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Review

Clinical significance of blood supply to the internal capsule and basal ganglia

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ABSTRACT

Although the general vascular supply of the basal ganglia and internal capsule is well known, precise data are lacking regarding the variations of the vascular territories in the two regions. Twelve hemispheres were studied following an injection of coloured ink into the main cerebral arteries, namely the anterior cerebral (ACA), middle cerebral (MCA), anterior choroidal (AChA) and posterior cerebral artery (PCA). Serial sections of the injected hemispheres were taken in the axial or coronal plane. In 75% of the hemispheres, ACA perforators were seen to supply the inferomedial part of the head of the caudate nucleus and the anterior limb of the internal capsule, as well as the anterior and inferior portions of the putamen and globus pallidus. The MCA vessels perfused the superolateral part of the head and body of the caudate nucleus, the superior part of the entire internal capsule, most of the putamen and part of the globus pallidus. The AChA perforators perfused the medial segment of the globus pallidus, the inferior part of the posterior limb, the retrolenticular and sublenticular portions of the internal capsule, and occasionally its genu. The same segment of the globus pallidus and the inferior part of the genu of the internal capsule were most likely supplied by the perforators of the internal carotid artery. A predominance of ACA territory was noticed in one specimen (8.33%) and a predominance of MCA territory in two specimens (16.67%). The obtained anatomical data may help radiologic determination of perforators involved in ischemic events, as well as a better understanding of the neurological deficits in the same events.

1. Introduction

Knowledge of the vascular supply of the central hemispheric region is very important for neurologists, neuroradiologists and neurosurgeons, as ischemic lesions in this region, especially within the internal capsule, may cause serious motor, sensory, cognitive or behavioural disabilities [1–10].

The aim of our study was to examine the vascular territories of groups of perforating vessels using a selective injection method, and to compare our results with the findings of other authors [5,6,11–18]. We hoped to solve at least some disagreements regarding the blood supply of portions of the internal capsule and basal ganglia [16,17]. In addition, this study aimed to contribute to a precise neuroanatomic understanding of the radiologic appearance of ischemic areas in this region. We aimed to create a better understanding of their clinical manifestations, enable prediction of possible neurological deterioration in stroke patients, and to assist safer neurosurgical interventions in the region of the perforating arteries [19–25].

2. Materials and methods

Twenty hemispheres from individuals aged from 38 to 67 years, who were free from neurological disease, were taken during routine autopsy 11 to 18 hours after death. The procedure was approved by the Institute of Pathology and the Ethics Committee of the University Clinical Centre. The corresponding basal cisterns were opened, and the main cerebral arteries in these regions were carefully microdissected under a stereoscopic microscope (Leica MZ6, Leica Microsystems, Belgrade, Serbia) using standard neurosurgical microinstruments. After placing catheters into the terminal part of the basilar artery and the supraclinoid segment of the internal carotid arteries (ICA), the cerebral vasculature of each hemisphere was washed out with an isotonic saline solution until clear fluid emerged from the cut superficial cerebral veins.

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In six hemispheres microcatheters were introduced into the initial part of the proximal (A1) segment of the anterior cerebral artery (ACA), the proximal (M1) part of the middle cerebral artery (MCA), the anterior choroidal artery (AChA), the proximal (P1) segment of the posterior cerebral artery (PCA), and the distal (P2) segment of the PCA. Each of those segments was also ligated just distal to the last perforating vessel arising from the corresponding parent artery. Thus, the A2 segment of the ACA was ligated close to the anterior communicating artery (AComA), that is just distal to the origin of Heubner's artery. The ligature was placed on the distal part of the M1 segment close to the limen insula. The AChA was not occluded. The PCA was ligated near the posterior communicating artery (PComA), as well as proximal to the thalamogeniculate arteries. All catheters were introduced through the ICA, except for those in the P1 segment which were placed through the basilar artery. Hence, both the ICA and basilar artery were ligated, as was the PComA. Therefore, the ICA and PComA themselves were not injected. Colored ink was selectively injected into the cerebral arteries of the six hemispheres as described above.

In the remaining 14 hemispheres the whole cerebral artery was injected, meaning both the perforating and leptomeningeal branches. A 10% mixture of gelatin and colored ink was manually injected at the same time through all the placed microcatheters of each hemisphere. The same coloured ink was used for the corresponding artery. Yellow ink was injected into the A1 segment, red into the M1 segment, blue into the AChA, black into the P1 segment, and brown into the P2 segment. All hemispheres were injected in this manner except four, in which the whole PCA territory was labelled with brown ink. As in the previous six hemispheres, the unlabeled areas belonged to the ICA and PComA territories. If a small poorly labeled patch appeared in a stained area, especially in the region of the white matter, which is less vascularized than the gray matter, its territory was easily determined by the color within the transversely sectioned vessels in that area.

Despite carefully performing each step of the technical procedure, the subarachnoid segments of tiny perforating vessels ruptured in some hemispheres during injection, whilst in others, an intracerebral rupture occurred. In some specimens air bubbles entered small perforators, so their region of supply was not labeled. Consequently, some specimens were excluded from the present study. The 12 best injected hemispheres were used for further examination.

All hemispheres were fixed in a 10% formaldehyde solution for 6 weeks. Serial sections of the hemispheres were made using a long, thin knife with two opposite blades. The sections of eight hemispheres were taken in the axial plane (Fig. 1) parallel to the bicommissural line, which interconnects the anterior and posterior commissures, and the remaining four hemispheres were cut in the coronal plane, perpendicular to the bicommissural line.

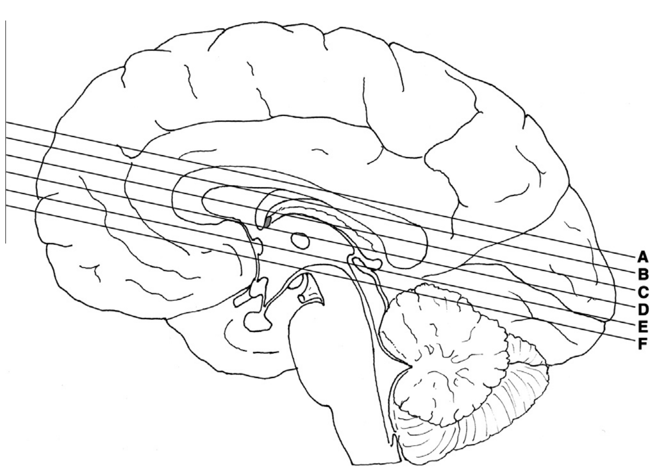

Fig. 1. Diagram of a sagittal view of the brain showing the planes of the axial sections in Supplementary Figures 1, 2 and 4.

Each slice was photographed from the same distance using a Nikon camera with macrolenses (Chiyoda, Tokyo, Japan) under three 1,000 watt spot lights. All the sectioned cerebral structures were identified and checked with corresponding brain atlases [26–28]. Percentages were calculated for variations in the supply of the internal capsule and basal ganglia. In order to enable comparison of the specimens, only right hemispheres are presented here.

Finally, the vascular system of two additional hemispheres was injected with methylmethacrylate. When polymerization was completed, the hemispheres were immersed in 30% potassium hydroxide for 6 days. The obtained corrosion specimens were washed, dried and examined under a stereoscopic microscope.

3. Results

The internal capsule, with its anterior limb, genu, posterior limb, and the retrolenticular and sublenticular portions, is supplied by the perforating branches of the main cerebral arteries (Supp. Fig. 1, 2). The perforators also perfuse the basal ganglia, that is, the caudate nucleus, putamen and globus pallidus. We present first the most common vascular pattern of the perforator territories identified in our hemispheres, and then variations in the perfusion.

3.1. Common vascular pattern

The blood supply of the internal capsule and basal ganglia was examined in the axial (Fig. 1) and coronal sections of the 12 injected hemispheres. The most common vascular pattern seen in our specimens was found in nine hemispheres (75%).

In the axial section through the upper part of the corpus callosum (Fig. 1A, Supp. Fig. 1A) MCA perforators were seen to supply solely the head of the caudate nucleus, the entire superior part of the internal capsule and a small part of the corona radiata.

The axial section through the inferior margin of the body of the corpus callosum (Fig. 1B, Supp. Fig. 1B) showed the MCA perforators to supply the whole or the lateral half of the head of the caudate nucleus, whilst the remaining medial part of the head was perfused by ACA perforators, predominantly Heubner's artery. The MCA perforators also supplied the entire putamen, anterior limb, genu and most of the posterior limb of the internal capsule. The most distal part of the posterior limb was supplied by the AChA perforators, except occasionally along the posterolateral region of the thalamus, where the posterior limb was perfused by PCA twigs.

The axial section through the genu and splenium of the corpus callosum (Fig. 1C, Supp. Fig. 1C) indicates MCA perforators supply one-half or one-third of the head of the caudate nucleus, with the remainder supplied by ACA perforators. The former twigs at this level also supply almost the entire anterior limb of the internal capsule, putamen, proximal part of the posterior limb of the capsule, and some parts of the claustrum and occasionally the external capsule. The most medial part of the anterior limb is supplied by ACA perforators. The genu at this level is most likely to be vascularized by ICA perforators, whereas the distal half or two-thirds of the posterior limb and the retrolenticular portion of the internal capsule are supplied by AChA perforators. Finally, the tail of the caudate nucleus is usually nourished by PCA twigs.

The axial section through the interventricular foramen of Monro, or just below that level (Fig. 1D, Supp. Fig. 1D), showed MCA perforators to supply a small, most lateral part of the head