Neurosurg. Rev.
8 (1985) 93–124

Hypophyseal region – anatomy of the operative approaches

Johannes Lang

Institute of Anatomy of the University of Wuerzburg, (Head: Prof. Dr. J. Lang), Wuerzburg, F. R. Germany

Summary

Landmarks and measurements for the transnasal approach (apertura piriformis, distance to the apertura sinus sphenoidalis) in children and adults are given. Included is the anatomy of the nasal septum, its vessels and nerves. The ostium of the sphenoid sinus, its development, types and dimensions are described. Also shown are the hypophyseal capsule, the hypophyseal vessels and the hypophyseal fossa with its variations and the sella turcica region with its adjacent dural structures (petroclinoid fold, diaphragma sellae, aperture for the internal carotid artery and pituitary cistern). For the intracranial approaches the arterial circle and its branches are important for neurosurgeons. The location, number, width and course of these branches are described. Distances and the most important vessels, which are seen by frontal, frontolateral and pterional approaches, are described.

Keywords: Anatomy of transnasal approach, frontal and frontolateral approaches, hypophyseal region, pterional approach.

The midpoint of the hypophyseal fossa (and the pituitary) is situated in the middle part of the skull base. The distance between the rounded transition area of the bottom of the anterior cranial fossa into the calvaria and the hypophyseal fossa, is about 60 mm, from the sidewall of the middle cranial fossa 65 mm, from the posterior margin of the foramen magnum 65.54 (54.5–77) mm and from the subspinal point (transnasal approach) 70.8 mm (mean). Thus from all sides it is a relatively long way to the hypophysis. Inside the skull in this area important arteries for different parts of the brain and especially for the interbrain are situated. In the following pages the anatomical relations of these nerves, vessels, brain parts and dural layers as seen in the different approaches, will be described.

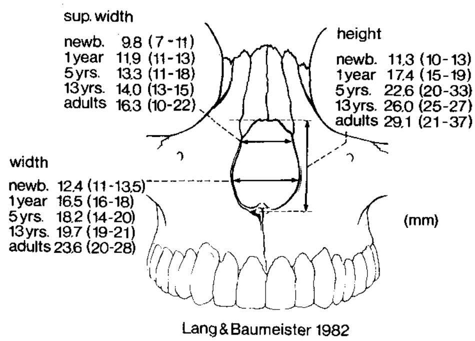

Fig. 1. Piriform aperture, measurements of the width (at two levels) and height during the postnatal period [37]. Measurements in mm (extremes).

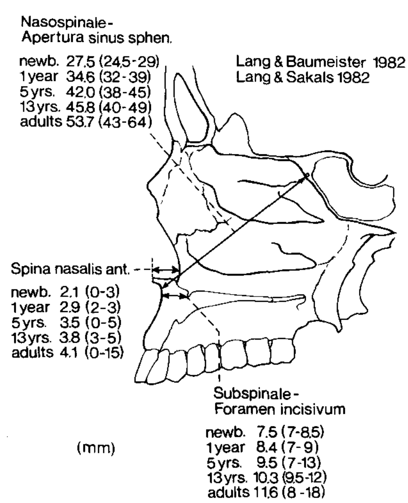

Fig. 2. Distances between the subspinal point and sphenoidal aperture, postnatal lengthening of the anterior nasal spine and distance between the subspinal point and nasal opening of foramen incisivum [37], [41]. Measurements between newborn and adults in mm (extremes).

Transnasal approach to the pituitary fossa

1 Measurements

The height and the width of the nasal aperture and its postnatal growth are shown in Fig. 1 (after Lang and Baumeister [37]), and the distance from the nasospinal point to the aperture of the sphenoid sinus in Fig. 2, in which are also given measurements of the length of the anterior nasal spine (Lang and Baumeister [37], Lang and Sakals [41]) and the distance from the subspinal point to the nasal opening of the canalis incisivus. It should be noted, that the nasospinal point (point spinal, point sous-nasal) is the deepest point of the lower border of the nasal aperture which is projected in the median-sagittal plane. Long anterior nasal spines or bent upward spines may be removed during operation. The approach to the aperture of the sphenoidal sinus is subperichondral and subperiostal along the nasal septum.

Fig. 3. Nasal septum, coronal section, viewed from anteriorly. 1. Angulus oculi medialis, lacrimal sac and nasolabial sulcus. 2. Apertura piriformis and accessory alar cartilage. 3. M. orbicularis oris and anterior nasal spine. 4. Septal cartilage, lower border and paraseptal cartilage. 5. Lamina perpendicularis, middle nasal concha and septal cartilage (tuber), mm-paper. 6. Mucous membrane, directly anterior to inferior nasal concha.

2 Septum nasi

The septum consists of the cartilaginous portion and its posterior (sphenoidal) process. Except for the posterior process it has a trapezoid shape. According to Masing [48] the angle between the dorsum nasi part and the cartilage on the bottom of the nasal cavity measures 25–30°. The lower anterior border of the septal cartilage is convex from the anterior nasal spine to the anterior septal angle. The width of the so-called columella depends on the development and orientation of the median crus of the alar cartilage. According to Cottle et al. [12] in adults the septal cartilage in the centre averages 3–4 mm in thickness and at its lower border 2–4 mm. On each side it forms a footplate 4–8 mm thick. Zuckerkandl named these lateral extensions processus laterales ventrales [70]. Cottle et al. [12] demonstrated subluxated and fractured lower cartilage areas and wings of the premaxilla and also some variations in cartilage and bone in deformities of the anterior portion of the septum. Metzenbaum [49] showed in infants and young children the self-inflicted traumas to the tip of the nose, occurring up to about the tenth year. Usually these displacements are limited to the lower end of the cartilaginous nasal septum and to the cartilage forming the nasal tip. He gives some methods for manual and instrumental reductions of the septal dislocation. It should be noted, that in our material (Seifert [58]) lateral to the lower border of the septal cartilage there are placed as a rule cartilagines vomeronasales (paraseptales) 2–5 mm long, which on rare occasions are 12–15 mm long (Fig. 3). Sometimes these cartilages consist of several pieces. Between these cartilages is placed the nasal septum. From the anterior nasal spine and a little bit lateral to it, run collagen fibres in the perichondrium of the septum and also with fibres from the perichondrium which lateral to the cartilagines vomeronasales run downwards and cross to the opposite side. In transverse sections this cartilage and the perichondrium looks like a cup in which the lower border of the septum is inserted. The septum is a little bit mobile in this area.

Above there is in the area of the middle concha a thick zone of the septal cartilage, the tuber septi. Below the nasal bones the septal cartilage has a sideward prolongation, the cartilago lateralis nasi. The processus posterior (sphenoidalis) of the septal cartilage is situated between the vomer and the lamina perpendicularis and dorsally it eventually reaches the sphenoidal sinus. It is developed in our material in about 50%. Often this cartilage part has an overgrowth laterally from the vomer (Fig. 4).

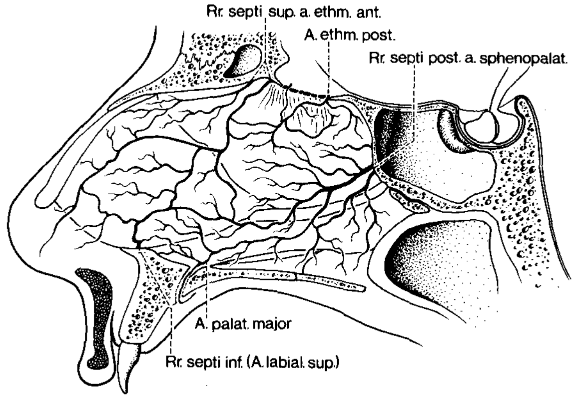

Fig. 4. Arteries of the nasal septum (and mucous membrane and their different origins). The borders of lamina perpendicularis, septal cartilage, vomer and crista nasalis are also visible.

The second part of the nasal septum is the lamina perpendicularis of the ethmoid bone. According to Zuckerkandl [69] its anterior border reaches the midzone of the osseous dorsum nasi in 49% and in 38% the border between the middle and upper third of the osseous dorsum, in 10% the border between the lower and middle third. In 3% there is no connection between these bony parts, and the lamina perpendicularis is only connected with the superior nasal spine.

The third part of the septal skeleton is the vomer, which is connected by its ala vomeris with the rostrum and body of the sphenoid bone. The posterior upper border of the vomer is always found in the median plane. Anteriorly areas of deviation exist or overgrowths of the posterior process which may also cause a narrowing of one of the nasal cavities. The lower border of the vomer is imbedded in the crista nasalis of the palatine process of the maxilla and lamina horizontalis of the palatine bone. It should be noted, that in our material (older people) sometimes the vomer or the lamina perpendicularis is very thin and easy to break.

2.1 Perichondrium and periosteum (Fig. 5)

To remove the periosteal layers from the lamina perpendicularis and the vomer is easier than removing the perichondrium from the nasal cartilage. Seltzer [59] mentioned, that the outer layer of the septal cartilage should not be termed perichondrium because this layer is not a capsule of the cartilage, it is a part of the cartilage itself and should be called epichondrium.

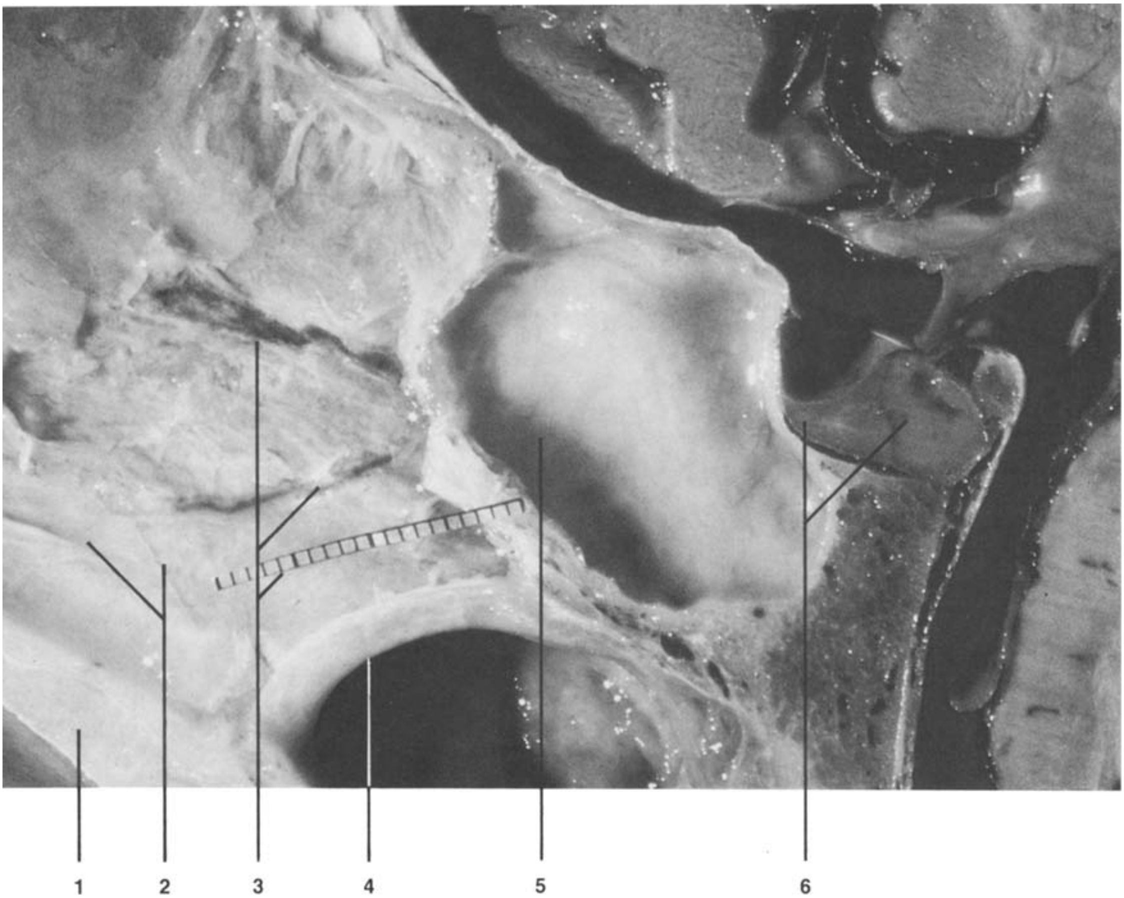

Fig. 5. Sphenopalatine arteries and septum of sphenoidal sinus.
1. Os palatinum. 2. Vomer, remnant. 3. Rr. septi post. from sphenopalatine artery and mm-paper. 4. Choana, medial wall. 5. Septum of sphenoidal sinus. 6. Anterior and posterior lobe of hypophysis.

2.2 Arteries and veins

After removal of the perichondral-periostal layer of the nasal septum its larger vessels and nerves are visible. The lower and anterior part of the septum is supplied by the ramus septalis inferior anterior of the a. labialis superior, a twig of the facial artery. At 11.62 (8–18)mm behind the nasospinal point a twig of the greater palatine artery pierces the bottom of the nasal cavity through the canalis incisivus and anastomoses with the sphenopalatine artery, the end-twig of the maxillary artery. The sphenopalatine artery twigs are the posterior lateral nasal arteries and the septal branches. In our preparations these are duplicated in most cases (see Figs. 4, 5 and 8). The upper area of the nasal septum is supplied by the anterior ethmoidal artery and the posterior ethmoidal artery (twigs of the ophthalmic artery and sometimes the posterior one of the middle meningeal artery (Lang and Schäfer [42], see Fig. 4). The veins of the nasal septum usually accompany the arteries.

2.3 Lymph vessels

The lymph vessels of the septum go mainly dorsally to the side wall of the pharynx in the area of the pharyngeal opening of the Eustachian tube and in the soft palate laterally. In the side wall of the pharynx there is a lower route with two to four lymph vessels (together with the lymphatics of the palatine tonsils) along the arches of the palate dorsally, from the submandibular gland and the digastric muscle to the deep cervical lymph nodes. In most cases the first lymph node is situated between the facial vein and the internal jugular vein.

Two to four lymph vessels run laterally from the opening of the Eustachian tube on the side wall of the pharynx dorsally to lateral pharyngeal lymph nodes and are connected with lymphatic vessels of the dorsal pharyngeal wall. Its lymph nodes are called the lateral deep cervical lymph nodes.

2.4 Nerves

The nerves in the anterior upper parts of the nasal septum are twigs of the anterior ethmoidal nerves, which supplies the anterior part of the septum; also in the anterior part of it is found the nervus terminalis, which contains sensory and autonomic fibres. Its ganglion cells are derived from the olfactory placode or from the anterior brain vesicle.

A large area of the septum is supplied by the nasopalatine nerve (of Scarpae) from the maxillary nerve. This nerve runs in a groove on the vomer and its finer twigs supply the mucous membrane of the nasal septum.

Sympathetic and parasympathetic fibres of the nasal septum run in twigs from the sphenopalatine ganglion. The parasympathetic part is formed by the greater petrosal nerve which pierces the fibrobasal cartilage and forms one part of the nerve of the pterygoid canal, which joins the sphenopalatine ganglion. This nerve carries vasodilator and secretory fibres for the glands of the nasal septum. The sympathetic fibres of the nasal cavity come from the upper thoracic segments and lower cervical segments through the communicating and intergangliar rami; these fibres go to the upper cervical sympathetic ganglion. Then they form synapses and run in the deep petrosal nerve on the internal carotid artery, which is connected with the greater superficial petrosal nerve forming the nerve of the pterygoid canal. These fibres have no synapses with the ganglion cells of the sphenopalatine ganglion and reach the nasal septum through the nasopalatine nerve. Most researchers think that the sympathetic fibres of the septum have a vasoconstrictor function, but other think, that they also have a vasodilator effect. The olfactory nerves are situated in the upper medial and lateral parts of the nasal cavity. The area olfactoria encircles 4–5 cm^2. On one side of the septum 133,99 mm^2 are placed. It should be noted, that this area becomes smaller each year and in 55% of adults more than ⅗ of the olfactory nerves have regressed and in 13% totally. Smith [62] found normal numbers of olfactory nerve fibres (10,000 or more) in only 29 of 163 adults.

The sensible nerve fibres of the nasal septum are mainly myelinated and belong to the trigeminal ganglion. Some (mainly unmyelinated) are fibres from the sphenopalatine ganglion and are possible sympathetic.

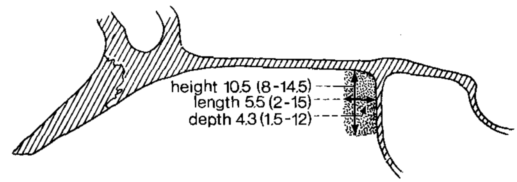

Fig. 6. Recessus spheno-ethmoidalis, developed in our material in 48.3%, measurements in mm (extremes).

3 Ostium of the sphenoidal sinus

Lateral to the upper and posterior parts of the septum and behind the superior nasal concha the spheno-ethmoidal recess is located in 48.3% of cases (see Fig. 6 for measurements). In this small recess or slightly more medially when it is absent is located the aperture of the sphenoidal sinus. In our material (Lang, Sakals [41]) we found round apertures of smaller diameter than 3.5 mm in 70%. Pinhead size apertures were found in 15% and sometimes the aperture is very small. In 28% it is oval in shape with the larger diameter mostly in the vertical plane, but sometimes oblique or transversely orientated. This aperture is the starting point for opening the sphenoidal sinus in the approach to the hypophysis.

4 Sphenoidal sinus

4.1 Development of the sphenoid sinus

The sphenoid sinus was first described by Fallopius 1561 [18] (Teed, [64]). The development of the sphenoid sinus begins in the third month of fetal life in the form of a mucosal bud arising from the upper posterior region of the nasal cavity. This well vascularized mucosal bud penetrates into the presphenoidal portion of the sphenoid bone, which is still cartilaginous. Cope [11] states that until puberty its development does not extend backwards beyond this boundary. During puberty the sphenoid sinus first develops dorsally and dorsolaterally, though incomplete septa or cristae often persist at the boundary zone, the former intrasphenoid synchondrosis. The anterior wall of the sphenoid sinus is bounded by the sphenoid concha (conchae sphenoidales, ossicula Bertini), which begins to develop in the fifth month of fetal life. It was not Jos. Bertin who first described these ossicles, but Prof. V. C. Schneider from Wittenberg (Hyrtl [26]). In addition to the ossicles, there are other structures which participate in the formation of these conchae, namely foci of membrane bone formation in the lower wall of the developing sphenoid sinus (around the tenth month of fetal life, Fig. 7). At the time of birth each concha

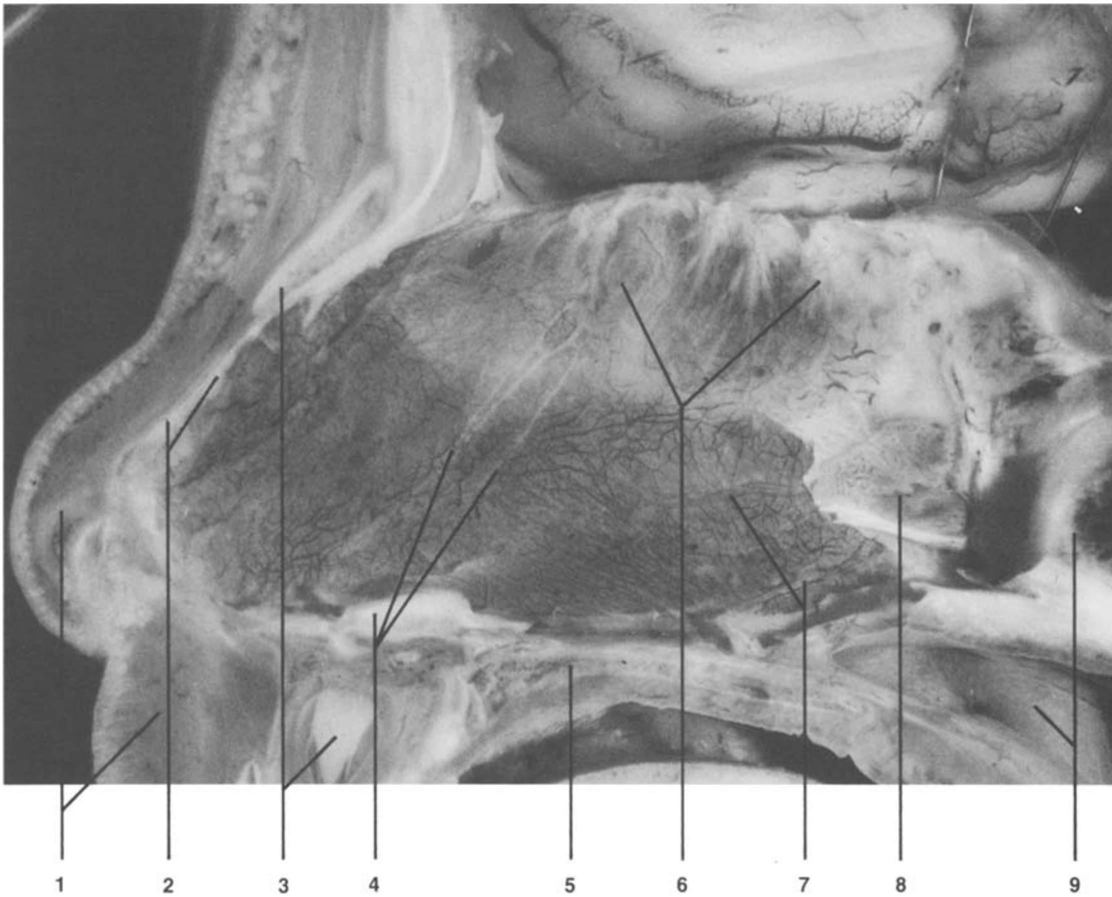

Fig. 7. Nasal septum and sphenoidal concha, 40 cm long fetus.
1. Alar cartilage and m. orbicularis oris. 2. Remnant of removed nasal septum. 3. Nasal bone and dens incisivus. 4. Vomeronasal cartilage and vomeronasal nerve. 5. Palatine process of the maxilla. 6. Olfactory fibres. 7. Rr. septi post. a. sphenopalat. 8. Sphenoidal concha. 9. Osseous nucleus in body of sphenoid and torus tubalis.

consists of a triangular bone plate, positioned roughly sagittally, adjacent to the primary sphenoid rostrum on each side. The inferior margins of the conchae reach the upper margin of the vomer. During the first year of postnatal life the conchae continue to grow, increasing chiefly in height and to a lesser extent in breadth, and covering the developing sphenoid sinus except in the vicinity of the ostium. Between four and nine years of age the sphenoid sinus increases in width, and the concha region covers its medial and anterior portion. During this time, the ostium migrates laterally. The lateral and upper margin of the bony ostium of the sphenoid sinus is derived from the ethmoid bone. According to Toldt [65] the sphenoidal conchae fuse with the body of the sphenoid between 9 and 12 years of age. **If the conchae remain small, the hindmost ethmoidal cell grows further dorsally and forms the medial wall of the optic canal or even comes to underlie the floor of the pituitary fossa.** This condition we found in about 10%.

4.2 Rostrum of the sphenoid bone

The sphenoidal rostrum is the prominent median ridge, wedge-shaped or more or less rounded, projecting from the anterior and inferior surface of the body of the sphenoid. At the boundary between the anterior and posterior segments of the body there is a funnel-shaped cleft, sometimes extending transversely. It penetrates the body of the sphenoid and may end within it or continue as a small canal as far as the pituitary fossa. Toldt [65] states that this portion is filled with hyaline cartilage, the remnants of the intrasphenoidal synchondrosis. Between one and three years of age the rostrum enlarges, usually becoming narrower and sharper, though sometimes broader and more obtuse.

4.3 Morphological types of the sphenoid sinus

Since the work of Hamberger et al. [22] the sphenoid sinus has generally been classified into conchal, presellar and sellar types. In the conchal type (3%) the surgeon encounters thick bone in the floor of the pituitary fossa during the transnasal approach. In the presellar type (11%) the anterior wall of the sella is pneumatized, and in the sellar type (86%) the entire floor of the sella is occupied by the sphenoid sinus.

Hammer and Rådberg [23] state that the sphenoid sinus is of conchal type in 2.5% and its posterior boundary is located in the transition zone between the sphenoidal concha and the body of the sphenoid bone.

Presellar types made up 11% of their material. Sphenoid sinuses of this type extend more or less dorsally into the body of the sphenoid bone as far as the junction between the presphenoid and postsphenoid components.

Hammer and Rådberg found sellar types in 59% [23]. In this type the anterior wall of the sella bulges into the sphenoid sinus. Mixed forms account for 27%; in such cases the sinus is of presellar type on one side and sellar type on the other.

4.4 Dimensions of the sphenoid sinus (Tab. I)

Tab. I. Sphenoid sinus, dimensions (Keller 1980) [30a]

	$\bar{x}$	s	$s_{\bar{x}}$	max	min
a) *Width (in mm)*					
1. In upper part					
Right	13.1	5.0	1.1	20.0	5.0
Left	13.8	3.0	0.7	20.5	9.0
Total	13.45	4.0	0.9	20.5	5.0
2. In middle zone					
Right	16.7	5.5	1.2	24.0	8.5
Left	17.2	3.7	0.9	24.0	13.0
Total	16.95	4.6	1.05	24.0	8.5
3. In lower part					
Right	18.9	6.5	1.4	26.0	6.5
Left	18.4	4.3	1.0	26.5	12.5
Total	18.65	5.4	1.2	26.5	6.5
b) *Length (in mm)*					
1. In upper part	19.4	7.0	1.1	32.0	6.5
2. In middle zone	24.8	7.5	1.2	36.0	9.0
3. In lower part	18.5	5.6	0.9	31.0	7.0

4.5 Septum of the sphenoid sinus (see Figs. 5 and 8)

As the mucosal buds arising from the nasal cavity grow backwards to the left and right of the median plane they create the septum between the two sphenoid sinuses. It is in fact formed by the central segment of the sphenoid bone. It has long been known that left-right differences are common and that the septum may consequently be oblique or even transverse, as mentioned by Morgagni (1682–1771). In 25% the septum has developed in a vertical sagittal plane (Hammer and Rådberg [23]). Sometimes, as emphasized by Blumenbach [6], the dividing wall may be completely absent or the sinuses may be lacking. In the latter case the space is filled with bone resembling the diploe. Postnatal enlargement of the sphenoid sinus takes place by bone resorption on the inner surface and bone apposition on the outer surface. Van Alyea [2] always found small septa (5–7 mm) on the dorsal wall of the sinus in his material (100 half heads). Other small septa were found in 41%. Such additional septa often develop in further zones of synchondroses. A transverse septum is sometimes found in the area of the earlier synchondroses between the pre- and postsphenoid (about 6% according to Van Alyea [2]).

Transverse septa: The transverse septum = septum trans-sphenoidale described by Cope [11] was frequently demonstrable in our material. It is usually situated in the roof of the sinus, immediately below the tuberculum sellae, which is also known as the olivary eminence. Transverse septa on the floor of the sphenoid sinus are less frequently met with.

4.6 Walls of the sphenoid sinus

Upper wall: The upper wall of the sphenoid sinus varies in length and width. When the sinus is large it abuts rostrally on the planum sphenoidale, in the lesser wing of the sphenoid, around the optic canal and the floor of the sella. Occasionally it extends into the dorsum sellae and the clivus. The upper wall may be very thin, especially in the vicinity of the optic canals.

Lateral wall: The lateral wall of the sphenoid sinus is formed by the body of the sphenoid [36].

Lower wall: The lower wall of the sphenoid sinus may form part of the upper wall of the nasal cavity or may even be situated behind the latter, forming part of the roof of the nasopharynx. It is usually the thickest wall of the sphenoid sinus, apart from the posterior wall.

Posterior wall: As a rule, the posterior wall is vertical and is slightly hollowed out from the front. Depending on the development of the sphenoid sinus, it may be situated in the presphenoidal or postsphenoidal portions of the sphenoid bone, or even occasionally in the clivus portion of the occipital bone.

Anterior wall: The anterior wall of the sphenoid sinus is also more or less vertical and its upper part is extremely thin. Situated here is the bony ostium of the sphenoid sinus, an orifice which is narrowed by reduplication of the mucosa.

The distance between the ostium of sphenoid sinus and sella floor is 17.1 (12–23) mm according to measurements of Fujii et al. [21] and 14,3±2,28 (9–21) mm in our material.

Projections within the sphenoid sinus are caused by the internal carotid artery and various nerves.

4.7 Internal carotid artery in the cavernous sinus – apposition to the lateral wall of the sphenoid sinus (Fig. 8)

The internal carotid artery emerges from the carotid canal in the petrous portion of the temporal bone and runs in the postero-lateral part of the cavernous sinus, leaving it anteriorly at a point medial to the anterior clinoid process. When the sphenoid sinus is well developed its lateral wall may be indented by the internal carotid artery, and the bone may occasionally be absorbed at this point. The internal carotid artery produces bulges on the lateral wall of the sphenoid sinus. They vary in length, prominence and orientation depending on the length and breadth of the sphenoid sinus and on the course of the internal carotid artery within the cavernous sinus.

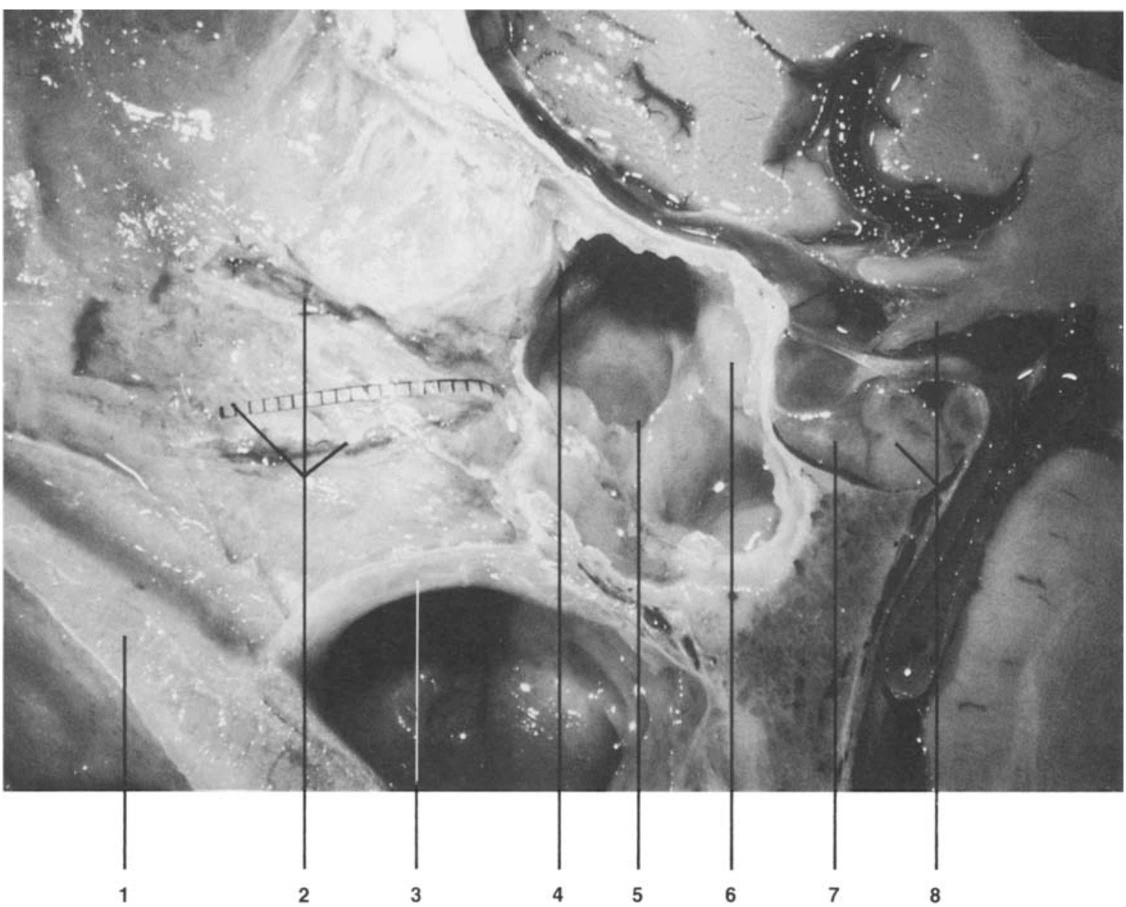

Fig. 8. Septal branches of sphenopalatine artery and sphenoidal sinus.
1. Hard palate. 2. Septal branches of sphenopalatine artery and mm-paper. 3. Medial wall of choana. 4. Aperture of sphenoidal sinus. 5. Accessory septum of sphenoidal sinus. 6. Prominence of internal carotid artery. 7. Anterior lobe of hypophysis. 8. Infundibulum and posterior lobe of hypophysis.

As a rule, the internal carotid artery makes a posterior bend in the dorsal part of the cavernous sinus. Next comes the pars cavernosa sagittalis, which according to Platzer [53] runs forwards and medially at an angle of 25–35° (in our material the angles were smaller). Then follows the anterior curve, which extends under the anterior clinoid process. Here the internal carotid artery bends in a curve convex anteriorly, running at first somewhat medially and then backwards and upwards. Our results are given in Fig. 9.

Platzer [53] found that in 16% the artery ran in an almost straight line from the transition zone of the carotid canal as far as the anterior convex curve. The corresponding figure in our material was 15%. There is an intermediate form in which the carotid is slightly curved; we found this in 50%. S-shaped curves may occur when the artery first ascends almost as far as the posterior clinoid process, then bends sharply downwards and leaves the cavernous sinus forwards and medially in a broad curve convex basally and rostrally (30% – Strobel [63], 36% – our recently collected material). A straight course is most commonly seen in children; in adults it occurs only in 3.2% (Lazorthes [45]). The tortuosities become more marked as age advances (Krayenbühl and Yasargil [32]).

According to Van Alyea [2] the sphenoid sinus is deeply indented by the carotid artery in 53%, and slightly indented in 12%. In 14% the entire course of the internal carotid artery along the lateral wall of the sphenoid sinus is conspicuously marked, while in 3% it is faintly marked. Seftel et al. [57] found projections of this kind in 65%, and noted that they were conspicuous in 53% of these. Renn and Rhoton [55] demonstrated carotid prominences in 71%. Fujii et al. [21] state that presellar indentations are present in 98% (in sinuses of presellar type). They noted infrasellar indentations in 80% and retrosellar indentations in 78% (in sphenoid sinuses of sellar type). According to their findings the mean length of an internal carotid artery prominence is 12.9 (8.0–18.0)mm. Figs. 10 and 11 demonstrate the different distances between the internal carotid arteries.

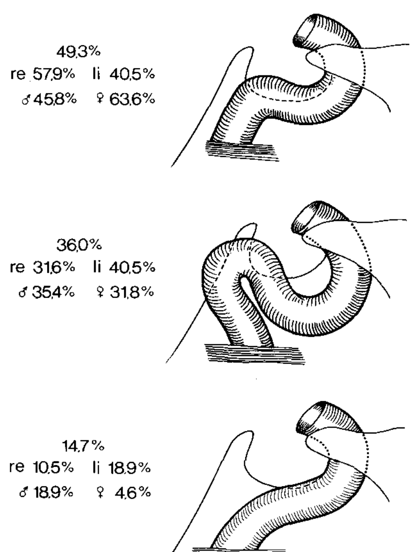

Fig. 9. Course of the internal carotid artery in the cavernous sinus on our material (mainly old people).

4.8 Recesses of the sphenoid sinus

We described an anterior, lateral, posterior, supraoptic recess and recess of the dorsum sellae. For the details see Lang [36].

5 Hypophysis

5.1 Location of the pituitary in the sella turcica

At operation the anterior lobe of the pituitary looks yellowish and feels relatively firm, while the posterior lobe looks gelatinous and gray. Hardy [24] states that the anterior lobe is surrounded by a potential cleft in which venous capillaries run between the pituitary capsule and the periosteum of the sella turcica. The posterior lobe, on the other hand, is usually firmly attached to the posterior wall of the pituitary fossa. In our material we found much the same relationships. Hardy [24] states that numerous colloid follicles and venous capillaries can be seen within the intermediate lobe, and that surgically they delineate the boundary between the anterior and

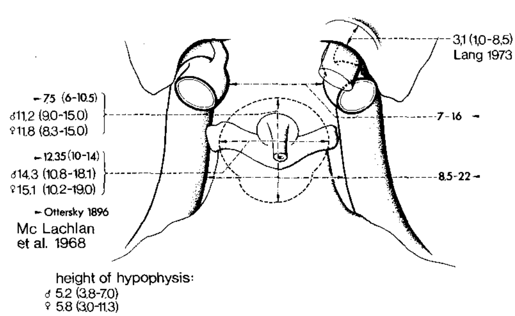

Fig. 10. Distances between the posterior and anterior part of the intracavernous course of ICA. Included are measurements of the length, width and height of the hypophysis and the dural roof of the optic canal. All measurements in mm (extremes).

posterior lobes. When the sphenoid sinus is of sellar type, the dissector working outwards from the sphenoid sinus will find that the periosteal layer of the dura comes into view after a thin layer of bone has been removed. The inferior intercavernous sinuses are incorporated into this periosteal layer. Next in sequence comes a potential cleft and then the pituitary capsule, which is attached to the pituitary (Fig. 12).

5.2 Development of the pituitary capsule

According to Arey [4] the developing pituitary is surrounded by a layer of mesoderm. Engels [17], Di Chiro and Nelson [13] and Ferner [19] believed that

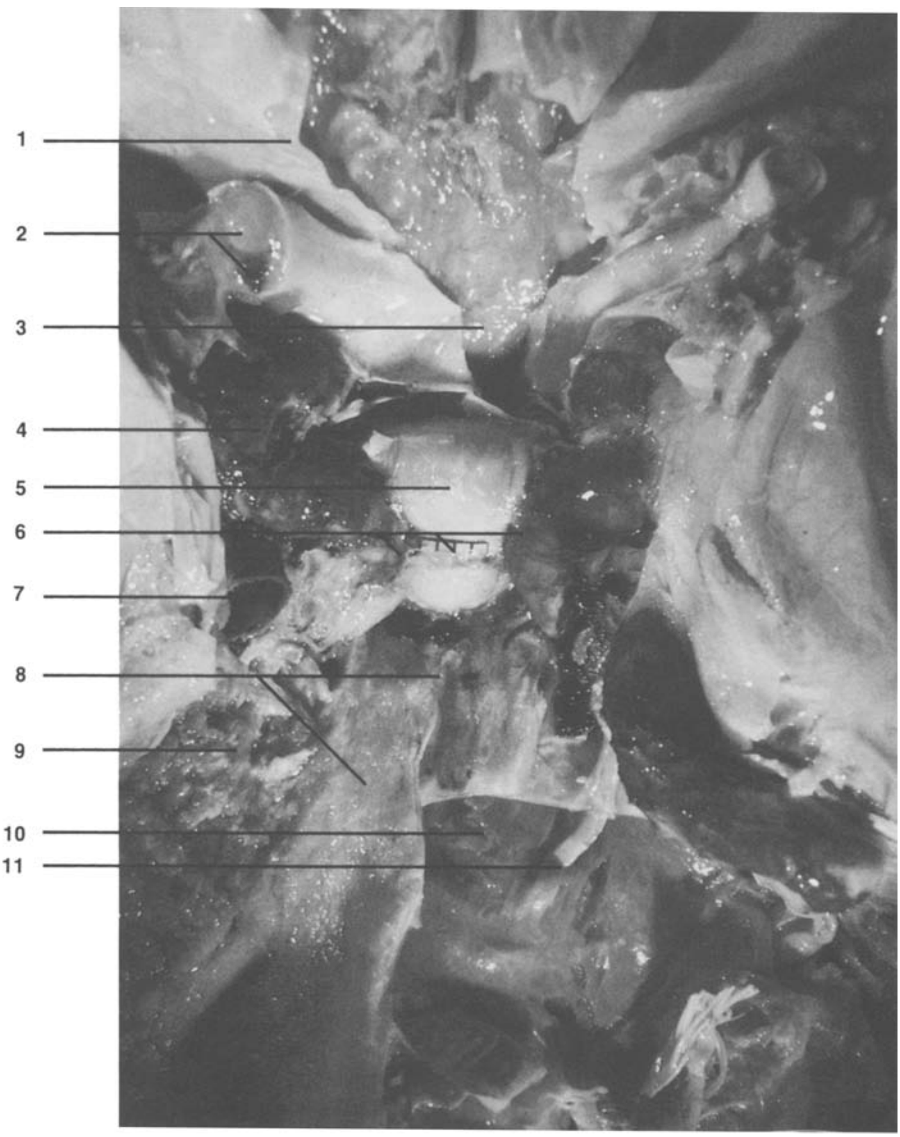

Fig. 11. Very short distance between the two internal carotid arteries in the cavernous sinus (cisterns injected yellowish, arteries red, dura mater partly opened), viewed from below.
1. Dura mater of planum sphenoid., displaced sidewards. 2. Optic nerve and ophthalmic artery at the orbital opening of the canal. 3. Subarachnoid space. 4. Internal carotid artery. 5. Anterior lobe of hypophysis. 6. Showing short distance between the two internal carotid arteries and mm-paper. 7. ICA, cut. 8. Dura of clivus. 9. Petrous bone. 10. Subarachnoid space of posterior fossa. 11. Abducent nerve.

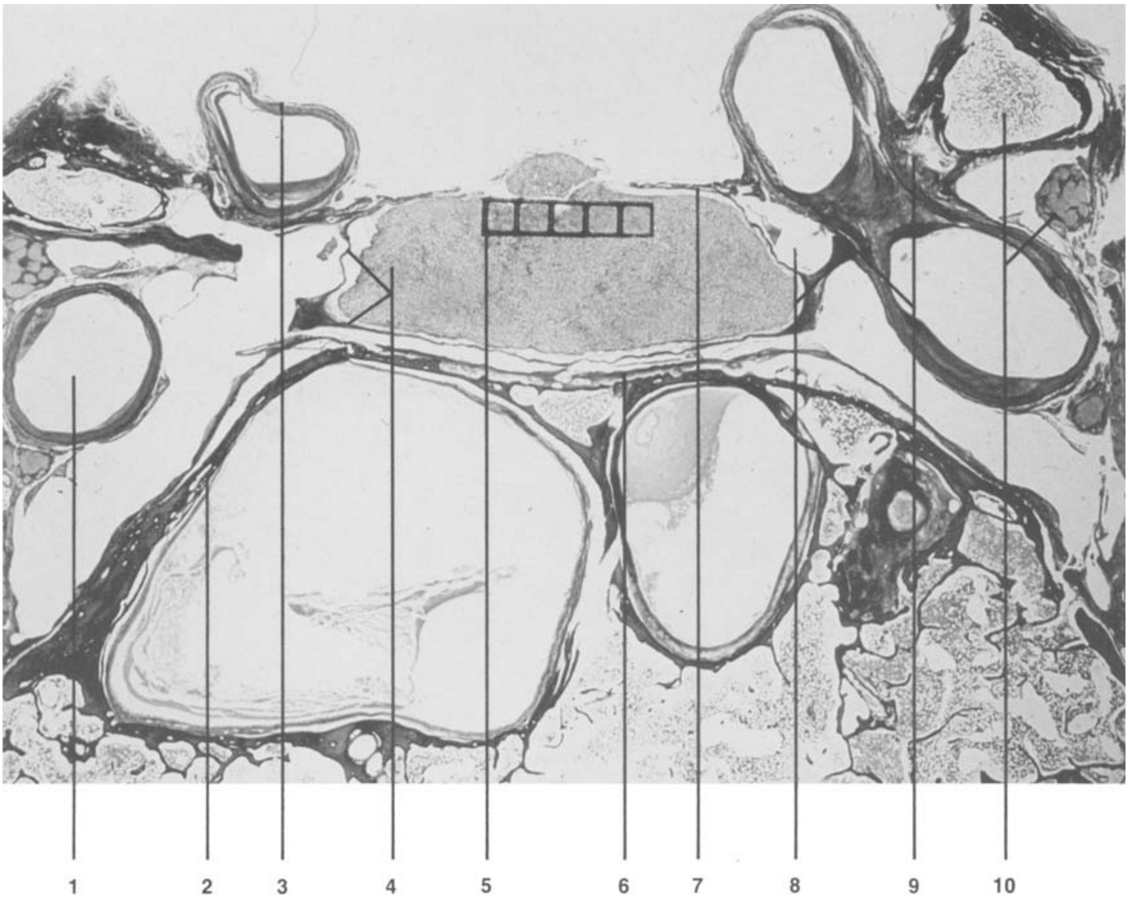

Fig. 12. Cavernous sinus, exit-zone of internal carotid artery, 50-year-old man (Goldner-Elastica).
1. Intracavernous course of ICA. 2. Sphenoidal sinus, sidewall. 3. Subarachnoid part of ICA. 4. Capsule of hypophysis and anterior lobe with artificial shrinking cleft.
5. mm-paper. 6. Endocranium of pituitary fossa. 7. Diaphragma sellae. 8. Blood space and trabeculae of cavernous sinus. 9. Exit zone of ICA. 10. Ant. clinoid process and n. III.

in some instances the entire hypophysis may be surrounded by arachnoid. Ciric [10] used an operating microscope to study the pituitary capsule in 150 patients undergoing trans-sphenoidal hypophysectomy. In his opinion the anterior lobe, the posterior lobe and the pituitary stalk are surrounded by a common layer of connective tissue of simple structure; he terms it the hypophyseal capsule (Fig. 13). He points out that this capsule is distinct from the arachnoid and proposes the following hypothesis: during the 4th week of gestation the hypophyseal sac (Rathke's pouch) is separated from the stomatodaeum by a mesodermal layer. From the distal end of the stomatodaeal ectoderm of Rathke's pouch an evagination develops and extends into the overlying mesoderm and the cerebral vesicle. The subsequent differentiation of this pouch of stomatodaeal epithelium leads to the formation of Rathke's pouch, the proximal segment of which rapidly develops into the pars distalis of the anterior pituitary lobe.

The distal segment does not expand and persists as the pars intermedia and pars tuberalis. Behind Rathke's pouch the primitive neurohypophysis invaginates into the surrounding mesoderm. The two layers of this neuroectodermal recess subsequently approach one another and form the pituitary stalk and the neurohypophysis. Between the adenohypophysis and neurohypophysis there is, according to this author, an uninterrupted layer of primitive pial tissue. During the development of the facial skeleton the mesoderm grows from rostral to dorsal between

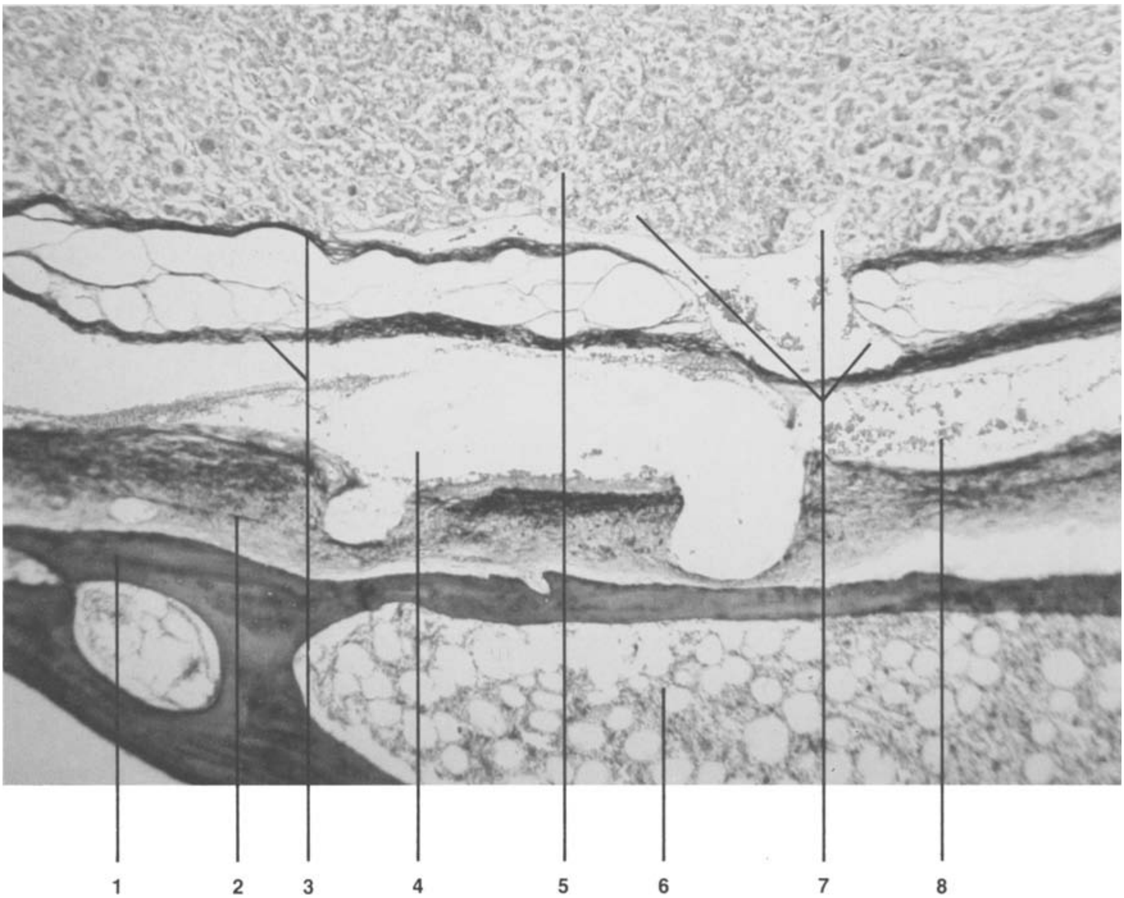

Fig. 13. Lower hypophyseal vein and surrounding structures (Ladewig).
1. Os sphenoidale (fossa hypophys.). 2. Endocranium. 3. Hypophyseal capsule, double layer. 4. Inf. intercavernous sinus. 5. Ant. lobe of hypophysis. 6. Bone marrow. 7. Inf. hypophyseal veins. 8. Red blood cells.

the stomatodaeum and the dorsal part of the cerebral vesicle, at first on the floor of the anterior cranial fossa, and causes an infolding of the primitive pia mater along the anterior face of the pituitary and the pituitary stalk. Subsequently the two layers of this reduplication fuse and form the relatively stout anterior wall of the pituitary capsule. That portion of primitive pia mater between the pars intermedia of the anterior lobe and the neurohypophysis may persist as a rudimentary mesodermal layer. The cleft between the anterior and posterior lobes, which is often noted by surgeons, can be explained, in Ciric's opinion [10], by this embryological fact. The posterior wall of the pituitary capsule also develops from the primitive pia mater. Along the pituitary stalk the pituitary capsule merges into the intracranial layer of pia mater. The arachnoid, dura mater, sphenoid bone and cavernous sinus develop from the surrounding mesoderm.

5.3 Location of the inferior hypophyseal artery and capsular artery

The inferior hypophyseal artery usually gives off small branches which run in the potential cleft between the pituitary capsule and the periosteal layer. Twigs from this vessel may run in a retrograde direction to the pituitary. Others pierce the floor of the sella turcica and contribute to the supply of the sphenoid bone and the mucoperiosteum of the sphenoid sinus (Figs. 14, 15).

5.4 Pituitary adenomas, the empty sella and cysts

According to Domingue et al. [15] pituitary adenomas sometimes occur in association with the "empty sella". The location of the hypophyseal cisterna within the sella seldom gives any guidance to the site of a pituitary tumour. Domingue et al. [15] state that the hypophyseal cistern was first described by Busch [8]. Further studies of the [29] "empty sella" and the hypophyseal cistern were made by Kaufman [8] and Kaufman et al. [30]. Bergland et al. [5] demonstrated a hypophyseal cistern in 20% of 225 autopsies. Domingue et al. [15] found partially empty sellae in 17.3% of patients with amenorrhoea and galactorrhoea and in 10% of patients with acromegaly.

Shanklin [60] found cysts in 13% of his material (100 hypophyses). These were located chiefly in the anterior lobe, but continuous in or near the pars intermedia. The cysts were surrounded by capsules and inside they showed columnar ciliated epithelium presumably derived from Rathke's cleft. Other cysts may be the result of disintegration (necrotic anterior lobe), other cysts are follicular cysts. It should be emphasized, that beside these cysts in our material we found also cysts in the posterior lobe.

6 Osteology of the pituitary region

6.1 Sella turcica

The space occupied by the pituitary gland is known as the sella turcica because it is narrowed from behind and from the front and resembles a Turkish saddle. In front, the anterior clinoid processes project backwards on each side. The middle part of the anterior boundary of the sella turcica is formed by the tuberculum sellae, a structure which varies in shape, while the posterior boundary is formed by the dorsum sellae and its lateral extensions, the posterior clinoid processes. The floor of the sella, to a variable extend pneumatized by the sphenoid sinus, is part of the body of the sphenoid. On either side of the site of the pituitary it slopes downwards and laterally toward the floor of the middle cranial fossa. The clinoid processes are important zones of dural attachment.

6.2 Tuberculum sellae

The anterior wall of the pituitary fossa is usually separated from the prechiasmal sulcus by a rounded transverse ridge which extends from side to side between the inferior borders of the two optic canals. This transverse ridge is known as the tuberculum sellae and can be demonstrated in a radiograph. Less

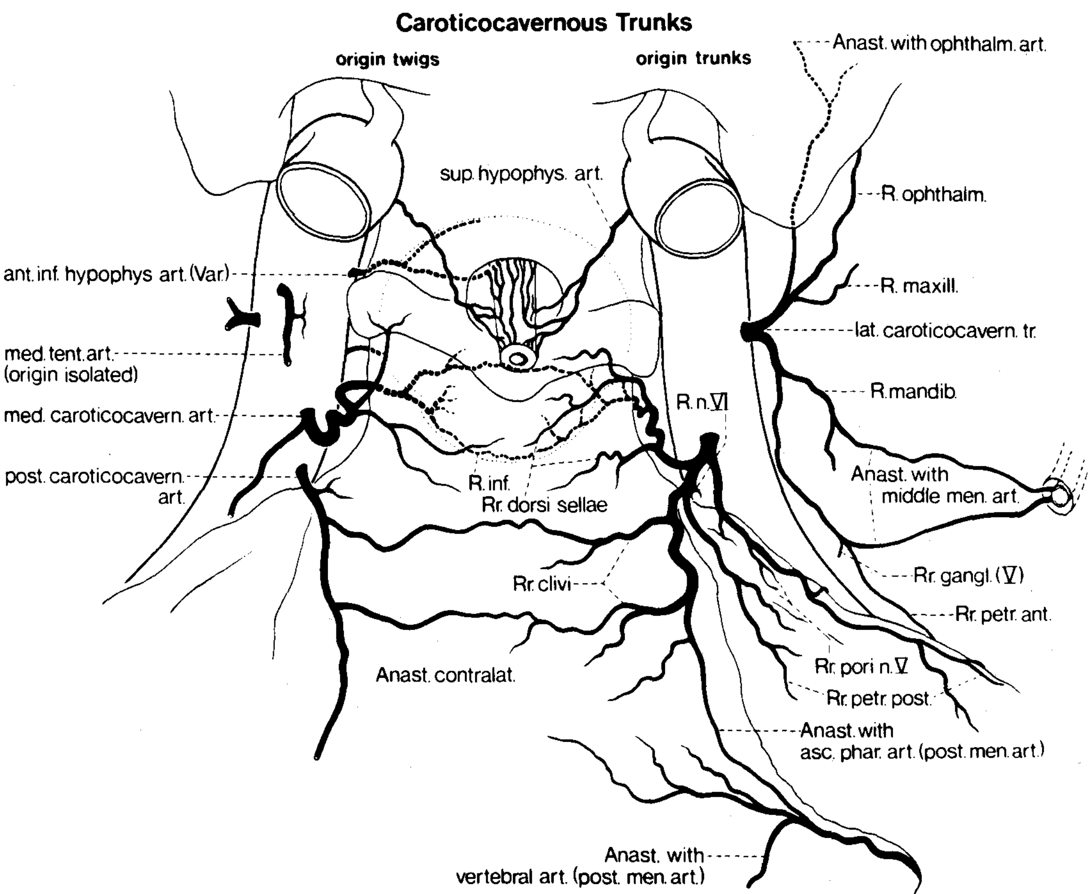

Fig. 14. Caroticocavernous trunks (according to Lang and Schäfer 1976 [42]).

Fig. 15. Capsule of hypophysis (viewed from medially). 1. Anterior lobe of hypophysis removed and placed anteriorly. 2. Sphenoidal sinus. 3. Capsule of hypophysis in situ. 4. Diaphragma sellae and mm-paper. 5. Posterior intercavernous sinus and inferior hypophyseal artery. 6. Optic chiasm and posterior communicating artery (fetal type). 7. Basilar plexus.

frequently there is a rounded transition from the anterior wall of the pituitary fossa into the prechiasmal sulcus.

6.3 Pituitary fossa

Peculiarly enough, a pituitary fossa conforming to the textbook description – a depression at the site of the pituitary – was demonstrable in only about half of our material. Instead of a fossa there is frequently a plateau. In approximately 20% this plateau has a concavity for the pituitary but in some 15% the plateau is flat. Various other combinations make up the remainder (Lang and Tisch-Rottensteiner [44]).

6.4 Measurements

Depth: A straight line was drawn between the tuberculum sellae and the dorsum sellae and the greatest depth of the sellar floor was measured. According to Camp [9] this distance averages 8 (4–12)mm, Eggemann and Inke [16] found an average of 6.85 mm in

Europids, 7.03 mm in Mongolids and 6.93 mm in Negrids.

Length: According to Camp [9] the average length of the sella is 10.5 (5–16)mm.

Width of the sella floor: According to Renn and Rhoton jr. [55] the horizontal plateau of the sella floor averages 14.0 (10–16)mm in width. We found that its greatest width is situated 3–7.5 mm dorsal to the tuberculum sellae, and that the right margin of the pituitary fossa is less often lower in relation to the Frankfurt horizontal plane than the left (Lang and Tisch-Rottensteiner [44]).

6.5 Median craniopharyngeal canal

There is sometimes a foramen in the floor of the pituitary fossa. It is commoner in neonates and young children than in adults and it may lead into a canal which runs through the body of the sphenoid to the base of the skull or it may lead into the sphenoid sinus. Arey [3] found an open craniopharyngeal canal in 0.42% of adults. Its diameter is 1–1.5 mm and its length 15–16 mm. It opens on the underside of the body of the sphenoid where the latter joins the vomer. Blind canals are commoner and these are filled with dura, periosteum and veins. In our material arteries not infrequently traverse the craniopharyngeal canal in newborn infants and even in adults. It has been suggested that canals of this kind represent relics of the pathway traversed by Rathke's pouch as it grew upwards from the stomodaeum to form the adenohypophysis.

6.6 Sellar spine

The first case where this variation was examined was a 23-year-old Caucasian male (Lang [34]). The osseous spine was 4.35 mm long and protruded from the dorsal side of the pituitary fossa into the fossa itself. The tip of the spine was 1.25 mm in diameter. Dietemann et al. [14] described five anatomical and radiological observations of a spine protruding into the pituitary fossa in living patients.

7 Cavernous sinus and measurements (Fig. 16)

7.1 Distances between clinoid processes

Anterior clinoid processes: In our material the distance between the mid zones (in the apical region) of the two dura-covered anterior clinoid processes was 29.32 (24–34)mm (Horn [25]).

Posterior clinoid processes: In our material the average distance between the left and right clinoid processes was 13.02 (8–18)mm in adults.

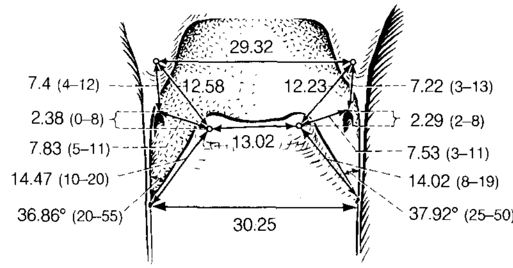

Fig. 16. Measurements of cavernous sinus from above. Given are the distances between anterior and posterior clinoid processes, entrance of the third nerve, angles between the anterior and posterior petroclinoid folds and length of the posterior petroclinoid fold.

Distance between the anterior and posterior clinoid processes: In our material the average distance (oblique line) from the middle of the anterior clinoid process to the middle of the posterior clinoid process was 12.58 (9–16)mm on the left and 12.23 (8–17)mm on the right (Horn [25]). Right-left differences of up to 3 mm were found in this dimension. On the left side increases in the distance of 1–3 mm were noted in 45% of cases, on the right side in 23% only. In 60 skulls (20 female and 40 male) from subjects aged between 30 and 93 years there was no evidence of any correlation between the distance between the clinoid processes and cranial length, cranial width or cranial index.

7.2 Dura mater of the cavernous sinus

The bony region between the tuberculum sellae, the anterior clinoid process, the posterior clinoid process and a triangular area of varying size lateral to and behind the posterior clinoid process is closed above by an approximately horizontal plate of dura which we term the transverse plate. The transverse plate of the pituitary region varies in length and breadth. Its middle part spans the sella turcica and is perforated for the pituitary stalk; this part is known as the diaphragma sellae. Lateral and dorsal to the diaphragma the transverse plate merges into a basin of varying depth drawn out into a point posteriorly: this is known as the basin region. The lateral boundary of the basin is the anterior petroclinoid fold, the anterolateral extension of the tentorium cerebelli. Posteromedially the basin is bounded by the posterior petroclinoid fold, which represents the posteromedial extension of the tentorial notch fibres.

The anterior petroclinoid fold is mainly composed of fibres from the tentorial notch. It is usually sharp edged, but may sometimes be rounded where it is in relation to the side wall of the sinus. In the vicinity of the anterior clinoid process, which is embraced by this group of fibres, the medial fibres radiate above the optic nerve and unite with the transverse fibres of the dura mater on the planum sphenoidale (Lang [33]). The lateral fibres run along the posterior margin of the lesser wing of the sphenoid and contribute to the relatively thick dural layer at this site. The fibres in the basin region of the transverse plate are likewise largely derived from the anterior radiation of the tentorium. The entry portal for the oculomotor nerve is formed by a concave border, sharp rostrally and rounded dorsally. That part of the basin situated behind the oculomotor nerve consists of fibres which originate from the ramification zone of both petroclinoid folds and form dense bundles dorsally. Anteriorly, these fibres diverge into a relatively thin roof layer for the cavernous sinus. The entry portal of the oculomotor nerve is usually situated at the anterior border of the basin.

7.3 Width of the cavernous sinus

In our material the average width of the cavernous sinus between the upper margins of the anterior petroclinoid folds and in the vicinity of the diaphragmatic foramen is 28.9 (26.5–34.0)mm.

7.4 Angles of the petroclinoid folds (see Fig. 16)

The angle enclosed between the two petroclinoid folds averages 37.92 (25–50)° on the right and 36.86 (20–55)° on the left. It may be noted that in our material (40 male and 20 female cadavers between 30 and 93 years of age) the distribution of cranial shapes was as follows: hyperbrachycephalic 38.98%, brachycephalic 28.81%, ultrabrachycephalic 11.86%, mesocephalic 18,65% and dolichocephalic only 1.70% (Horn [25]). Most values for the angle were between 30 and 50° on right and left alike. Surprisingly enough, large cranial widths seem to be associated with narrow angles between the clinoid folds. There is no correlation between the width of the cavernous sinuses, measured at the level of the posterior clinoid process, and the size of the angle.

7.5 Topographical relations

The anterior petroclinoid fold lies against part of the parahippocampal gyrus. The fold produces the so-called uncal notch in the latter, but when the fold is rounded this notch may not be apparent. The oculomotor nerve may be pressed against and involved by the posterior petroclinoid fold in displacement of the brain.

8 Diaphragma sellae

8.1 Measurements

The larger and medial portion of the transverse plate of the cavernous sinus is known as the diaphragma sellae. It is perforated centrally for the pituitary stalk, this perforation being known as the diaphragmatic foramen. The diaphragma sellae stretches from the region of the tuberculum sellae to the upper border area of the dorsum sellae and the posterior clinoid processes, its average length being 8 (5–13)mm and width 11 (6–15)mm. In the material studied by Renn and Rhoton jr. [55] the width exceeded the length in 84% of cases. In 16% the diaphragma is approximately square. The diaphragma frequently originates from the bone a few millimetres below the tuberculum sellae. Renn and Rhoton jr. [55] found that the diaphragma was truly flat in 42%, concave upwards in 54% and convex upwards in 4%.

8.2 Dural construction

In the neighbourhood of the diaphragmatic foramen the dural covering of the pituitary is usually very thin and consists of circular fibres. Traced peripherally towards the tuberculum sellae, the portal for the internal carotid artery and the anterior clinoid process, the diaphragm becomes thicker. In this part its fibres run from posterolateral to anteromedial. Behind the diaphragmatic foramen there are oblique fibre strands which extend from the apical region of the posterior clinoid process; in the vicinity of the back rest of the "Turkish saddle" they run almost exactly transversely.

8.3 Aperture for the internal carotid artery (Fig. 12)

Medial to the anterior clinoid process the internal carotid artery traverses the diaphragma sellae. This part of the vessel has a curve convex forwards and medially where it passes from the cavernous part to the subarachnoid part. The dural portal is rounded in outline and is sometimes situated exactly in the transverse plane. More frequently its anterior border is somewhat higher than its posterior. The diaphragma sellae and the adventitial layer of the arterial wall are densely interwoven.

8.4 Size of the diaphragmatic foramen

According to Bergland et al.[5] in old people the diaphragmatic foramen has a diameter of 5 mm or more. Renn and Rhoton jr. [55] state that it is round in 54% and transverse oval in 46%. With advancing age the infundibular orifice seems to enlarge. Apart from the infundibulum, the superior hypophyseal arteries often pass through this hole to reach the anterior lobe. Occasionally one of these arteries penetrates the diaphragma itself.

According to Busch [8], who examined no fewer than 788 pituitary regions and uses the term operculum for the diaphragma sellae, in 38.4% the diaphragma is complete and there is a small opening for the pituitary stalk. The diaphragma consists of dense fibrous tissue and is positioned horizontally. In 3.5% the diaphragma has a funnel-shaped depression in the vicinity of the pituitary stalk, though in other respects it is as described.

8.5 Empty sella
Kaufman and Chamberlin [30] examined the pituitary region of 69 patients without any endocrine disorders (30–93 years). They classified the diaphragma sellae along the lines suggested by Busch [8] and found that his types II and III, with a relatively small diaphragma sellae, were present in 71.9%. In 23.5% there seemed to be an empty sella. However, sagittal sections through these specimens showed that in only 6 of these 21 cases (6.7% of the total) was there an involuted pituitary as described by Busch. In 14 of the 21 specimens the pituitary was merely flattened. They point out that the "empty sella" is a common finding and that expansion of the sella turcica, symmetrical or asymmetrical, is by no means infrequent even in the absence of a tumour.

8.6 Attachments of the diaphragma sellae
According to McLachlan et al. [47] (50 specimens) the diaphragma sellae is attached anteriorly to the tuberculum sellae and posteriorly to the anterior part of the posterior clinoid processes. In 45 of their specimens the attachment of the diaphragm was situated on the most anterior zone and the apical region of the dorsum sellae. In the remaining five it was situated on the uppermost zone of the dorsum. McLachlan et al. state that the tuberculum sellae is sometimes difficult to define. According to Joplin [28] it is usually situated 5–8 mm posterior to the limbus sphenoidalis, which is usually easily recognized but may occasionally be absent. According to these authors, the prechiasmal sulcus runs horizontally or in various other positions, occasionally even vertically.

8.7 Contour and location of the diaphragma sellae
McLachlan states that the diaphragma sellae is usually visible as an elongated line in a lateral radiograph [47]. They drew a straight line between the tuberculum sellae and the apex of the dorsum sellae and measured the distance of the centre of the diaphragm from this line. In 14 out of 27 female specimens the distance was 1 mm or more, and in 7 it was 2 mm or more. In 23 male specimens the distance was 1 mm or more, and in 10 it was 2 mm or more; in no instance was the diaphragm above the line. In 8 specimens (both male and female) the distance was 3 mm or more.

8.8 Pituitary cisterna (Fig. 17)
The arachnoid invariably extends through the diaphragmatic foramen and spreads out on the upper surface of the anterior lobe of the pituitary. In adults there is a fluid-filled space within this arachnoid tissue; it is known as the pituitary cistern and usually enlarges with advancing age. This cistern may extend for a variable distance forwards and laterally and may occasionally even overlap the posterior lobe. At the diaphragmatic foramen the arachnoid is always interwoven with the dura, a fact which has prompted various workers to infer that the diaphragma sellae is composed of arachnoid (Shealey et al. [61] – in 65%). In the Würzburg material the pituitary cistern was clearly demonstrable in corrosion preparations. Bergland et al. [5], using roentgenological methods, were successful in demonstrating the cistern inside the sella turcica in roughly 20% of cases.

9 Hypophyseal vessels

9.1 Superior hypophyseal arteries (Fig. 18)
The superior hypophyseal arteries, usually two (1–4) in number, branch off mostly from the medial and inferior surface of the subarachnoid part of the internal carotid artery shortly after it passes through the diaphragma sellae. They run backwards and upward towards the infundibulum, reaching it at various levels. On their way to the pituitary stalk they give off some small twigs to the inferior surface of the optic chiasm and optic nerve and to the tuber cinereum. At the pituitary stalk they usually form an arterial circle, from which originate an anterior superior hypophyseal artery and a posterior superior hypophyseal artery; they commonly run downwards on the anterior and lateral sides of the pituitary stalk. From the anterior superior hypophyseal artery further branches extend upwards to the chiasm and the hypothalamic region (Xuereb et al. [68]). The superior hypophyseal arteries usually communicate by several anastomoses. As they run forwards and downwards they often give off several fine arterioles on the anterior and posterior surfaces of the infundibulum. These send twigs into the pituitary stalk (infundibular rami). Ascending vessels supply the median eminence. During its downward course one superior hypophyseal artery may separate from the

rest; it then continues as the trabecular artery, approximately 3 mm in front of and lateral to the infundibulum, and disappears into the anterior lobe of the pituitary. It was given this name by Xuereb et al. [68], who used the term trabecula to denote a more or less compact zone of connective tissue with blood vessels on the surface of the anterior lobe.

Accessory hypophyseal arteries: (Fig. 14) In our material there were not infrequently small branches from the posterior communicating artery which ran to the tuber cinereum and contributed to the supply of the infundibulum. There were also anastomoses with the superior hypophyseal artery.

9.2 Smaller hypophyseal vessels

Arterioles branch off in a radial direction from the superior hypophyseal arteries and penetrate the pituitary stalk. There they form loops resembling glomeruli (glomeruli haemocapillares), which are regarded as special vessels and are equipped with a narrow afferent and a wide efferent capillary loop. These vessels frequently form capillary convolutions. They have an unusual wall structure which makes them easily permeable to certain substances. The large calibre efferent capillary loops run to the so-called portal vein system (vasa portalia – vv. portae hypophysis) which follows an extended course to the anterior lobe and supplies its cell groups with blood. These pathways enable humoral agents to be swiftly transported to the anterior lobe of the pituitary. Inside the adenohypophysis and the pars infundibularis there is a dense network of large calibre capillaries, known as the vasa capillaria sinusoidea. Where the trabecular artery runs from the

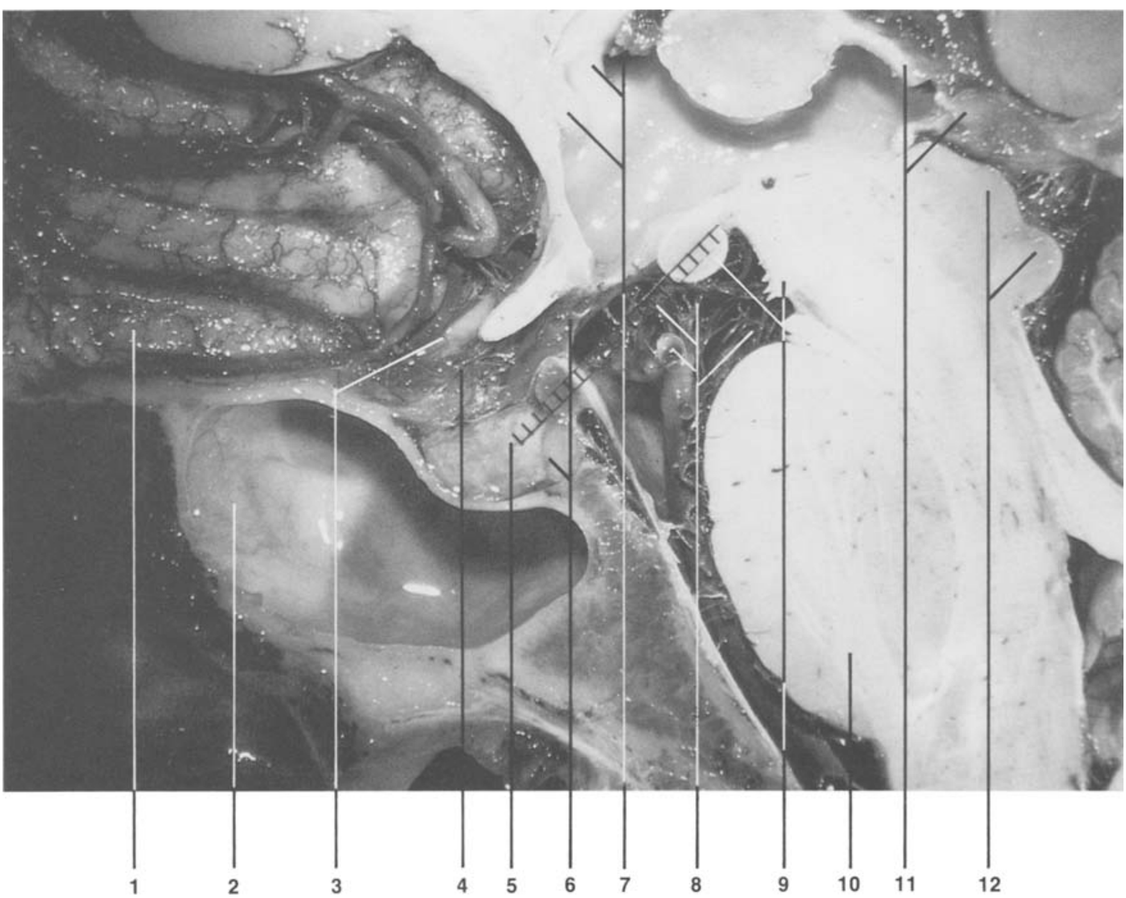

Fig. 17. Inf. diencephalic branches, viewed from medially (paramedian sagittal section). 1. Gyrus rectus. 2. Septum of sphenoid sinus. 3. Optic nerve. 4. Arachnoid tissue and sup. hypophyseal artery. 5. Adenohypophysis. 6. Infundibulum and neurohypophysis. 7. Anterior commissure, fornix and interventricular foramen. 8. Post. inf. diencephal. brs., mm-paper and PCA, cut. 9. Mamillary body and third nerve, cut. 10. Corticospinal fibres in pons. 11. Stria medull. thalami and pineal body. 12. Superior and inferior colliculus.

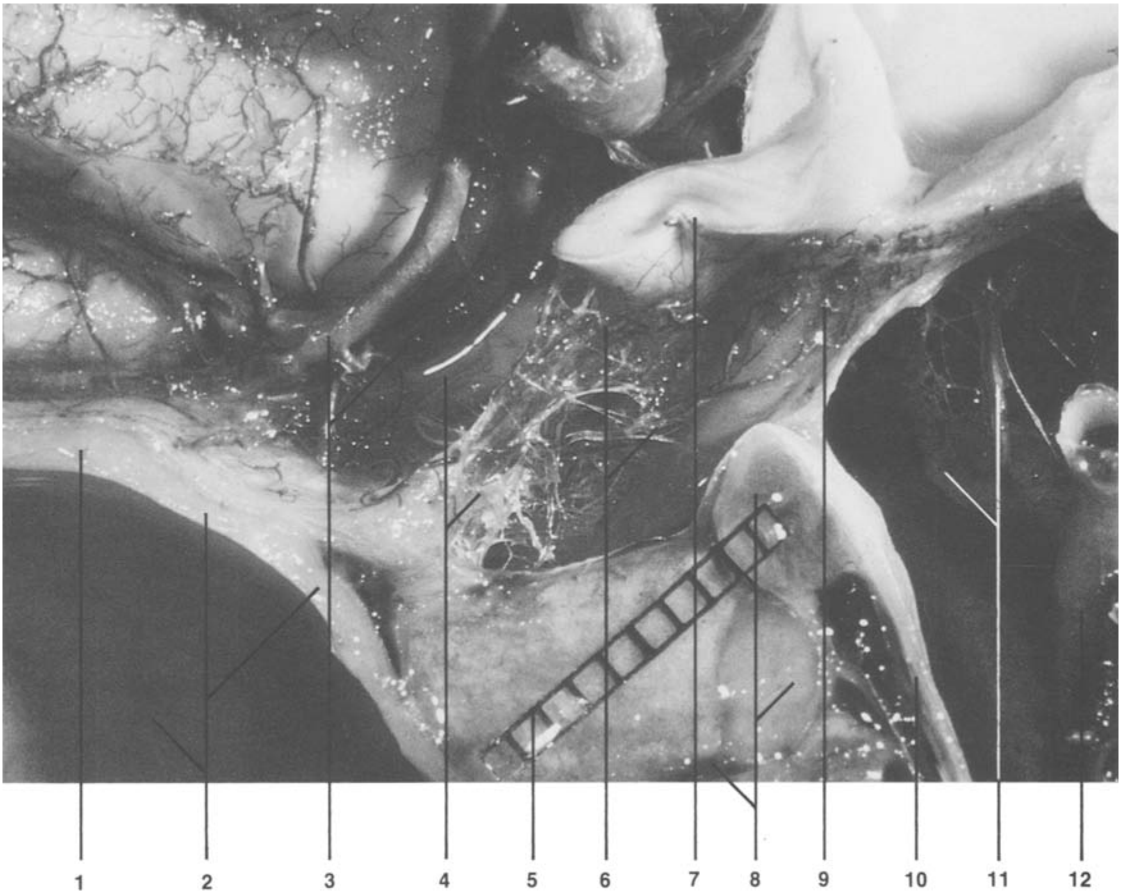

Fig. 18. Inferior diencephalic branches and hypophyseal arteries, twigs.
1. Planum sphenoidale. 2. Tuberculum sellae, oblique and sphen. sinus. 3. Common trunks for med. frontobasal and frontopolar branches. 4. Optic nerve and arachnoid tissue. 5. Adenohypophysis and mm-paper. 6. Inf. diencephalic branches from ICA and sup. hypophyseal artery. 7. Chiasma, retracted upwards. 8. Post. clinoid process and neurohypophysis and twigs of inferior hypophyseal artery. 9. Infundibulum. 10. Dura mater of clivus. 11. Post. inf. diencephalic branches of PCA-Segment. 12. Basilar artery.

pars infundibularis into the anterior lobe it also forms similar glomeruli haemocapillares and anastomoses with twigs from the superior hypophyseal arteries.

9.3 Hypophyseal veins

According to Popa and Fielding [54], who reconstructed serial sagittal sections through the pituitary of a newborn infant, the so-called hypophyseal-portal veins arise from sinusoids in the anterior lobe of the pituitary and from capillaries in the posterior lobe and the pars intermedia. They run upwards inside the pituitary stalk without anastomosing with one another. In the infundibulum they are in part enveloped in peculiar glial sheaths, and then split up into a secondary capillary network, which is demonstrable in the vicinity of the infundibular recess of the third ventricle. In their opinion it communicates with the vessels of the paraventricular and supraoptic nuclei of the hypothalamus. Blood discharged from the sinusoids of the anterior lobe drains both into the portal venous system and directly into the cavernous sinus. The venous capillary segments of the posterior lobe may also open both into the portal venous system and into the cavernous sinus.
Further details see Lang [36] and Fig. 13.

9.4 Inferior hypophyseal artery

In our material (Lang and Schäfer [42]) there are two to six small arteries arising from the cavernous part of the internal carotid artery. Most commonly there are two main trunks which we term the posterior and lateral caroticocavernous trunks. The posterior caroticocavernous trunk branches off in the vicinity of the posterior sinus curve of the internal carotid artery. It is approximately 1 mm in diameter and runs at first dorsally for 2–7 mm inside the cavernous sinus, then dividing into two or three branches. The posterior inferior hypophyseal artery usually runs medially and forwards. This vessel usually pursues a tortuous course between the internal carotid artery and the dorsum sellae, running medially to the basal part of the posterior pituitary lobe, where it frequently divides into two branches which embrace the posterior lobe. A ramus superior runs on the upper posterior part of the posterior lobe, and a ramus inferior on the lower posterior part (Fig. 14).

Variations: 1. A small branch of the posterior inferior hypophyseal artery can also be followed to the basal part of the anterior pituitary lobe.

2. A posterior inferior hypophyseal artery proceeds directly to the middle and basal region of the pituitary.

3. In one instance a small artery arose from an upper caroticocavernous vessel group and ran directly below the diaphragma sellae to the hypophysis, breaking up into twigs at the boundary between the anterior and posterior lobes (there was also a posterior inferior hypophyseal artery and an anterior inferior hypophyseal artery arising from a capsular artery).

4. In one instance a small artery arose from the medial side of the anterior cavernous curvature of the internal carotid artery and ran medially to the anterior surface of the pituitary (posterior and middle inferior hypophyseal arteries were also present).

5. We were also able to demonstrate a middle inferior hypophyseal artery in several instances. This vessel branches off directly from the medial wall of the sagittal portion of the internal carotid artery, crosses the cavernous sinus and breaks up into branches on the basal parts of the pituitary (= capsular artery).

Capsular arteries (Fig. 15): These vessels, which we also term the middle and anterior inferior hypophyseal arteries, are difficult to demonstrate in injection preparations. As a rule they arise from the sagittal cavernous portion of the internal carotid artery or from the posterior caroticocavernous trunk. They run through the medial blood space of the cavernous sinus into the cleft between the pituitary capsule and the periosteum. The lower branches enter the bone through nutrient foramina and supply the floor of the pituitary fossa, also contributing to the blood supply of the mucosa of the sphenoid sinus. The upper branches of this vessel may pierce the pituitary capsule and contribute to the blood supply of the pituitary (middle inferior and anterior inferior hypophyseal arteries).

There are usually left-right anastomoses between these pituitary vessels and also between the capsular arteries.

Minor branches of the inferior hypophyseal artery: The inferior hypophyseal arteries together with the upper branches supply the posterior pituitary lobe. One of their larger twigs runs forwards and upwards between the posterior and anterior lobes and connects with the trabecular artery. Glomeruli haemocapillares forming a characteristic portal circulation also occur in this junctional area.

10 Circulus arteriosus (Willis) and diencephalic branches (Fig. 19)

The major arteries at the base of the brain form a circle within the pentagon, centred upon the pituitary. It receives blood from the two internal carotid arteries and the vertebral arteries. The anterior communicating artery connects the precommunicating parts of the two anterior cerebral arteries. The precommunicating parts of the two posterior cerebral arteries are connected to the middle cerebral arteries by the posterior communicating arteries. In 3–4% of cases the circulus arteriosus is not complete (von Mitterwallner [50]). This finding has been confirmed

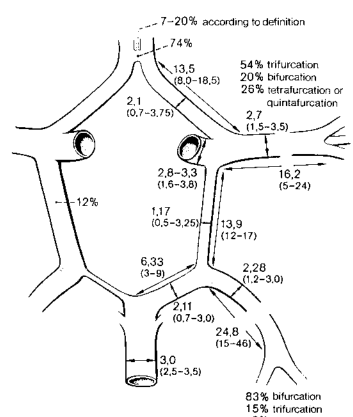

Fig. 19. Circle of Willis.
Mean length and width in mm (extremes) and the fetal type of post comm, art.; more than 2 mm in diameter: 12%, anterior median cerebral artery: 7–20%.

by the studies of later investigators (Jain [27]; Tseng and Li [66] and others). McCormick [46] points out that only in some 54% of cases does the development of the circulus arteriosus conform to the textbook descriptions. Alpers and Berry [1] give similar figures.

10.1 Affluents and divisions of the circulus arteriosus

Internal carotid artery: In our material the average length of the subarachnoid part of the internal carotid artery was 13.4 (8–18.0)mm. Its average diameter is 2.9 (2.2–4.3)mm on the right and 3.3 (2.2–4.5)mm on the left side.

Anterior cerebral artery: In our material the precommunicating part of the anterior cerebral artery averaged 13.5 (8–18.5)mm in length and 2.1 (0.75–3.75)mm in diameter. According to Wollschlaeger et al. [67] hypoplastic arteries are present in approx. 8.6% (in approx. 4% on the left and in rather more than 3% bilaterally); these arteries have diameters of 1 mm or less. When the calibre of the anterior cerebral artery is unusually narrow the main blood flow usually reaches the post-communicating segment of the vessel via the anterior cerebral artery and anterior communicating artery of the opposite side, both of which are correspondingly large. The precommunicating part of the artery is occasionally absent – in 1.1% (von Mitterwallner [50] or 0.7% (Krayenbühl and Yasargil [32]).

Anterior communicating artery: In roughly 75% of cases the anterior communicating artery conforms to the textbook (von Mitterwallner [50]), but in approx. 9% it is reduplicated and in the remainder it is V-shaped, Y-shaped or net-like. Riggs and Rupp [56] found hypoplastic arteries in 9.3%. According to Perlmutter and Rhoton [52] the average length of the anterior communicating artery is 2.6 (0.3–7.0)mm.

Middle cerebral artery: In our material the middle cerebral artery averaged 16.2 (5–24)mm in length and 2.7 (1.5–3.5)mm in diameter (Lang and Brunner [38]).

Posterior communicating artery: In our material the posterior communicating artery had an average length of 13.9 (12.0–17.0)mm and a diameter of 1.17 (0.5–3.25)mm. The posterior communicating artery is sometimes unusually large (more than 2 mm in width); in such cases it is regarded as being of fetal type and provides the main inflow to the post-communicating part of the posterior cerebral artery. In our material such fetal types made up 12%. In 22.2% the posterior communicating artery is larger than the precommunicating part of the PCA.

Precommunicating part of the posterior cerebral artery: In our material the precommunicating part of the posterior cerebral artery averaged 6.33 (3.0–9.0)mm in length and 2.11 (0.7–3.0)mm in diameter. When the precommunicating part of the posterior cerebral artery is unusually narrow the posterior communicating artery is usually of the fetal type.

The posterior communicating artery and the precommunicating part of the posterior cerebral artery may occasionally be absent.

Basilar artery: The basilar artery supplies blood to the precommunicating parts of the posterior cerebral arteries and its average diameter in our material was 3.0 (2.5–3.5)mm.

Central branches of the circle of Willis (Fig. 20): The central branches of the circulus arteriosus are of clinical importance not only because of the territories which they supply, but also because of the occurrence of aneurysms at their points of origin. Among the structures supplied by these branches the most important is the diencephalon.

Anterior choroid artery: In our material the anterior choroid artery arose from the internal carotid artery in 96%, and from the posterior communicating artery in 2%; in a further 2% it had a double origin from both these vessels. Its point of origin is situated at an average of 2.9 (0.5–5)mm proximal to the division of the internal carotid artery (Brunner [7]). The vessel has an average diameter of 0.77 (0.4–1.25)mm. It runs dorsally along the lower and lateral surface of the optic tract and passes through the choroid fissure into the temporal horn of the lateral ventricle. On its way it gives off numerous twigs to the diencephalon.

10.2 Inferior diencephalic branches (Fig. 21)

Even in the latest Nomina Anatomica [51] the subclassification of the branches of the arterial circle at the base of the brain is extremely inconsistent. The vessels arising from the anterior cerebral artery and anterior communicating artery and entering the diencephalon are designated as anteromedial central arteries and branches, to which are added the anterolateral central arteries from the middle cerebral artery and the posteromedial central arteries and thalamic branches from the posterior cerebral artery. Nomina Anatomica gives a further breakdown for the twigs of the anterior choroid artery (rami to optic tract, lateral geniculate body, internal capsule,

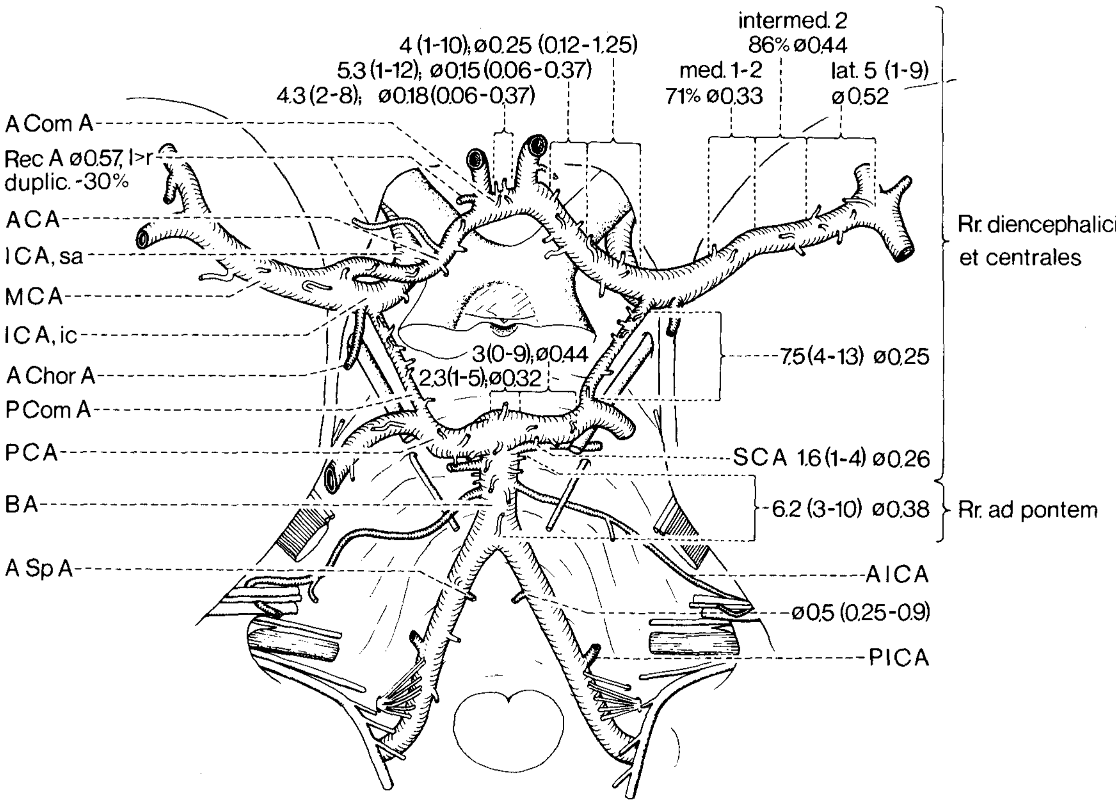

Fig. 20. Central twigs of the arterial circle and the vertebral system. Definitions, numbers, mean values (extremes), diameters ∅ (extremes).

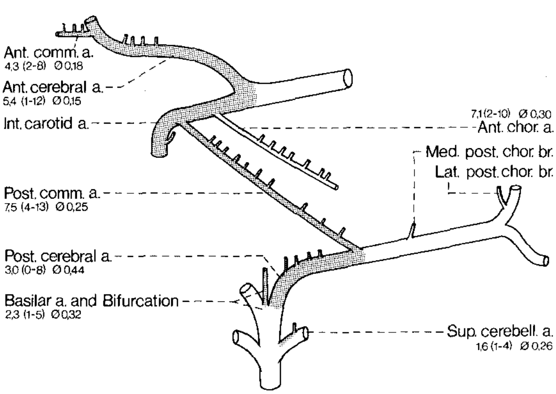

Fig. 21. Inferior diencephalic branches, origin zones, number (extremes) and mean diameters.

globus pallidus, tuber cinereum, hypothalamic nuclei, etc.). Before the publication of these Nomina we suggested that these diencephalic vessels, arising from the anterior cerebral artery and anterior communicating artery, should be named anterior inferior diencephalic branches. We propose the term inferior diencephalic branches for the vessels arising from the posterior communicating artery, and posterior inferior diencephalic branches for those arising from the precommunicating part of the posterior cerebral artery, the basilar artery and the superior cerebellar artery. We use the term lateral inferior diencephalic branches to denote the twigs from the middle cerebral artery which contribute to the blood supply of the anterior parts of the diencephalon, and those arising from the anterior choroid artery which perfuse mainly the posterior and lateral parts of the diencephalon. The latter enter the diencephalon at various points along its lower surface and also supply other parts of the brain (portions of the midbrain and telencephalon).

The mamillary arteries are not listed in the new Nomina Anatomica. On average, three arteries run to the mamillary body, each of which then divides into 3–12 fine twigs with diameters of 0.05–0.15 mm and forms an arterial rete. The affluents arise in 47% from the posterior inferior diencephalic branches, in 29% directly from the posterior cerebral artery and in 24% from the posterior communicating artery (Brunner [7]).

10.3 Posterior diencephalic branches

Posterior and superior diencephalic branches: In our classification (Lang [35]) the diencephalic twigs from the posterior choroid branches are regarded as posterior and superior supply channels. The medial posterior choroid branch has an average diameter of 0.56 mm and usually supplies the pineal body and sends 3–5 small twigs to the dorsal aspect of the diencephalon. These run to the geniculate bodies and to the posterior surface of the thalamus, piercing the posterolateral half of the latter. In the lateral geniculate body it is mainly the medial portion which they supply. Fine twigs (usually two in number) also run from the lateral posterior choroid branches to the thalamus, in particular the dorsolateral nucleus and the fornix (Lang and Käpplinger [40]). The posterior lateral choroid branches send twigs to the thalamus (average 0.89) and to the lateral geniculate body (average 0.82). Twigs from the artery of the lamina tecti (quadrigemina) can be traced to the medial geniculate body in 3.9% and to the thalamus in 1.6%. However, as anastomoses with the posterior medial choroid branch are present in one-fifth of cases, blood can also reach the thalamus via that channel.

Entering the thalamus from behind there are also the thalamogeniculate branches, most frequently including five twigs from the posterior cerebral artery. Within the thalamus they run forwards and upwards,

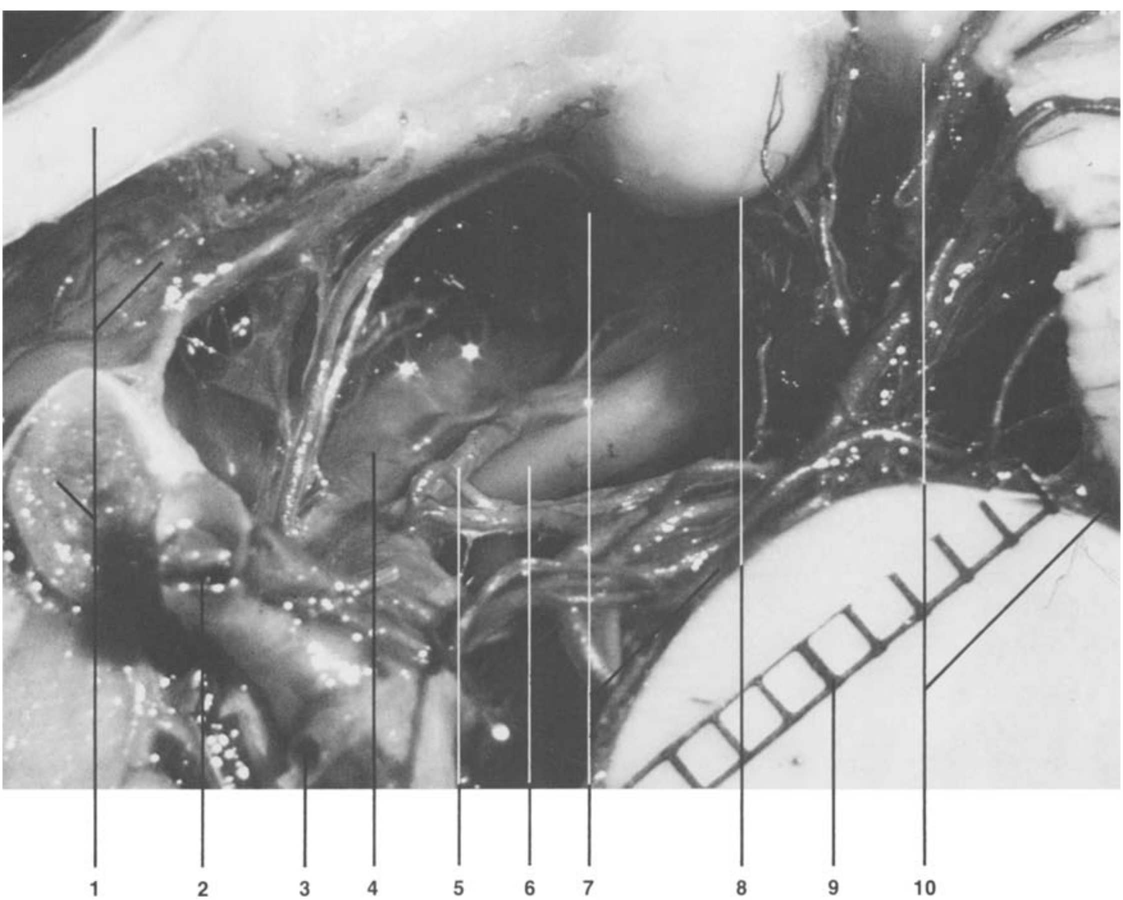

Fig. 22. Interpeduncular branches, viewed from medially.
1. Chiasm, hypophyseal stalk and post. clinoid process. 2. PCA (Lt.), retracted forwards. 3. Sup. cerebellar artery (Lt.) cut. 4. PCA_1-segment. 5. R. chor. post. med., piercing the third nerve. 6. Oculomotor nerve. 7. Interped. branches. 8. Mamillary body. 9. mm-paper and pons. 10. Interpeduncular fossa.

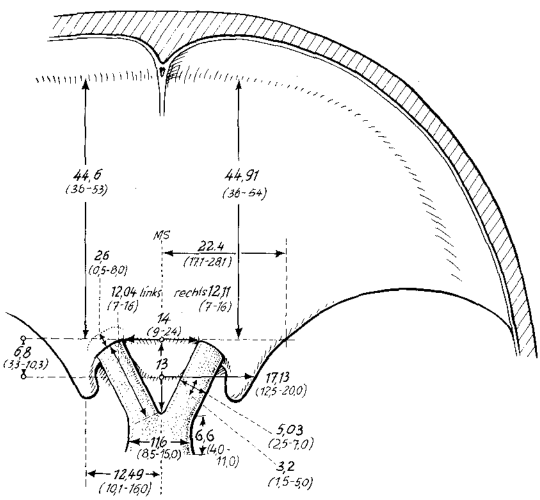

Fig. 23. Anterior cranial fossa, optic nerve and chiasm, measurements in mm (extremes).

supplying the posterior half of the lateral thalamus, the centro-median nucleus and the intralaminar nuclei (Lang and Käpplinger [40]).

Posterior inferior diencephalic branches (Fig. 22): The twigs which enter the diencephalon from below and behind run first through the interpeduncular fossa. In the current issue of Nomina Anatomica those which arise from the precommunicating part of the posterior cerebral artery are termed posteromedial central arteries. Other workers have called them the branches of the interpeduncular fossa and the thalamoperforate arteries. In our material 80% of the vessels entering the brain in the interpeduncular fossa were derived from the posterior cerebral artery, 14% from the basilar artery and 5% from the superior cerebellar artery. The twigs from the posterior cerebral artery are invariably present and most commonly arise from its dorsal surface. On average there are 3 (1–9) of these vessels with average diam-

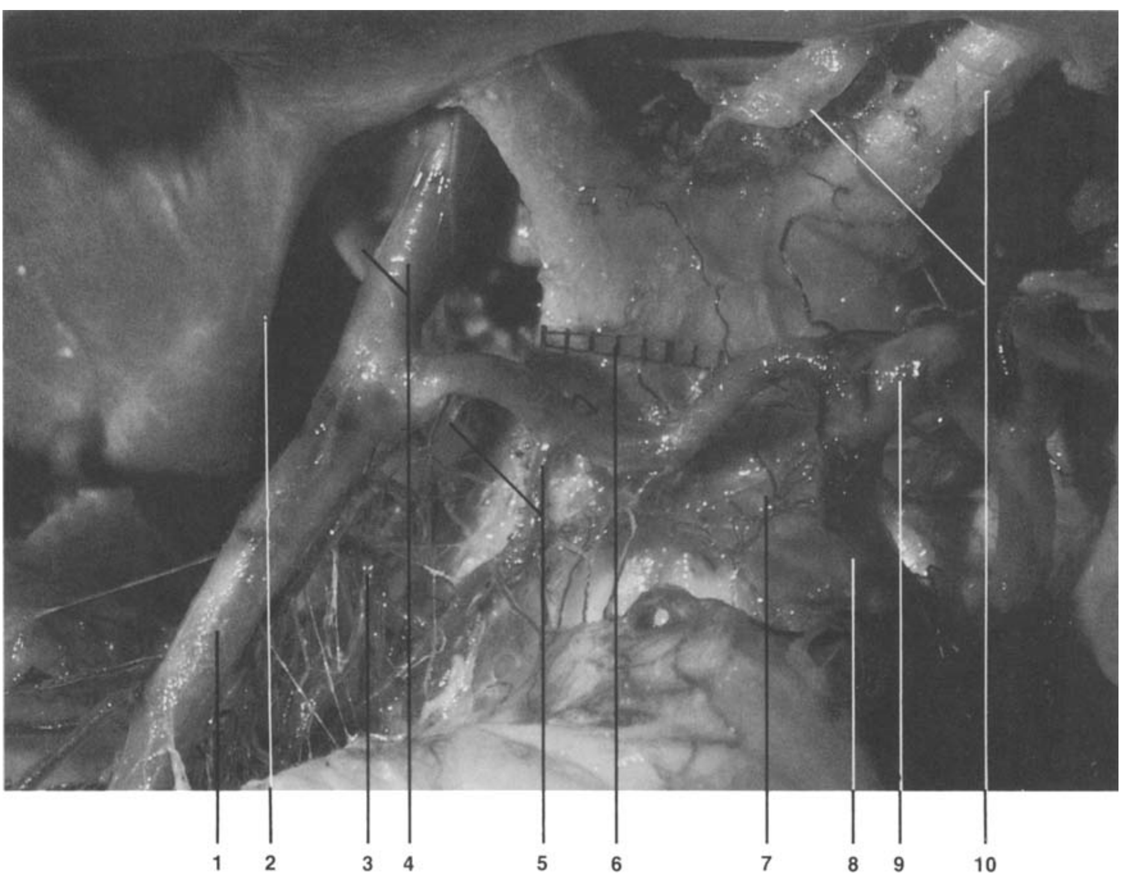

Fig. 24. Frontal approach.
1. MCA. 2. Anterior petroclinoid fold. 3. Central branches of MCA. 4. Third nerve and ICA. 5. Central branch of A_1-segment and Heubner's artery, proximal origin. 6. mm-paper on chiasm. 7. Inf. diencephalic branches. 8. A_2-segment. 9. Anterior comm. artery. 10. Optic nerve and anterior membrane of Lillijeqvist.

eters of 0.44 (0.1–1.0)mm. Arising from the basilar artery there is an average of 2.3 (1–5) of these twigs with average diameters of 0.32 (0.1–0.5)mm, while the superior cerebellar artery has an average of 1.6 (1–4) twigs with average diameters of 0.26 (0.1–0.5)mm. Twigs of this kind arising from the basilar artery are demonstrable in 86%, and from the superior cerebellar artery in 28% (Lang and Brunner [38]).

Frontal and frontolateral approaches to the hypophyseal region

1 Anterior cranial fossa, floor (Fig. 23)

In adults, the average length of the anterior cranial fossa, measured to its rounded transition into the squamous part of the frontal bone, is 35 mm laterally and 47.7 mm medially (as far as the intracranial aperture of the optic canal). The length of the cribriform plate is 20,8 mm and that of the crista galli 21,6 mm. These measurements are variable. By this approach the ACA, ant. comm. artery, ICA, the optic nerves and chiasm and the hypophyseal stalk and hypophyseal tumours can be reached. The starting point of the frontolateral approach is the frontotemporal point. This is an inexact but definite zone in adults 17,8 (11–26) mm above the zygomaticofrontal suture and on the beginning of the superior temporal line. Burr holes on this area opened the skull just above the bottom of the anterior cranial fossa. The distance to the lateral border of the intracranial opening of the optic canal measures about 45 mm. This approach is used for operations on the anterior communicating, the anterior cerebral arteries and also some tumours in this area (Figs. 24 and 25).

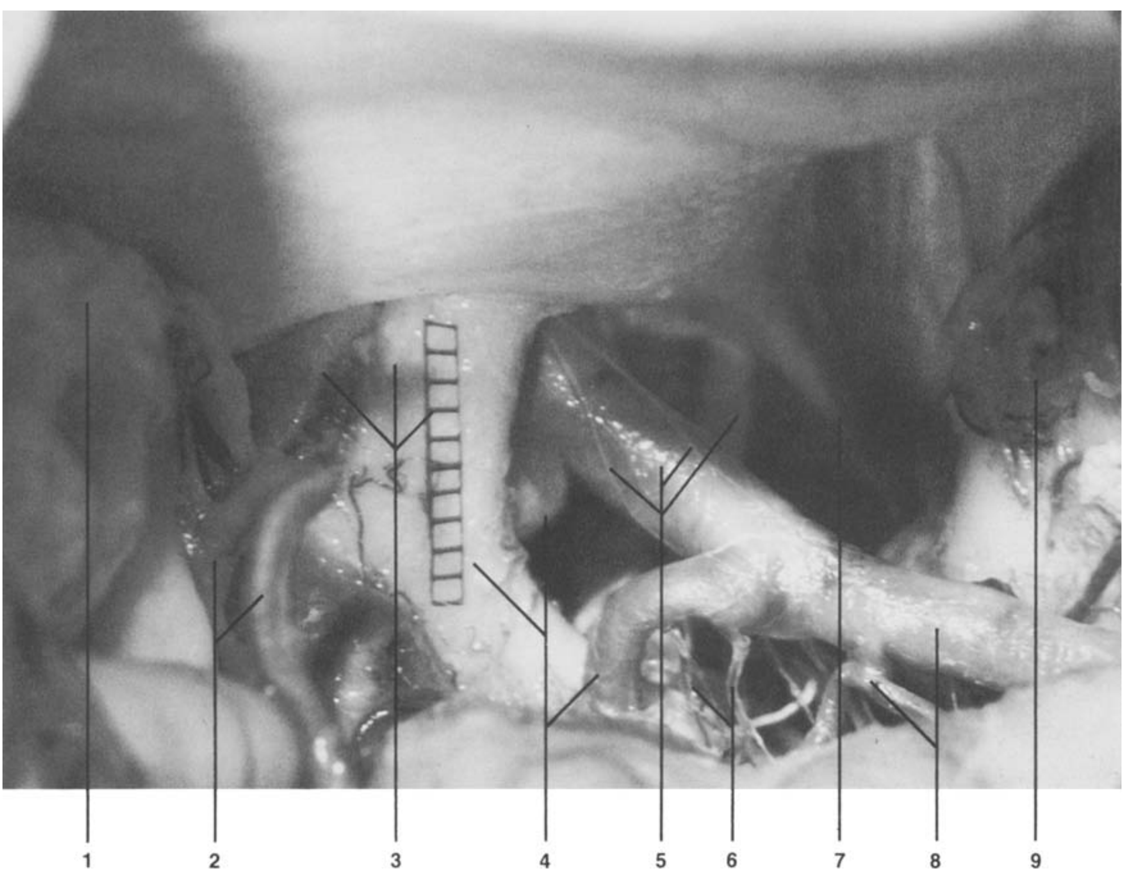

Fig. 25. Frontolateral approach to hypophyseal region.
1. Gyrus rectus. 2. Anterior cerebral arteries. 3. Anterior Lillijeqvist's membrane, optic nerve and mm-paper. 4. Proc. clinoideus post., optic chiasm and pars precomm. a. cerebr. ant. 5. Internal carotid, with nerves and third nerve.
6. Central branches of ant. cerebral a. to anterior perforated substance. 7. Anterior petroclinoid fold. 8. A. cerebri med. and prox. r. centralis. 9. Temporal pole.

2 Arteries

The length, course, width and central branches of the anterior cerebral artery are of clinical importance in the surgical approach to the pituitary region from the front or from the frontolateral aspect. The anterior cerebral artery arises in 61.8% from the anterior circumference and in 38,2% from the superior circumference of the ICA (Firbas and Sinzinger [20]). The precommunicating part of the anterior cerebral artery has an average length of 13.5 mm and an average width of 2.1 mm and runs medially and forwards above the optic chiasm or the optic nerve. It then gives first off the anteromedial central arteries (anteromedial thalamostriate aa.), which continue backwards and laterally to the rostral perforated substance. Arising further distally, close to the anterior communicating artery, there are smaller twigs running to the inferior anterior regions of the diencephalon; we have termed these the anterior inferior diencephalic rami (Lang and Brunner [38]). Together with direct branches from the internal carotid artery, they supply the optic tract, optic nerve, optic chiasm, lamina terminalis and the anterior inferior parts of the diencephalon. Separate twigs also run upwards to a small anterior segment of the caudate nucleus and the thalamus. The paraventricular, dorsomedial, preoptic, supraoptic and tuberal nuclei are supplied by these twigs, as are the anterior portion of the infundibulum and the lateral wall of the third ventricle as far as the interventricular foramen and also the anterior commissure. There

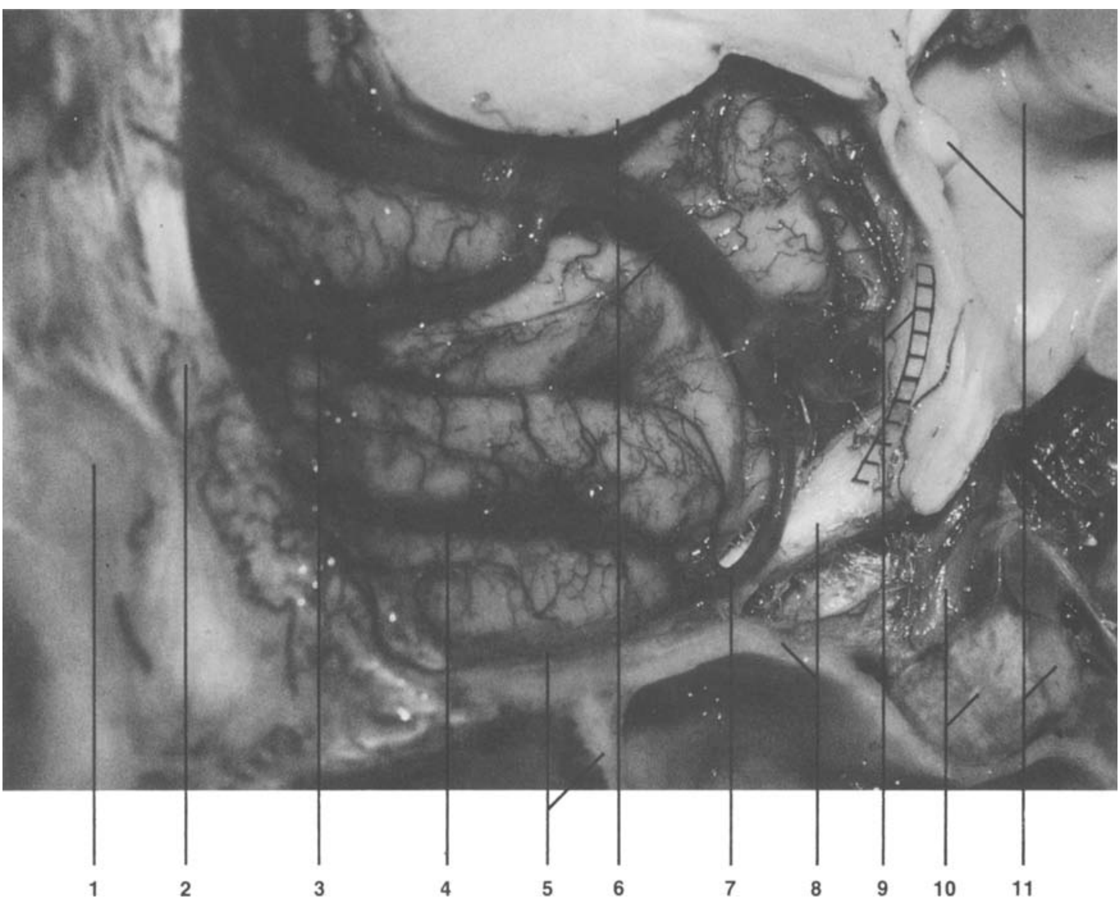

Fig. 26. Sagittal section of forebrain and third ventricle, viewed from medially and anteriorly.
1. Crista galli. 2. Falx cerebri. 3. Anteromed. front. branch. 4. Frontopolar branch. 5. Med. frontobasal branch and ant. wall of sphenoid sinus. 6. Corpus callosum and ACA. 7. Common trunk for med. frontobasal and frontopolar branches. 8. Optic nerve and rounded transition to pituitary fossa. 9. A. cerebr. ant. med. with ant. diencephalic branches, mm-paper. 10. Hypophyseal stalk and adenohypophysis.11. Anterior commissure, interthalamic adhesion (massa intermedia) and neurohypophysis.

are also inferior and anterior diencephalic branches, averaging 4.26 in number, which arise from the anterior communicating artery and supply these regions and the subcallosal area.

2.1 Long central artery (anterior recurrent artery, Heubner's artery)

The origin of the long central artery, which runs to the rostral perforated substance, is situated from 8 mm proximal to 3 mm distal to the origin of the anterior communicating artery from the anterior cerebral artery. On average it is situated 0.4 mm distal to the anterior communicating artery, and that is its site of origin in approximately 60%. In approx. 30% the artery arises at the level of the anterior communicating artery; it arises proximally to it in only 11.3% (Lang und Brunner [38]). In our material the long recurrent artery was duplicated in approx. 30% and a triple artery existed in approx. 1%. The average diameter of the long central artery is 0.57 (0.31–0.87)mm. On the left side the vessel is somewhat wider (0.60 mm) than on the right (0.54 mm), this difference being statistically significant. In roughly two-thirds of cases the artery has branches which contribute to the supply of the olfactory bulb, olfactory tract and the orbital part of the frontal lobe.

The artery runs backwards and laterally in close proximity to the anterior cerebral artery, crosses the latter approximately 15 mm distal to its origin and usually penetrates the anteromedial region of the rostral perforated substance (Kollmannsberger [31]).

2.2 Anterior communicating artery

As a rule, the two anterior cerebral arteries are connected by a short trunk (anterior communicating

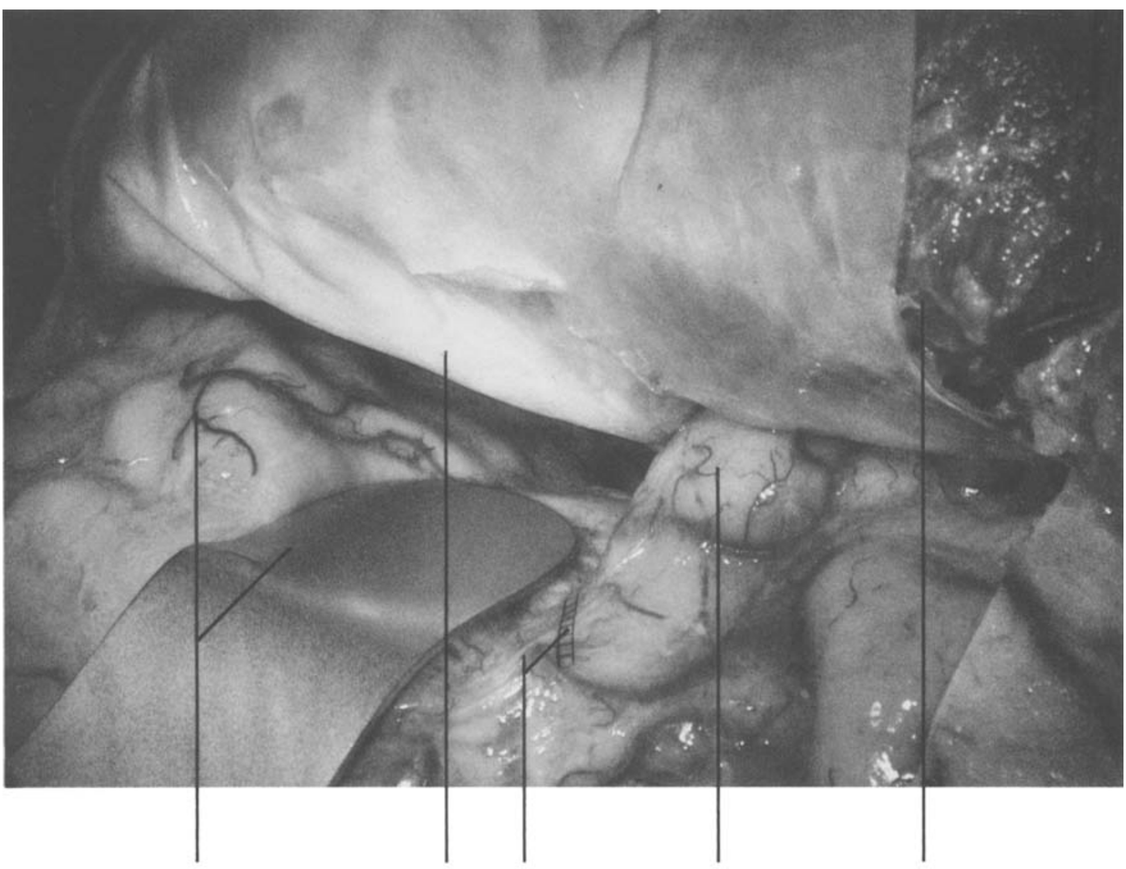

Fig. 27a. Pterional approach to hypophyseal region (Right).
1. Basal forebrain, elevated, and retractor. 2. Dura mater. 3. Arachnoid membrane of cisterna valleculae and mm-paper. 4. Inferior temp. gyrus. 5. Temporalis muscle.

a.) situated above the optic chiasm (in 70%, according to Perlmutter and Rhoton jr. [52]). In 30% of cases the anterior communicating artery is situated at the level of the optic nerves and 5–30 mm above the planum sphenoidale (angiographic studies by Krayenbühl and Yasargil [32]). There are numerous morphological variants.

2.3 Medial frontobasal branch (Fig. 26)

The medial frontobasal branch (medial frontobasal artery) of the anterior cerebral artery runs forwards and basally along the medial surface of the hemisphere in the direction of the frontal pole. Several twigs from this artery curve round the medial inferior edge of the hemisphere and supply the orbital part of the frontal lobe from its medial side. In our material (100 hemispheres) the artery usually arises from the anterior cerebral artery at a point averaging 3.55 (0–15) mm distal to the anterior communicating artery; in approx. 8.5% it arises from the frontopolar branch, in 8.5% from the anteromedial frontal branch and in 1% from the long central artery. Reduplication of the medial frontobasal branch is not uncommon, and sometimes it runs on the orbital surface of the frontal lobe (Lang and Häckel [39]).

2.4 Frontopolar branch

The frontopolar branch, not listed in Nomina Anatomica, arises from the anterior cerebral artery; in our material its point of origin was most commonly situated in the vicinity of the rostrum of the corpus callosum and 9.18 (2–25)mm distal to the anterior communicating artery. Less commonly it arises in conjunction with the frontobasal branch. In approx.

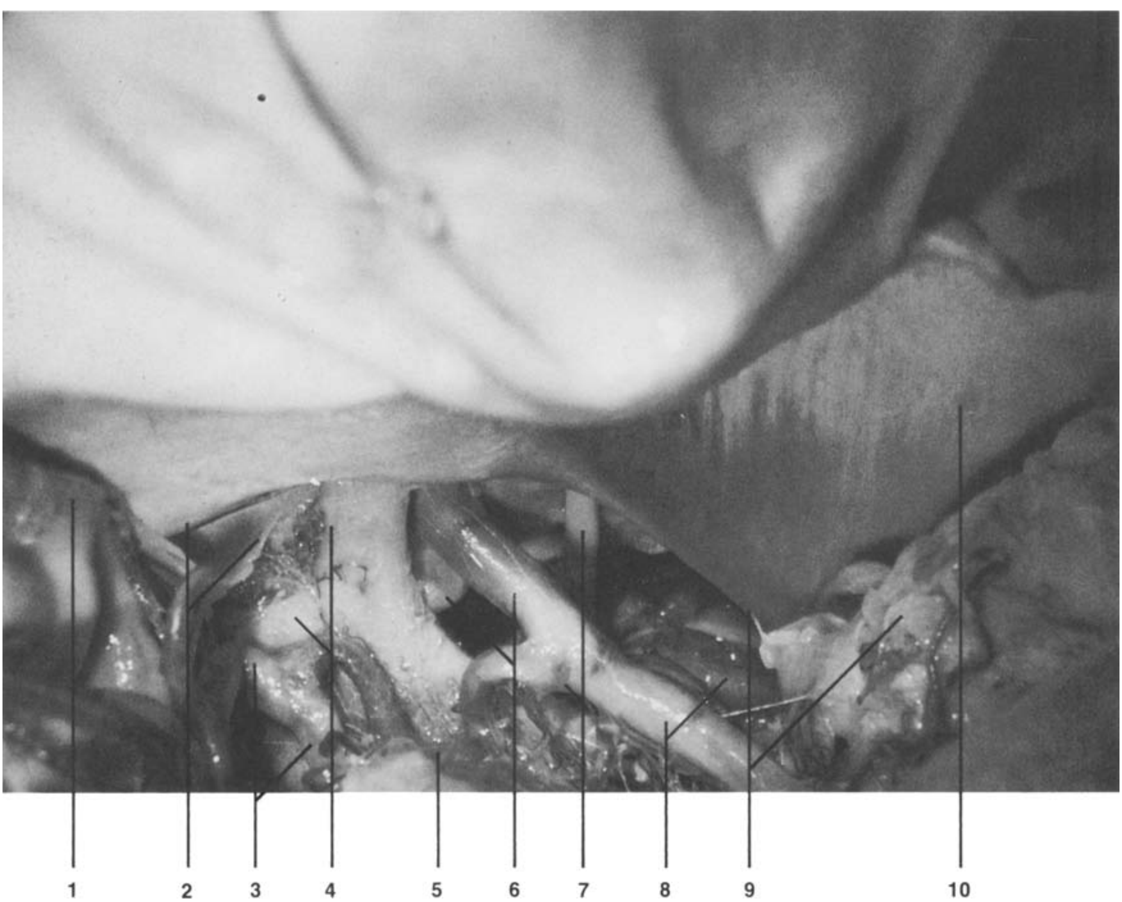

Fig. 27b. Pterional approach to hypophyseal region (Right).
1. Right gyrus rectus. 2. Jugum sphenoid. and ant. Lillijeqvist's membrane. 3. Anterior communicating artery and A_2-segment. 4. Optic chiasm and optic nerve. 5. A_1-segment. 6. Posterior clinoid process and ICA. 7. Third nerve and bifurcation of ICA. 8. Middle cerebral artery and posterior cerebral artery. 9. Incisura tentorii and temporal lobe. 10. Tentorium cerebelli.

30% it originates from the anteromedial frontal branch and in just over 3% from a cingulomarginal artery (Lang and Häckel [39]). The vessel has an average diameter of 0.97 (0.5–1.5)mm and runs obliquely across the medial surface of the hemisphere towards the frontal pole, supplying the medial aspects of the hemisphere, the anterior inferior portions of the superolateral surface and in 10% also the anterior part of the orbital surface of the frontal lobe. Combined supply of this area from the contralateral artery has been observed.

2.5 Lateral frontobasal branch

The lateral part of the orbital surface of the frontal lobe is usually supplied by the lateral frontobasal branch arising from the middle cerebral artery. As regards its area of supply, it has a vicarious relationship with the medial frontobasal branch and the frontopolar branch of the anterior cerebral artery.

Pterional approach (Figs. 27a, b)

The pterion is the sutural zone between the frontal bone, the greater wing of the sphenoid bone, the parietal bone and the anterior border of the squama temporalis. In the most cases there is a sutural zone like an H. Sometimes the squama temporalis reaches in this area the frontal bone but mostly the greater wing is connected with the parietal bone. In about 80% there is a slight impression in the area which reaches upwards and dorsally and corresponds to the ridge on the inner surface of the skull in the area of the lateral cerebral sulcus. Below this impression in most conditions a protuberance which corresponds

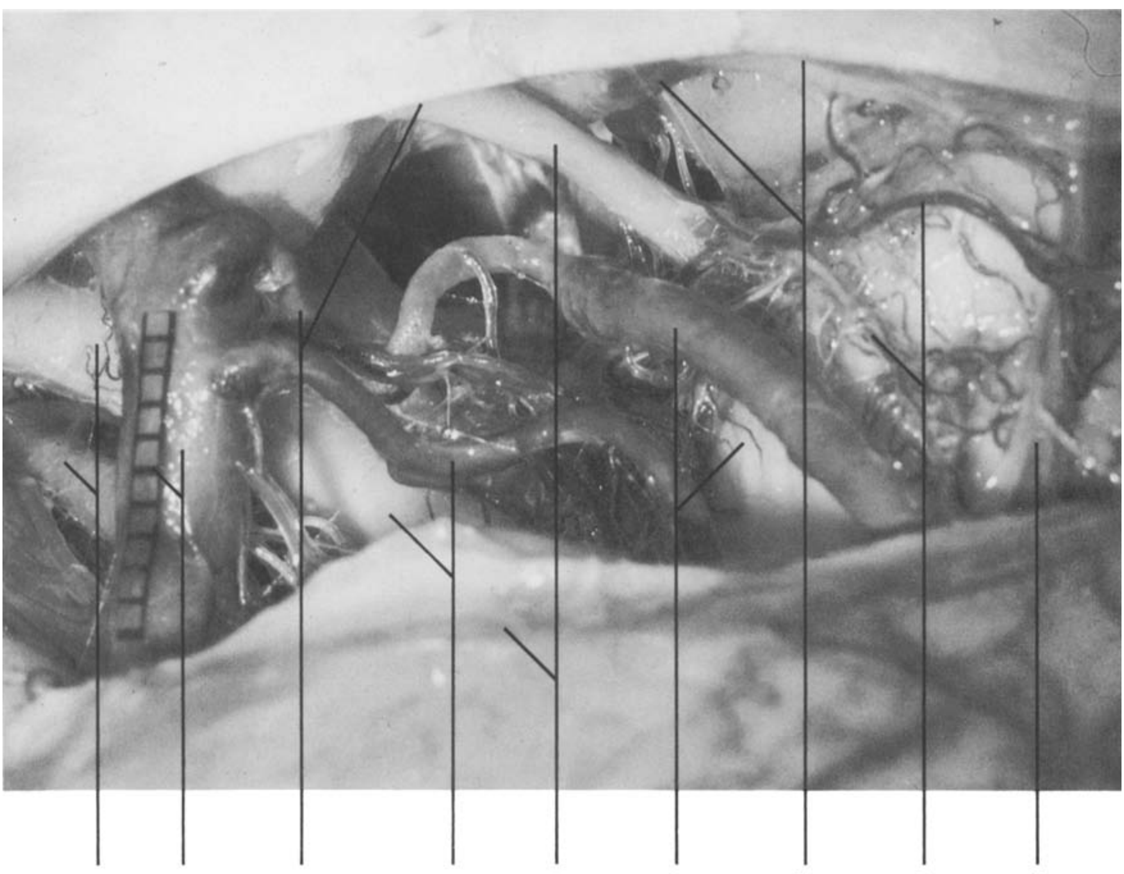

Fig. 28. Subtemporal approach to hypophyseal region (Right).
1. Optic nerve and anterior cerebral artery. 2. Internal carotid artery, mm-paper. 3. Posterior communicating a. and ant. petroclinoid fold. 4. Anterior choroidal artery and optic tract. 5. Oculomotor nerve and parahippocampal gyrus. 6. P_2-segment and cerebral peduncle. 7. Incisura tentorii and superior cerebellar artery. 8. A. laminae tecti and r. chor. post. med. 9. Lateral mesencephalic vein.

to the superior temporal gyrus is palpable and more often one corresponding to the middle temporal gyrus below this. The frontal ramus of the middle meningeal artery reaches this area in the bone in about 33%. In the other cases the middle meningeal branches are imbedded in the dura mater of this area. After opening the dura some neurosurgeons try to go along the sphenoidal ridge and anterior to the arachnoid membrane of the vallecula to the anterior cerebral and anterior communicating arteries. In these cases the arachnoid membrane is opened far medially.

The dorsally placed lesions are reached by opening the arachnoid membrane of the vallecula and insula. In these cases the middle superficial cerebral vein which often communicates with the sphenoparietal and paracavernous sinuses should be (if possible) preserved. By this approach are visible the internal carotid artery, the posterior communicating artery, the anterior choroidal artery and the posterior cerebral artery and its central branches. In the presence of tumours the basal cisterns are often widened and the basilar bifurcation, the posterior choroidal branches and the tectal artery as the superior cerebrellar artery and the superior part of the basilar artery with its central branches are visible.

Subtemporal approach (Fig. 28)

The pterional opening can be widened by removal of the posterior part of the greater wing of the sphenoid bone and the anterior area of the temporal squama. This approach allows a view of the hypophyseal area from laterally and a little bit below. The trigeminal ganglion area, the lateral wall of the cavernous sinus, the posterior communicating and anterior choroidal arteries with their central branches (inferior diencephalic branches) are visible by this approach (see figures).

Acknowledgement

I would like to express my best thanks to Mr. Charles Langmaid for the revision of the English text.

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Prof. Dr. Johannes Lang
Anatomisches Institut der Universität
Koellikerstr. 6
8700 Würzburg
F. R. Germany