vertebral arteries.*—When the junction occurs some distance below the caudal border of the pons (19 per cent.), the distribution of the vertebral and anterior spinal is curtailed, and that of the basilar increased; whereas, in cases where the junction was distinctly above this point (8 per cent.), the area supplied by the vertebral was increased, with a corresponding decrease in that supplied by the basilar.

The latter two factors will influence the cephalic limit of distribution.

The percentage variation in the distribution of the vertebral, together with the factors which cause it, is of enormous clinical interest, and helps to elucidate many of the outstanding difficulties that arise in connection with the localisation of the occlusion of vessels in this region. Attention must be directed again to the division of the bulbar branches of the vertebral into three sets (upper, middle, and lower), as a clear conception of their arrangement makes the involved description somewhat less complex.

Floor of the Fourth Ventricle.

The injection always demarcated the trigonum vagi and, usually, the trigonum hypoglossi in the neighbourhood of the striæ acusticæ. There

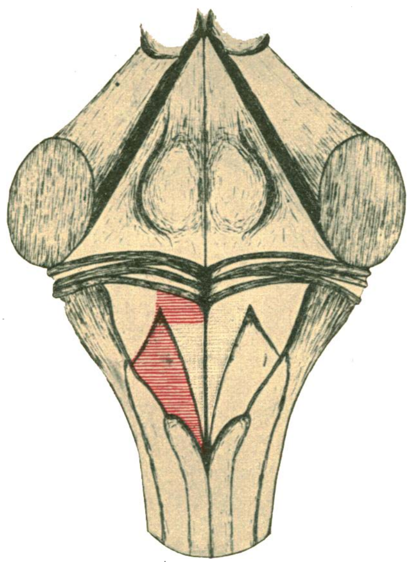

FIG. 12.—Floor of fourth ventricle.

was rarely some extension to the trigonum acustici and the inferior part of the colliculus facialis. The staining of the latter region was only seen in cases where the two vessels united cephalic to the lower borders of the pons.

Level of Pyramidal Decussation.

At this level the most caudal set of branches have been seen to enter the lateral region of the medulla. They are found to supply a triangular interval having its apex towards the central canal, which was bounded ventrally by the detached head of the anterior cornu and decussating fibres, and dorsally by the funiculus cuneatus.

This area included the spino-cerebellar tract, remains of the posterior cornu, substantia gelatinosa of Rolando, nucleus and tractus spinalis nervi trigemini, and a few of the fibres which formed the lateral cerebrospinal tract.

When the posterior spinal arose from the vertebral (on the right in 18 per cent. and on the left in 20 per cent.), and was also injected, the funiculi gracilis and cuneatus with their nuclei were also stained; and consequently

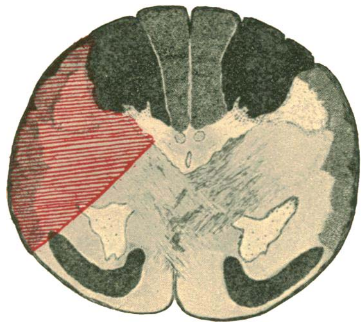

FIG. 13.—Decussation of pyramids.

the whole area of the medulla, at this level, was supplied by the vertebral arteries and their two spinal branches. It is quite inconceivable that such a widespread occlusion could occur clinically.

Level of Sensory Decussation.

The distribution here was very similar to that seen in the previous section, only the tract of Gowers was also supplied, as, at this level, it is found to be situated in a more lateral position, owing to the occupation of the ventral region by the motor fibres.

Calamus Region.

Here the area supplied was the same as the above, with the addition of the nucleus and tractus solitarius, in those cases in which they did not lie within the anterior spinal district (see p. 261). Hitherto no variation of any moment has been described, unless we include the posterior spinal, which is, strictly speaking, a separate artery with a definite distribution of its own, and the supply has been provided practically by the caudal set of bulbar branches.

Mid-Olivary Region.

At this level the study is restricted to the distribution of the middle set of vessels, composed of branches passing chiefly to the postero-lateral sulcus. They are the branches which vary according to the distribution of the posterior inferior cerebellar artery, and consequently considerable variation in the vertebral supply is to be expected.

When the posterior inferior cerebellar freely provided branches for the retro-olivary region, the area supplied by the vertebral was represented by a narrow "wedge" between the anterior spinal district medially and that of the posterior inferior cerebellar dorso-laterally. This wedge included the medial and ventral parts of the formatio reticularis grisea, the dorsal half of the inferior olive, and frequently the dorsal vago-glossopharyngeal nucleus. The injected portion of the formatio reticularis grisea included the fasciculus tegmento-olivaris, the olivo-cerebellar fibres, and the dorsal accessory olive.

The wedge increased in size proportionately to the decrease in the

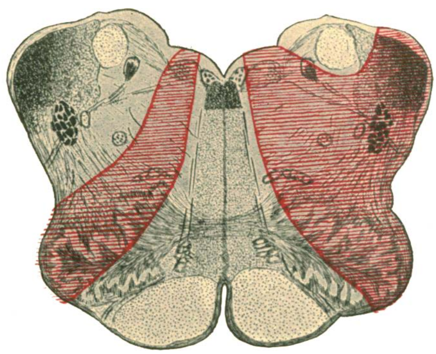

FIG. 14.—Absence of posterior inferior cerebellar on right. Mid-olivary region.

area supplied by the posterior inferior cerebellar, so that, in the absence of the latter vessel, the whole of the dorso-lateral region of the bulb was dependent upon the distribution of the vertebral. The significance of the percentage variation in distribution of the posterior inferior cerebellar now becomes manifest. According to the figures stated, some increase in the area supplied by the vertebral, at this level, was to be found in 36 per cent. on the right, and 32 per cent. on the left; but in the vast majority of these the posterior inferior cerebellar failed to provide any bulbar branches, so that in 31 per cent. on the right and 29 per cent. on the left the vertebral was found to supply the whole of the formatio reticularis grisea in this region. Therefore, in the latter number, the vertebral also supplied the spino-thalamic, rubro-spinal, and the anterior and posterior spino-cerebellar tracts, as well as the nucleus ambiguus, descending root of the vestibular nerve, nucleus and tractus spinalis nervi trigemini, and a large part of the inferior cerebellar peduncle. This variation, dependent upon the distribution of the posterior inferior cerebellar, will be maintained as far as the pons; but, for brevity, future reference to it will be omitted.

Upper Olivary Region.

We now gradually come to the consideration of the upper set of bulbar branches.

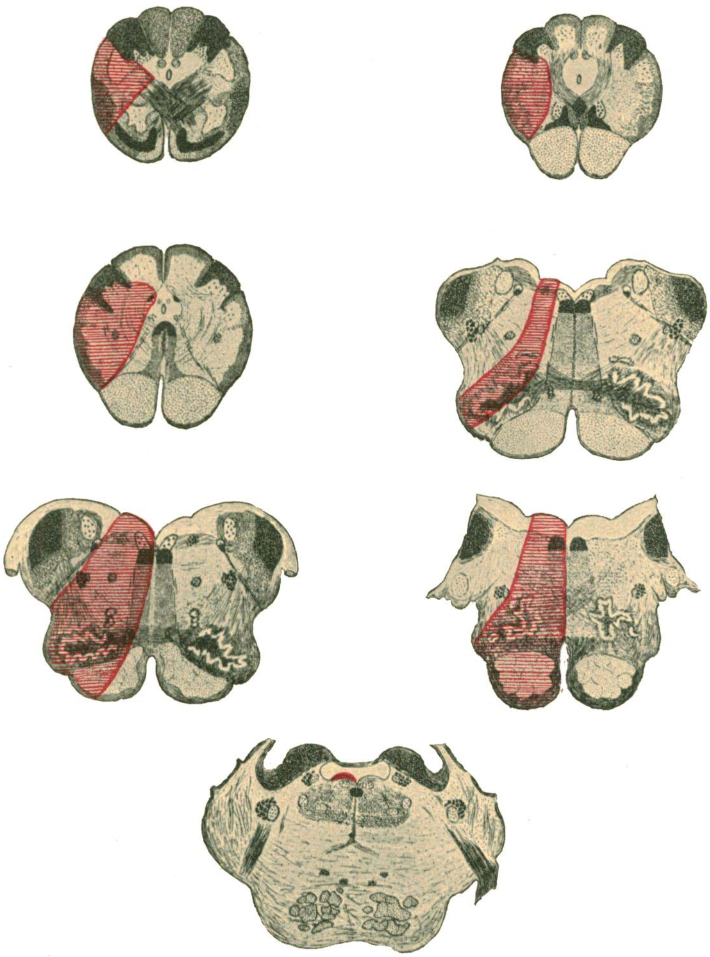

Fig. 15.—Normal distribution of vertebral artery.

From this level the wedge-shaped area was seen to increase medially owing to the diminishing anterior spinal district, and laterally at the expense of the posterior inferior cerebellar district, when traced in a cephalic direction. The whole of the inferior olive was supplied, and the more lateral part of the pyramid, together with an increasing amount of the formatio reticularis grisea. At this level normally a considerable amount of the inferior cerebellar peduncle was supplied by the vertebral, and consequently the diminishing posterior inferior cerebellar district was situated between two parts of the area supplied by the former artery.

Lower Border of the Pons.

Normally, at the most cephalic limit of the medulla, the vertebral completely replaced the anterior spinal and posterior inferior cerebellar arteries. So that, in addition to the whole of the formatio reticularis alba, including the medial lemniscus, dorsal longitudinal bundle, tecto-spinal

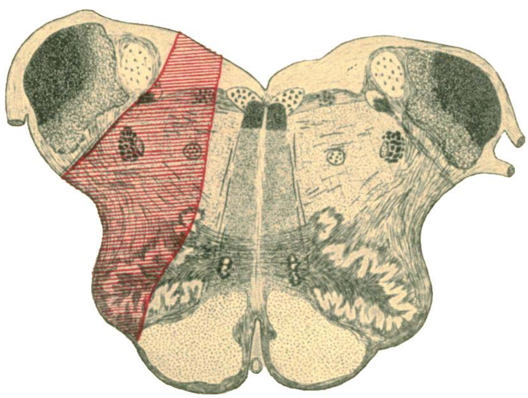

FIG. 16.—Variation dependent upon low origin of basilar (19 per cent.).

tract, and the most cephalic part of the hypoglossal nucleus were also almost entirely supplied by the vertebral. Consequently, just at this level, practically the whole of the medulla was supplied exclusively by the upper set of bulbar branches from the two vertebral arteries.

Provided the arteries maintain what is described as their normal arrangement, the only structures ever to be found outside the vertebral district were the inferior cerebellar peduncle, which may be supplied by the posterior spinal or posterior inferior cerebellar, the most medial portion of the pyramid supplied by the anterior spinal, and perhaps more frequently a small part of the retro-olivary region supplied by the posterior inferior cerebellar artery.

The above account is only for the normal arrangement and distribution, and even that is not quite constant; the two factors which cause variation in the vertebral supply in the upper part of the medulla have still to be considered. From the foregoing it can be seen easily that abnormally low origin of the anterior spinal will cause the vertebral to take over at a lower level, and consequently more completely, the supply of the pyramid hypoglossal nucleus and the tracts contained in the formatio reticularis alba.

The low junction of the two vertebrals, unless the origin of the anterior spinal is abnormally low (an association which is of extreme rarity), will result in the basilar replacing the anterior spinal. Consequently, in 19 per cent. the vertebral failed to supply the pyramid, hypoglossal nucleus, and formatio reticularis alba, and its occlusion would not cause hemiplegia, as is generally thought to be the inevitable result of such a lesion.

When the vertebrals fused abnormally high (8 per cent.) they replaced the

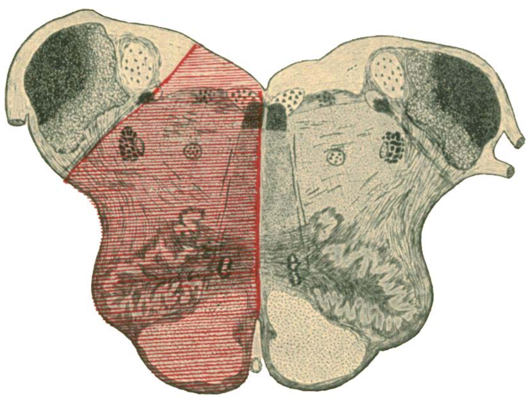

Fig. 17.—Variation dependent upon low origin of anterior spinal.

basilar caudally, and supplied the pyramidal bundles and medial lemniscus in the pons, together with the abducent nucleus and fibres of the facial nerve. The more caudal part of the abducent nucleus has been supplied occasionally by the vertebral in cases where this vessel terminated normally at the lower border of the pons. The specimens produced strong evidence to support the opinion that the terminal ramifications of the median bulbar and pontine branches spread out and run for some distance, in a cephalic direction, in the grey matter of the floor of the fourth ventricle. This is indicated by the persistence, repeatedly, of some injection in this situation in sections cut cephalic to the lower border of the pons, *i.e.* the upper limit of the normal distribution (see fig. 15).

The only alternative to this supposition is that the median vessels do not run directly dorsally, but incline slightly in a cephalic direction as they pass towards the floor of the fourth ventricle.

The deep staining of the nuclei in the floor of the fourth ventricle supported the opinion expressed by previous writers that there is a vascular network in this situation, which is formed by the terminal ramifications of the median nutrient branches from the various arteries.

The Posterior Inferior Cerebellar Artery.

Considerable attention has been directed to this artery, first, because of its increasing clinical importance, and secondly, because our unsatisfactory and incomplete anatomical knowledge of its distribution demands revision and additional research. It has long been known that it supplied branches to the retro-olivary region of the medulla, but even Duret and subsequent anatomical observers have failed to determine the precise extent of, or variation in, its distribution, as it is only during recent years that it has sprung into such remarkable eminence.

Eight years ago Burrows, at Thomas' (140) instigation, made some injections to illustrate its distribution, but neglected to study the variation in its supply: although reference to the literature on the subject of the clinical manifestation of its occlusion demonstrates clearly that its distribution cannot be constant.

For a similar reason, Wallenberg's (148) study of this artery fails to provide the necessary knowledge which modern neurology demands. Anatomical research alone can explain the discrepancies in the symptomatology of the numerous reported cases of occlusion of the posterior inferior cerebellar artery.

Reference to Part I. will show how frequently the vessel was absent, and how commonly (31 per cent. on the right and 29 per cent. on the left), when present, there was an absence of bulbar branches to the retro-olivary region. Furthermore, in 5 per cent. on the right and 3 per cent. on the left it will be seen that these branches were inefficient, and only entered the most caudal part of the postero-lateral sulcus, and consequently merely supplied a small area of the bulb. This variation has been seen to depend very largely upon the course of the artery, as it curves round the medulla to reach the inferior surface of the cerebellum. The other important factor which influenced its distribution was the origin of the posterior spinal artery, which arose from the posterior inferior cerebellar in 73 per cent. on either side.

Excluding the district supplied by the posterior spinal, the usual distribution of the vessel under consideration is confined to the limits of the inferior olive. The majority of its bulbar branches entered the postero-lateral sulcus, but some certainly penetrated dorsal to this point and passed into the inferior cerebellar peduncle. These branches did not appear to bear any marked relation to the vagus and glossopharyngeal nerves, as indicated by Duret, although some might be termed "radicular."

Mid-Olivary Region.

This is the most typical section in which to see the district it supplies, as the latter is at its maximum, and decreases when traced from this point in either a caudal or a cephalic direction.

FIG. 18.—Four variations in the distribution of posterior inferior cerebellar. Mid-olivary region.

The injected area was limited ventrally by the inferior olive, except laterally, where the tegmento-olivary tract invariably intervened, and medially by the fibres of the hypoglossal nerve. Dorsally its limits were not so well defined. Usually the ventral part, at least, of the inferior cerebellar peduncle was injected, and frequently part of the dorsal vago-glossopharyngeal nucleus and a small portion of the descending root of the vestibular nerve. Thus it was seen that the posterior inferior cerebellar artery, at this level, supplied most of the formatio reticularis grisea—all except that part included in the vertebral district. Consequently its obstruction will affect the spino-thalamic, anterior spino-cerebellar, and rubro-spinal tracts, the olivo-cerebellar fibres, as well as the dorsal nucleus, or fibres, of the glossopharyngeal and vagus nerves, nucleus ambiguus, and the more ventral part of the inferior cerebellar peduncle. When the artery maintained its more normal course and distribution, the nucleus and tractus spinalis of the trigeminal nerve were also invariably supplied. This is in contradiction to the opinion expressed in an early paper (30), but more extensive investigation has proved that the spinal nucleus and tract are only excluded from the posterior inferior cerebellar district when the bulbar branches of this vessel are reduced in number, as a result of its more irregular course.

The variation at the mid-olivary level, and the compensatory increase of the area supplied by the vertebral, have been fully considered with the distribution of the latter vessel.

Above and below the level considered, the posterior inferior cerebellar district became gradually reduced; in the former direction it was replaced by the vertebral and basilar, and in the latter by the vertebral alone. It is important to note that it is the more central part of the formatio reticularis grisea which is persistently injected in both directions, and consequently the spino-thalamic and rubro-spinal tracts and the nucleus ambiguus were supplied most extensively by the posterior inferior cerebellar artery.

The Posterior Spinal Artery.

The small size of this vessel prevented its separate injection. But, owing to its very constant distribution, it was easily possible to appreciate its own district when it was injected along with either the posterior inferior cerebellar or vertebral arteries. It arose from the former in 73 per cent. and the latter in 27 per cent., but appeared to be frequently absent, when it was usually replaced by supernumerary short bulbar branches from the vertebral.

Normally it has been seen to bifurcate into an ascending ramus, which was somewhat inconstant, and a descending ramus, which commenced the tortuous posterior spinal chain.

The descending ramus supplied the funiculi gracilis and cuneatus with their nuclei, and in all cases where the branch was present this distribution was found to be absolutely constant. The ascending ramus was more variable. It usually supplied the caudal and dorsal part of the inferior cerebellar peduncle, but, in addition, occasionally provided branches for the descending root of the vestibular nerve and the trigonum acustici. In the absence of the ascending ramus, small branches from the descending limb of the posterior inferior cerebellar arteries replaced its supply for the inferior cerebellar peduncle and part of the descending root of the vestibular nerve.

From the foregoing accounts it will be seen that the blood supply of the inferior cerebellar peduncle is both complex and subject to very considerable variation. Caudally (at its origin) it was normally supplied ventrally by the posterior inferior cerebellar, and dorsally by the posterior spinal. Usually in the cephalic direction both arteries were replaced gradually by the vertebral and, to a less extent, by the basilar.

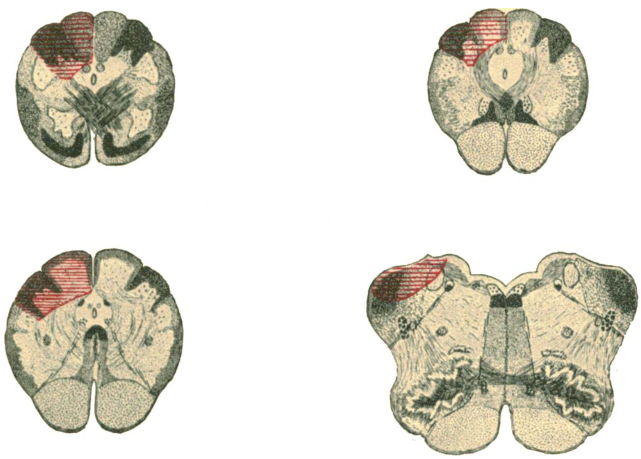

Fig. 19.—Normal distribution of posterior spinal.

Quite frequently the anterior inferior cerebellar, or even the internal auditory, provided for the inferior cerebellar peduncle a few branches, which merely augmented those supplied by the other vessels, and which were not of the same clinical importance as the latter.

The Basilar Artery.

More failures have occurred in the injection of this artery than in any of the others. This was apparently due to the greater difficulty experienced in removing the blood from the numerous small pontine branches, and the considerable and prolonged pressure required to inject satisfactorily the perforating branches of the transverse pontine rami.

The only factor which materially affected its distribution was the variation in the level of its formation by the two vertebral arteries. This has been very fully discussed previously.

Floor of the Fourth Ventricle.

The striæ acusticæ and that part of the ventricular floor situated cephalic to them were usually stained.

The colliculus facialis on each side, and the most medial part of the

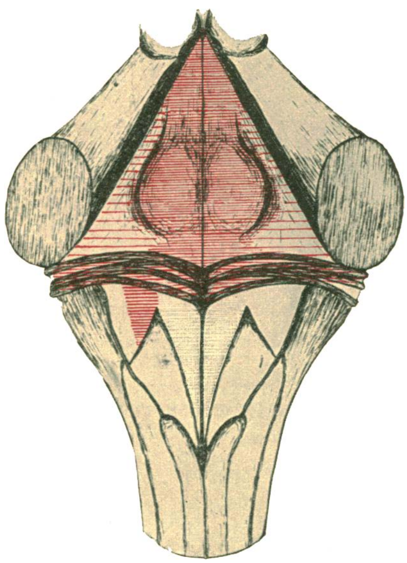

Fig. 20.—Floor of fourth ventricle.

floor, were supplied by the median pontine branches, and the more lateral parts by the perforating branches of the transverse rami.

Frequently the more medial part of the trigonum acustici was injected in addition. When the vertebral arteries fused some distance below the caudal border of the pons, the most cephalic part of the trigonum hypoglossi was also stained.

Upper Limit of the Medulla.

Normally the medial part of the pyramids and the ventral portion of the formatio reticularis alba were injected; but if the level of the formation of the basilar was caudal to the more usual point, this artery was found to have replaced completely the vertebrals. In a few cases where the posterior inferior cerebellar supplied inefficient bulbar branches to the upper part of the postero-lateral sulcus, the basilar was found to replace it at this level, and consequently supply the whole of the formatio reticularis grisea, and the inferior cerebellar peduncle.

Obviously the various pontine branches of the basilar must, practically alone, supply under normal conditions the whole of the pons; consequently it will only be necessary to describe separately the distribution of the

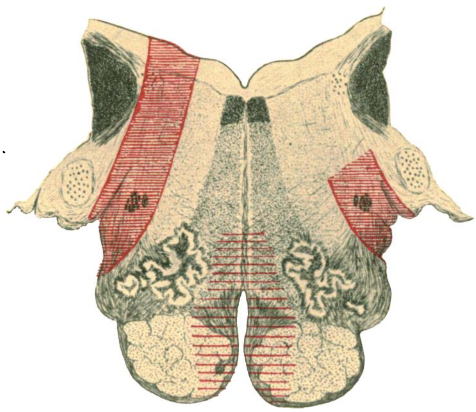

FIG. 21.—Upper limit of medulla.

median and transverse sets, instead of continuing the method adopted for the other arteries.

The *median set* supply the structures immediately lateral to the middle line in the tegmental part, and the greater proportion of the pyramidal bundles and transverse pontine fibres in the basilar part as well as the more medial part of the corpus trapezoidum.

The injected portion of the tegmental part will include the nuclei of the abducent trochlear and oculo-motor nerves, and the fibres of the facial nerve which are in such intimate relation with the former, the medial longitudinal bundle, the medial lemniscus, and the tecto-spinal and thalamo-olivary tracts.

The perforating branches from the *transverse set* supply the more lateral parts of the pons.

Within their field of injection are to be found: the brachium pontis, lateral part of the corpus trapezoidum, superior olive, and the nuclei of the fifth, seventh, and eighth cranial nerves.

In 19 per cent. the origin of the basilar was abnormally low, and consequently it replaced the vertebral above, and supplied the pyramids, formatio reticularis alba, and the most cephalic part of the hypoglossal nucleus, as well as a variable part of the lateral portion of the upper medulla.

In 8 per cent., owing to the cephalic origin of the basilar, it failed to supply the caudal part of the pons, including the facial and abducent nuclei.

Anterior Inferior and Superior Cerebellar Arteries.

No definite distribution to the pons can be given in the case of either of these two vessels.

The former often assists the posterior inferior cerebellar by providing branches for the upper and dorso-lateral part of the bulb, which supply a variable part of the inferior cerebellar peduncle and the descending

FIG. 22.—Pons.

root of the vestibular nerve. It frequently gives a variable number of branches to the lateral and caudal part of the brachium pontis, as it passes on to the inferior surface of the cerebellum.

The superior cerebellar artery has been shown, by Alezais and d'Astros, to supply branches to the region of the inferior colliculus, but it also frequently gives a few branches to the lateral and cephalic part of the brachium pontis, although no precise area of distribution can be defined.

SUMMARY.

1. The *anterior spinal* supplied—

(*a*) *In the cord:*

(1) Anterior and base of posterior cornua.
(2) Grey matter around central canal.
(3) White matter of ventral columns and region of anterior roots.

(*b*) *In the medulla:*

(1) Pyramids and pyramidal decussation.
(2) Medial lemniscus and tecto-spinal tract.
(3) Dorsal longitudinal bundle.
(4) Hypoglossal nucleus (except cephalically).
(5) Nucleus and tractus solitarius (at decussation).
(6) Gowers' tract (at decussation).
(7) Dorsal nucleus of vagus (at calamus region).
(8) Olivo-cerebellar fibres as they cross the middle line.
(9) The internal and ventral external arcuate fibres with nucleus.

2. The *vertebral* supplied—

(1) Few pyramidal fibres at formation of lateral cerebro-spinal tract.
(2) Pyramids at the lower border of pons, and a variable part of the lateral part below.
(3) The whole of the ventral part, and the cephalic portion of the dorsal part, of the inferior olive.
(4) The dorsal accessory olive.
(5) Tegmento-olivary tract and olivo-cerebellar fibres in formatio reticularis.
(6) Generally the dorsal vago-glossopharyngeal nucleus above the calamus region.
(7) Most cephalic part of hypoglossal nucleus.
(8) Nucleus and tractus solitarius (at calamus).
(9) Nucleus and tractus spinalis nervi trigemini (at decussation).

When it replaced the posterior inferior cerebellar it also supplied:—the spino-thalamic, rubro-spinal, and anterior and posterior spino-cerebellar tracts, nucleus ambiguus, descending root of the vestibular nerve, and nucleus and tractus spinalis of the trigeminal nerve, as well as part of the inferior cerebellar peduncle. In 8 per cent., owing to the high level of fusion to form the basilar, the vertebral supplied the abducent and facial nuclei as well as the other more medial structures in the lower part of the pons.

3. The *posterior inferior cerebellar* supplied—
   (1) Spino-thalamic tract.
   (2) Rubro-spinal tract.
   (3) Olivo-cerebellar fibres as they passed to inferior cerebellar peduncle.
   (4) Dorsal vago-glossopharyngeal nucleus or the emerging fibres of the vagus and glossopharyngeal nerves.
   (5) Nucleus ambiguus.
   (6) Nucleus and tractus spinalis of trigeminal nerve.
   (7) Ventral part of inferior cerebellar peduncle.

4. The *posterior spinal* supplied—
   (1) Funiculi and nuclei gracilis and cuneatus.
   (2) Caudal and more dorsal part of the inferior cerebellar peduncle.
   (3) Occasionally part of the descending root of the vestibular nerve.

5. The *basilar* supplied—

   (*a*) *Medial set of pontine branches:*
   (1) Abducent nucleus and trochlear nucleus.
   (2) Oculo-motor nucleus (caudal part).
   (3) Medial longitudinal bundle.
   (4) Medial lemniscus.
   (5) Tecto-spinal tract.
   (6) Thalamo-olivary tract.
   (7) Transverse pontine fibres.
   (8) Medial part of corpus trapezoidum.

   (*b*) *Transverse set of pontine branches:*
   (1) Brachium pontis.
   (2) Lateral part of corpus trapezoidum.
   (3) Superior olive.
   (4) Facial nucleus.
   (5) Remaining nuclei of eighth nerve.
   (6) Remaining nuclei of fifth nerve (including motor nucleus).

When the origin of the basilar was abnormally low (19 per cent.) it supplied the pyramids, medial lemniscus, tecto-spinal tract, dorsal longitudinal bundle, and most medial part of the hypoglossal nucleus, together with a variable part of the lateral portion of the upper medulla.

6. The *anterior inferior cerebellar* supplied a variable part of the most caudal portion of the brachium pontis and upper and dorso-lateral limits of the medulla.

7. The *superior cerebellar* supplied a variable part of the most cephalic portion of the brachium pontis.