Microanatomy and Possible Clinical Significance of Anastomoses Among Hypothalamic Arteries

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We examined anastomoses among the hypothalamic arteries in 14 human brains using an injection technique, microdissection, and a stereoscopic microscope. Five to 22 anastomoses (mean 10.1) were found in all 14 brains on each side, varying from 20 to 280 (mean 71) μm in diameter and from 0.1 to 5.3 (mean 1.52) mm long. A single hypothalamic artery may be connected to other vessels by one to 10 anastomoses. The anastomoses were channel-like or plexiform; both types may be ipsilateral or right-left. They connected the hypothalamic arteries “end-to-end,” “end-to-side,” and “side-to-side.” The interconnected arteries ranged from 30 to 1,900 (mean 148) μm in diameter. Anastomoses were most frequent among the commissural arteries and in the distribution of the superior hypophyseal arteries and the tuberoinfundibular branches of the posterior communicating artery. The largest anastomoses were found among the tuberoinfundibular branches of the posterior communicating and internal carotid arteries, as well as among the premamillary arteries and the mamillary branches. We discuss the neurologic, neuroendocrinologic, and neurosurgical significance of the described anastomoses. (Stroke 1989;20:1341-1352)

Most previous studies dealing with the anatomic examination of the hypothalamic arteries1-8 have only mentioned the presence of a “circuminfundibular plexus” without giving any information about the frequency, number, or size of the anastomoses within the plexus. Others9-12 drew special attention only to capillary connections and not to arterial anastomoses in the hypothalamopituitary region. Hence, there is an obvious lack of data concerning anastomoses among the hypothalamic arteries. These anastomoses could be of great neurologic, neuroendocrinologic, and neurosurgical significance for several reasons. Neurologists need information about the vascular pattern in the hypothalamic region to predict the risk of ischemic damage in that region following thromboembolic events and other pathologic processes that may compromise local blood flow; neurosurgeons, who perform delicate operations in the perichiasmatic, tuberal, and interpeduncular regions, must have detailed information on the hypothalamic microvasculature; and, finally, ongoing presence of these anastomoses could be a way of locally regulating neurosecretory activity.

Subjects and Methods

We examined 28 sets of hypothalamic arteries in 14 brains of individuals aged 28–67 years. Each brain was carefully removed from the skull after cutting the internal carotid arteries (ICAs), optic nerves, and pituitary stalk as low as possible. Plastic catheters were placed in the basilar artery and in both ICAs. In most instances, the main stems of the middle cerebral and anterior choroidal arteries were ligated, as were the distal segments of the anterior cerebral arteries (ACAs) and the posterior cerebral arteries (PCAs). Thereafter, the components of the circle of Willis were irrigated with isotonic saline and injected with a solution of gelatin, 10% India ink, and formaldehyde. The injected brains were then fixed in 10% formaldehyde solution for 3 weeks. The arteries of the fixed brains were dissected under a stereomicroscope, using neurosurgical microinstruments, while the brains were immersed in water.

We microdissected several thousand hypothalamic vessels from 14 brains, drew the microvasculature of each brain, and identified each hypothalamic vessel. The 10 best-prepared brains were used for photographs, measurements, and statistical analysis. All photographs were taken parallel
FIGURE 1. Summarized drawing of anastomoses (black) among a: right (1), left (2), anterior median (3), and posterior median (4) commissural arteries; b: median preoptic branch (5) of anterior communicating artery (6) and anterior cerebral artery (ACA) (7); c: two preoptic arteries (8) arising from ACA; d: preoptic artery and commissural arteries; e: preoptic artery (8) and optic branch (9) of ACA; f: preoptic artery (8) and supraoptic artery (10); g: supraoptic artery (10) and optic branch (11) of internal carotid artery (ICA) (12); h: right (13) and left (13’) superior hypophyseal arteries (SHAs); i: superior (13) and inferior hypophyseal arteries (cut); j: two ipsilateral SHAs (13); k: collateral branches of same SHA (13’); l: SHA (13) and optic branch (9); m: SHA (13’) and tuberoinfundibular artery (14) arising from ICA (12); n: SHA (13) and tuberoinfundibular artery (15) arising from posterior communicating artery (PCoA) (16); o: two tuberoinfundibular branches (14) of ICA; p: tuberoinfundibular branch (14) and optic branch (11) of ICA; q: tuberoinfundibular branch (14) and PCoA (16); r: tuberoinfundibular branch (14) of ICA and tuberoinfundibular branch (15) of PCoA; s: tuberoinfundibular artery (15) and optic branch (11); t: tuberoinfundibular artery (15) and PCoA (16); u: collateral branches of tuberoinfundibular artery (15); v: two ipsilateral tuberoinfundibular arteries (15); w: two contralateral tuberoinfundibular arteries; x: tuberoinfundibular artery (15) and mamillary branch (17) of PCoA; y: tuberoinfundibular artery (15) and mamillary branch (18) of PCA (19); z: two mamillary branches (17) of PCoA; a: mamillary branch (17) of PCoA and mamillary branch (18) of posterior cerebral artery (PCA); b: mamillary branch (18) and perforating branch (20) of PCA (19); c: mamillary branch (17) and premamillary artery (21); d: premamillary artery (21) and PCoA; e: premamillary artery (21) and peduncular branch (22) of PCA; f: premamillary artery (21) and anterior choroidal artery (23). 24, basilar artery; 25, left crus cerebri; 26, left mamillary body; 27, pituitary stalk (cut); 28, optic chiasm; 29, left optic nerve.
FIGURE 2. Anastomotic plexus (1) formed by branches of right (2), left (3), anterior median (4), and posterior median (5) commissural arteries. Anterior median commissural artery arises from median preoptic artery, which is connected (arrow) to anterior cerebral artery (6). Compare with Figure 1, a and b. 7, anterior communicating artery; 8, left anterior cerebral artery; 9, preoptic arteries; 10, supraoptic artery; 11, left optic tract. Basal and slightly caudal view after displacing optic nerves and optic chiasm ventrally. ×9.

Results

The hypothalamus is supplied by several groups of arteries. Thus, the rostral part of the hypothalamus (the preoptic area and a part of the supraoptic region) is mainly nourished by the commissural, preoptic, and supraoptic vessels that usually arise from the ACA and anterior communicating artery. The intermediate part of the hypothalamus (the supraoptic and tuberal regions and the rostral portion of the lateral hypothalamic area) is mainly supplied by the superior hypophyseal and tuberoinfundibular branches of the ICA and the posterior communicating artery (PCoA). The caudal part of the hypothalamus (the mamillary region and the caudal part of the lateral hypothalamic area) is nourished by the premamillary and mamillary branches of the PCoA as well as the mamillary branches of the PCA (Figure 1).

We examined the anastomoses among all the mentioned vessels and found them to be present in all 14 brains studied. The number of anastomoses varied from five to 22 (mean±SD 10.1±4.3) on either side of the brain and from 11 to 40 on both sides. A single hypothalamic artery may be involved in as many as 10 anastomoses. The anastomoses for each hypothalamic artery are as follows.

Four commissural arteries may be distinguished (Figure 1): the anterior median commissural artery, one of its branches, including the median preoptic arteries (Figure 1); the right and left commissural arteries, originating from the ACA or the preoptic arteries; and the posterior median commissural artery, arising from the right or left superior hypophyseal artery (SHA). The anastomoses among the commissural arteries themselves formed a delicate plexus in the middle of the lamina terminalis (Figures 1a and 2), and anastomoses were also observed among the commissural arteries and their neighboring arteries (Table 1).

There were usually three groups of preoptic arteries (Figure 1). The median preoptic arteries arose from the anterior communicating artery or one of its larger branches, while the medial and lateral preoptic arteries originated from the right and left ACAs. Anastomoses (Table 1) were found among the preoptic arteries as well as among the commissural arteries (Figure 1a and d), other preoptic vessels (Figure 1c), the optic branch of the ACA (Figure 1g), the supraoptic artery (Figure 1f), and the SHA (Figure 1d). In one brain we also found an anastomosis between a median preoptic artery and the main stem of the ACA (Figures 1b and 2) with a channel diameter of 210 µm.

The supraoptic artery was connected to the preoptic arteries (Figure 1f, Table 1), to the perforating branch of the ACA, to the optic branch of the ICA (Figure 1g), and to the tuberoinfundibular branch of the ICA. Anastomoses were usually located close to the lateral part of the optic chiasm (Figure 1).

One or two SHAs were present, arising from the ICA 95% of the time (Figure 3) or from the PCoA 5% of the time. Among various anastomoses that involved the SHA, we found one to three vessels connecting the collateral branches of the SHA (Figures 1k and 3) in 20% (four hemispheres). These
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<th>Artery</th>
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<th>Preoptic</th>
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<tr>
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<td>Optic branch of ICA</td>
<td>70%</td>
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<tr>
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<td>45%</td>
<td>10%</td>
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<td>PHA</td>
<td>60-110 (115)</td>
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<tr>
<td>PHA</td>
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**TABLE 1. Anastomoses Among Hypothalamic Arteries in Humans**
vessels connected the optic branches (Figures 1k and 3), the tuberoinfundibular branches, or both; the anastomotic vessels were 30–90 (mean±SD 51±20) μm wide and 0.2–2.1 (mean±SD 1.2±0.6) mm long. The interconnected branches were 50–170 (mean±SD 93±38) μm wide.

The two ipsilateral SHAs were connected in 15% of the hemispheres (Table 1, Figure 1j). The anastomoses between the right and left SHAs (Figures 1h and 4) were present in all 14 brains examined and connected the branches descending along the pituitary stalk, the optic vessels, the tuberoinfundibular branches, and the posterior median commissural arteries. There were one to four anastomoses, occasionally forming a small network, located just rostral to the proximal pituitary stalk, that is, between it and the optic chiasm (Figures 1h and 4). The anastomoses were 20–180 (mean±SD 68±44) μm wide and 0.1–1.7 (mean±SD 0.6±0.4) mm long. The interconnected branches were 90–280 (mean±SD 161±51) μm wide. The remaining anastomoses (Table 1) were observed among the SHA and the commissural arteries (Figures 1a and 2), the preoptic arteries (Figure 1d), the optic branch of the ACA (Figure 1l), the optic and/or tuberoinfundibular branch of the ICA (Figures 1m and 5), and/or the tuberoinfundibular branch of the PCoA (Figures 1n and 6). The anastomoses were usually observed at the level of the optic chiasm and the proximal pituitary stalk (Figure 1) or between the stalk and the optic tract (Figures 5 and 6).

The middle hypophyseal arteries, also called the loral or trabecular arteries, connect the SHA and the inferior hypophyseal artery. Since the middle hypophyseal arteries were cut in all 14 brains examined (Figures 1i and 3), we did not examine these anastomotic channels in this study.

In two hemispheres (10%), we found anastomotic channels 30–150 μm wide and 0.4–2.3 mm long among the collateral branches of the tuberoinfundibular branch of the ICA. The two ipsilateral tuberoinfundibular branches were occasionally interconnected (Figure 1o). Table 1 shows that anastomoses may exist among the tuberoinfundibular artery and the supraoptic vessel, the SHA (Figures 1m and 5), the optic branch of the ICA (Figure 1p), the PCoA (Figure 1q), and the tuberoinfundibular branch of the PCoA (Figures 1r and 7). These anastomoses were usually situated between the optic tract and the proximal pituitary stalk (Figures 5 and 7).

Anastomoses were found not only between the tuberoinfundibular branch of the PCoA and the neighboring vessels, but also among the collateral branches of the branch itself in 20% (two brains) (Figure 1u). There were one to three anastomotic channels 30–100 (mean±SD 62±29) μm wide and 1.0–1.8 (mean 1.4) mm long. The interconnected branches were 70–210 (mean±SD 134±53) μm in diameter. In brains with several tuberoinfundibular arteries, the anastomoses could connect the ipsilat-
FIGURE 3. 

Anastomosis (arrows) between two optic branches (1 and 2) of left superior hypophyseal artery (3). Note left trabecular artery (4). Compare with Figure 1, k and i. 5, right superior hypophyseal artery; 6, pituitary stalk (cut); 7 and 7', right and left internal carotid arteries; 8 and 8', right and left optic nerves; 9, anterior cerebral arteries. Basal view. ×5.1.

FIGURE 4. Small anastomotic plexus (arrows) between rostral stems (1 and 1') of right (2) and left (2') superior hypophyseal arteries. Compare with Figure 1h. 3, posterior median commissural artery; 4, optic chiasm; 5, pituitary stalk (cut). Basal view. ×36.5.
FIGURE 5. Anastomosis (large arrows) between caudal stem (1) of right superior hypophyseal artery (2) and branch (3) of tuberoinfundibular artery (4) arising from internal carotid artery. Compare with Figure 1m. Note also anastomoses (small arrows) connecting two branches of same tuberoinfundibular artery. 5, right posterior communicating artery; 6, right posterior cerebral artery; 7, right optic tract; 8, pituitary stalk (cut). Basal and slightly caudal view. X13.8.

FIGURE 6. Anastomoses (arrows) between branch (1) of right superior hypophyseal artery (2) and branch (3) of tuberoinfundibular artery (4) arising from right posterior communicating artery (5). Compare with Figure In. 6, internal carotid artery; 7, right optic tract; 8, pituitary stalk (cut). Basal view. X6.3.

FIGURE 7. Anastomosis (arrows) between branch (1) of tuberoinfundibular artery (2) arising from left internal carotid artery (3) and branch (4) of tuberoinfundibular artery (5) arising from posterior communicating artery (6). Compare with Figure 1r. 7, left mamillary body; 8, left optic tract. Basal view. X7.9.
FIGURE 8. Anastomosis (small arrows) between two (1 and 2) tuberoinfundibular arteries arising from left posterior communicating artery (3). Note also anastomosis (large arrow) between tuberoinfundibular artery (1) and posterior communicating artery (3). Compare with Figure 1v and t. 4, superior hypophyseal artery; 5, left optic tract. Basal view. x15.5.

The mamillary branches of the PCA (Table 1) were either interconnected or connected to the tuberoinfundibular branch of the PCoA (Figures 3y and 3d), the mamillary branch of the PCoA (Figures 3a and 3e), the interpeduncular branch of the PCA (Figure 3b), and/or the premamillary artery (Figure 3c). The anastomoses were situated close to (Figure 1) or on the surface of the mamillary body (Figure 10).

The premamillary (thalamotuberal, anterior thalamoperforating) artery always arose from the PCoA. The anastomoses involving the premamillary artery were rare and, when present, few. We observed vascular connections among this artery and (Table 1) the tuberoinfundibular branch of the PCoA, the mamillary branch of the PCoA (Figure 3c) or of the PCA (Figure 3d), the PCoA (Figure 3e), the peduncular branch of the PCA (Figures 3f and 9), and/or the perforating branch of the anterior choroidal artery (Figure 3g). The latter anastomotic channel was 280 \( \mu m \) wide and 0.3 mm long. The anastomoses were usually located among the mamillary body, optic tract, and cerebral peduncle (Figures 1 and 9).

Anastomoses among the hypothalamic arteries varied from 20 to 280 (mean±SD 71±44) \( \mu m \) wide and from 0.1 to 5.3 (mean±SD 1.5± 0.9) mm long. The diameter of the connected arteries ranged from 30 to 1,900 (mean±SD 148±83) \( \mu m \). The number of anastomoses was correlated with their common diameter; the more common the anastomoses, the larger their diameter. The common diameter varied from 620 to 3,170 (mean 1,044) \( \mu m \). There were five to 22 anastomoses (mean 10.1), with five anastomoses seen in 30% (six) of the hemispheres. A correlation between the number and size of certain hypothalamic arteries, and the number and caliber of their anastomoses, was not observed.

The anastomoses were like channels or like a network, with channel-like anastomoses connecting...
FIGURE 10. Anastomosis (arrows) between mamillary branch (1) of left posterior communicating artery (2) and mamillary branch (3) arising from interpeduncular perforating branch (4) of left posterior cerebral artery (5). 6 and 6', right and left mamillary bodies; 7, median eminence. Basal and slightly caudal view. ×8.8.

FIGURE 11. Anastomosis (small arrows) between mamillary branch (1) arising from right posterior cerebral artery (2) and branch of tuberoinfundibular artery (3) arising from left posterior communicating artery (4). Compare with Figure 10. Note also anastomosis (large arrows) between mamillary branch (5) of left posterior cerebral artery (6) and branch (7) of premamillary artery (not visible). 8, median eminence; 9 and 9', right and left mamillary bodies. Basal view. ×11.
either the proximal (Figures 8, 9, and 12) or the distal (Figures 4–7, 10, and 11) portions of the hypothalamic arteries. Where there were many anastomoses, we observed various arrangements such as parallel, alternating, or successive. While some anastomoses connected two adjacent vessels, others connected several hypothalamic arteries (Figure 13). The channel-like anastomoses connected these arteries "end-to-end" (Figure 6), "end-to-side" (Figure 5), or "side-to-side" (Figures 8–10 and 12). The plexiform anastomoses were located at the level of the lamina terminalis and sometimes around the proximal pituitary stalk, as well as in the region of the median eminence (Figure 1).

The anastomoses most often involved the commissural arteries and the SHAs as well as the tuberoinfundibular branches of the PCoA (Table 1). The largest anastomoses were observed among the tuberoinfundibular branches of the PCoA or ICA, as well as among the premamillary arteries and the mamillary branches, and were rarest in the distribution of the supraoptic and premamillary arteries.

Discussion
The small central branches of the cerebral arteries, especially the perforating arteries, have been regarded for decades as end arteries. Subsequent investigation has confirmed the opinion for all of these vessels except the interpeduncular (thalamoperforating) branches of the PCA. Our present study not only revealed the existence of hypothalamic arterial anastomoses in all 14 brains examined, but also the possibility of involvement of all the hypothalamic arteries in such connections.

The hypothalamus is highly protected against ischemic lesions because so many anastomoses among the hypothalamic arteries are continually present and of considerable size. Hence, lesions are possible only in systemic disorders (such as arteriosclerosis, diabetes mellitus, multiple microembolism, bleeding disorders, and increased intracranial pressure), following trauma, and during neurosurgery. However, there is a greater risk of ischemic lesions in the hypothalamus of patients having few anastomoses. Such a lesion may lead to various clinical signs and symptoms, depending on the hypothalamic region involved, and may be categorized as visceral, autonomic, endocrine, or metabolic disorders, or as personality changes. Also, more frequent ischemic lesions can be expected in the supplying region of those hypothalamic arteries with sparse anastomoses, such as the premamillary artery. Earlier data confirm that this artery is often mentioned in relation to lateral hypothalamic and
antrolateral thalamic infarcts. Sparse anastomoses in the territory of some other hypothalamic arteries are compensated for by their varied supply sources. For example, the supraoptic nucleus can be nourished by the supraoptic vessels arising from the ACA, ICA, and SHA. Occlusion of one of these vessels usually is not sufficient to cause any neuroendocrine disorder.

In addition to the role they play in preventing ischemic lesions of the hypothalamus in most patients with cerebrovascular disease, these anastomoses may also be of considerable neuroendocrinologic significance. It is well known that branches of the SHA and tuberoinfundibular artery form the primary capillary plexus in the median eminence and the proximal pituitary stalk. The portal vessels leave this plexus to form the adenohypophyseal sinuses. There is experimental evidence that under some circumstances, blood flow reverses from the anterior pituitary to the median eminence. Three findings are particularly important: the presence of some adenohypophyseal hormones in portal vessels, the detection of certain substances in the hypothalamus after injecting them into the pituitary, and a few veins draining the blood from the adenohypophysis. Because of the reversed blood flow, pituitary hormones, and perhaps the peptide hormones released within the median eminence, may reach certain hypothalamic arteries and, through anastomoses, almost all other hypothalamic arteries. These hormones may influence the hypothalamus in two ways. First, some hormones may change the diameter of the hypothalamic vessels and so regulate the neurosecretory activity of certain hypothalamic nuclei. The presence of the peptidergic receptors and nerves in the walls of cerebral and hypothalamic arteries in humans has been reported. Second, thanks to anastomoses, these hormones can reach any part of the hypothalamus and thus may regulate its activity directly, especially in regions lacking a blood-brain barrier, such as the organum vasculosum of the lamina terminalis. Although other authors have reported similar suggestions, our hypotheses will remain speculative until new evidence of reversed blood flow is provided, especially direct observation of blood flow in living animals.

Finally, the hypothalamic arteries and their anastomoses are very important from a neurosurgical point of view for at least three reasons. First, the hypothalamic arteries’ parent vessels are often the sites of aneurysms, which may compress and/or distort the hypothalamic arteries. Second, we have observed roughly 400–500 hypothalamic arteries, branches, and anastomoses at the level of the hypothalamus, a region measuring approximately 2×2 cm. Finally, unexpected anastomotic channels may be injured during aneurysm surgery, especially during dissection of the interconnected hypothalamic vessels from the aneurysmal wall. Hence, great care must be taken during any operation in the hypothalamic region.

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