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The vascular territories of the carotid and vertebrobasilar systems. Diagrams based on CT studies of infarcts

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We present 9 diagrams illustrating the vascular territories in the posterior fossa and in the supratentorial compartment of the head in transverse sections and briefly discuss variations and peculiarities of territories and within territories.

Key-Words: Vascular territories - CT - infarcts - carotid artery - vertebrobasilar system.

When a patient with clinical diagnosis of stroke is submitted to CT, the chances of misdiagnosis are negligible and the differential diagnosis is usually restricted to ischemic or hemorrhagic infarction, or intracerebral hematoma. Extravasated blood is immediately recognizable on CT, but in ischemic infarct the possible range of images is wide: there may be various changes in density or none at all and there may or may not be enhancement after intravenous contrast medium injection, depending on the time elapsing since the stroke. Knowledge of the patterns of evolution of these changes is essential in the diagnosis of infarct.

In the early phase of edema, which is not always easily recognizable (first week), or in the phase of macrophage migration and capillary proliferation (second-third week), the extent of the infarction may be underestimated. The full extent of the infarcted area is usually best appreciated in the late phase of necrosis and of cystic transformation, which begins 3-4 weeks after stroke. Knowledge of the clinical history or at least of the date of onset of clinical symptoms and signs is therefore essential for any meaningful interpretation of the CT findings and for correlation of the lesion with the time of stroke.

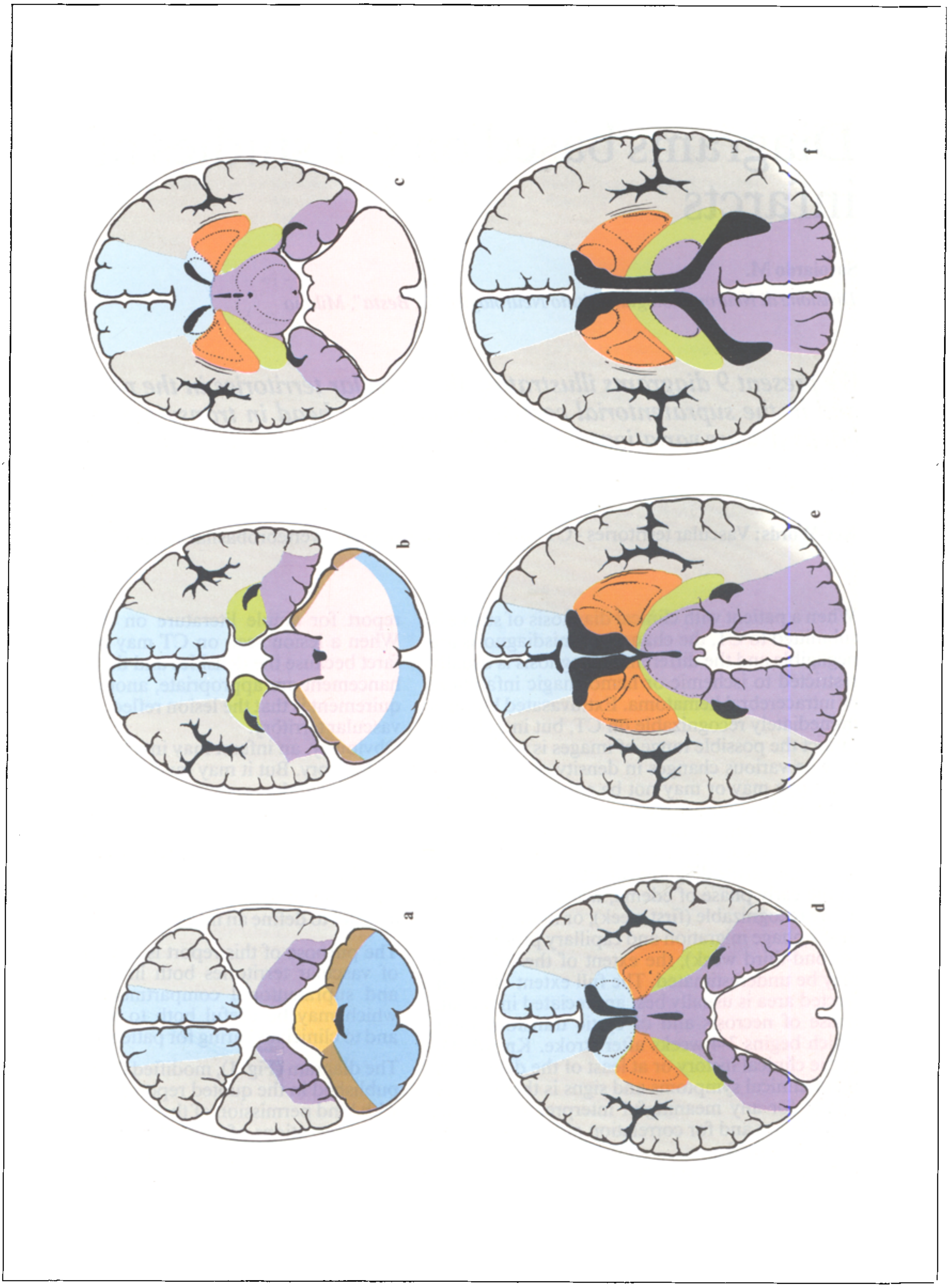
Detailed reports about changes of density and of enhancement in the different phases of evolution of an infarct have been published by several authors. A review of all the aspects that may be observed in CT studies in stroke has been recently published by us and the reader may refer to that report for ample literature on the subject [11].

When a lesion seen on CT may represent an infarct because the densities and the patterns of enhancement are appropriate, another essential requirement is that the lesion reflect, in some way, a vascular territory.

Obviously, an infarct may involve a whole vascular territory. But it may involve only a part, being limited to the area supplied only by a few branches or by a single branch of a major artery. It is also well known that infarcts may occur in the border zone between two adjacent vascular territories. Therefore, knowledge of the vascular territories and of their possible variations is essential in order to define an infarct.

The purpose of this report is to present diagrams of vascular territories both in the infratentorial and supratentorial compartments of the head, which may be useful both to neuroradiologists and to clinicians caring for patients with stroke.

The diagram (Fig. 1), modified from a similar one published in the quoted report [11] and presented with kind permission of the publisher, is based on the observations of more than two thousand CT scans performed in patients with stroke, on correlations between CT pictures and angiograms, and on the knowledge of the vascular anatomy gained from the work done by several authors, particularly Salamon [9, 10]. Essential other references are Lazorthes [8], Berman, Hayman and Hinck [1, 2, 6] and Damasio's templates [4].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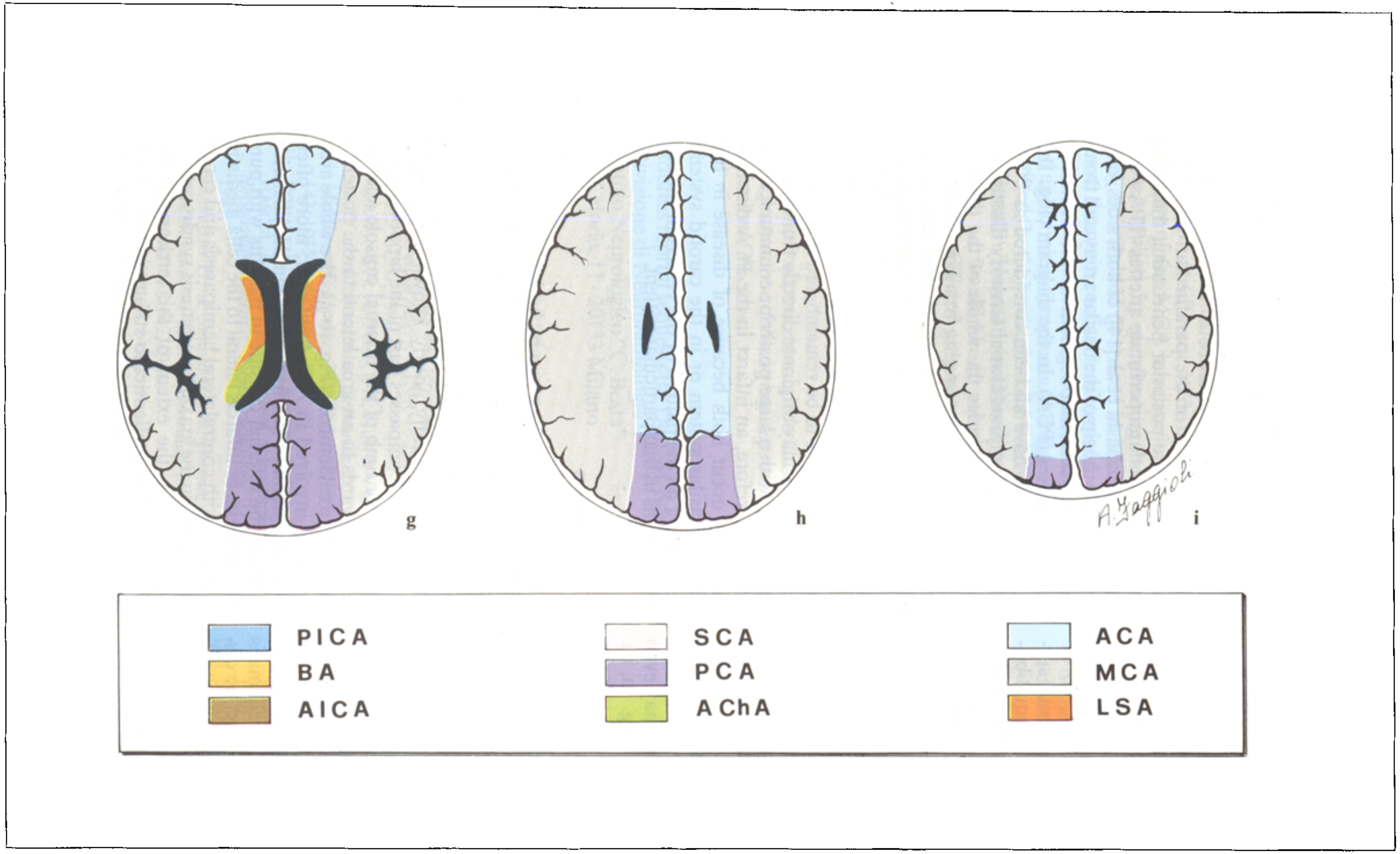

Fig. 1. *Vascular territories. PICA = posterior inferior cerebellar artery; BA = basilar artery; AICA = anterior inferior cerebellar artery; SCA = superior cerebellar artery; PCA = posterior cerebral artery; this territory includes that of the perforating branches of the posterior communicating artery; AChA = anterior choroidal artery; ACA = anterior cerebral artery; MCA = middle cerebral artery. Territory of the perforating lenticulostriate arteries (LSA) of the MCA is indicated separately.*
Modified from Fig. 15-3 of "CT scanning". In: "Stroke: pathophysiology, diagnosis, and management"; Barnett, Mohr, Stein, and Yatsu eds. By permission of Churchill Livingstone Inc.

Vertebrobasilar system

The vascular territories in the posterior fossa are poorly known. Very few papers have correlated the areas of infarction seen on CT scans with the specific vascular territories of the major cerebellar arteries (posterior inferior cerebellar artery or PICA, anterior inferior or AICA, and superior cerebellar artery or SCA) [3, 7]. A detailed report about cerebellar and brain stem vascular territories is in press [12].
The most important features appear in the first four schemes (Fig. 1 a-d).
The PICA territory is on the inferior, occipital surface of the cerebellum and is in a sort of equilibrium with that of the AICA. The larger the former, the smaller the latter, and viceversa. The variations in size and length of the PICA and AICA are well known from angiography. What is characteristic of a PICA infarct is its inferior location with posterior extension which is at a slightly higher level than the remainder of the territory, as is well demonstrated by sagittal sections on magnetic resonance imaging (MR) [12]. Therefore, in infarcts in the PICA territory, the transverse sections of CT demonstrate a characteristic posterior superior extension with a crescent shape (Fig. 1b).
The AICA territory may be limited to the lateral inferior pontine area and the adjacent floccular region, but it usually includes the whole anterior petrosal surface of the cerebellum, and may even extend posterior to the lateral angle (Fig. 1a, b).
The border between AICA and PICA territories on the lateral part of the inferior surface of the cerebellum has an oblique direction, antero-posterior, medio-lateral, because the course of the hemispheric branches both on the inferior and the superior surface of the cerebellum is oblique, antero-posterior, medio-lateral.
The SCA territory has fewer variations, and infarctions on this superior, tentorial surface are more easily recognized because of less bone-related artifacts. In unilateral infarcts, there is always a sharp delimitation on the midline because the superior vermian branches do not cross the midline but have a sagittal course. However, this sharp delimitation may not be evident until the late phase of infarction; in the early phases, when edema is present, the midline structures may in fact be displaced across the midline, creating diagnostic difficulties if the clinical history is unknown.
Infarcts in the brain stem may be recognized at the level of the medulla oblongata only by MR [12]. At pontine level, they are often paramedian, sharply delimited on the midline because the paramedian penetrating branches of the basilar artery have a sagittal course and do not cross the midline [12]. Obviously, bilateral infarcts may occur, but are rarely observed unless they are small: patients with extensive brain stem infarcts often do not survive long enough to be studied by CT.
At mesencephalic level the rule of sharp delimitation on the midline is not valid. Rather, the opposite situation occurs: the most frequent infarcts observed in this area are central with bilateral upward extension in the thalami in a butterfly shape. This is due to simultaneous involvement by thrombi or emboli of the paramedian mesencephalic and of the posterior penetrating thalamic branches (or thalamoperforate arteries -TPAs- according to Takahashi et al. [14]) of both sides, originating from the tip of the basilar artery and from the precommunicating segment of the posterior cerebral arteries (PCA). In the diagram (Fig. 1b, c), these areas have all been considered as PCA territory. PCA supratentorial territory illustrated in the figures includes the whole of the thalami (Fig. 1d-f), where penetrating branches from the posterior communicating arteries (or thalamotuberal arteries-TTAs-), the thalamogeniculate arteries-TGAs- and branches from the posterior choroidal arteries have distinct areas of supply, described by Takahashi et al. [14].
Of course, hit has to be remembered that the "fetal-type" PCA may originate directly from the carotid artery with a large posterior communicating artery; therefore, an infarct in the PCA distribution may occur both because of disease in the vertebrobasilar system or in the carotid system, depending on the pattern of the vessels of the circle of Willis in that particular patient.

Carotid system

This is much better known by both neuroradiologists and neurologists and the diagrams are self-explanatory. A few points are, however, worth stressing.
First, the territory of the anterior choroidal artery (AChA) is generally poorly known but is quite distinct: it encompasses part of the hippocampus, the posterior limb of the internal capsule and extends upwards to an area lateral to the posterior part of the cella media (Fig. 1b-g). The whole area is rarely involved in AChA infarcts; more often one sees small or lacunar infarcts in the posterior limb of the internal capsule in patients with pure hemiplegia, or infarcts lateral to the cella media in patients with contralateral hemiparesis and cerebellar signs, in the ataxic hemiparesis syndrome.
Variations in the extent of the territory of the AChA and of the lenticulo-striate arteries (LSA) of the middle cerebral artery (MCA), the neighboring territory, are possible but not as frequent and as extensive as variations observed in the posterior fossa with PICA and AICA.
Regarding the territory of the LSAs of the MCA (Fig. 1c-g), it is worth remembering that it includes most of the basal ganglia; a review of the

CT aspects of infarcts in this territory has been published by Takahashi et al. [13]. The inferior part of the head of the caudate nucleus is not involved in LSA infarcts because it is the territory of Heubner's artery, a branch of the anterior cerebral artery (ACA) (Fig. 1c, d).

The territory of the LSAs is indicated in the diagrams with a different color from the rest of the territory of the MCA because it is a well-defined area supplied by penetrating branches, which may be involved or spared in infarcts separately from the main cortical territory of the MCA.

Functional correlations between the area infarcted and clinical symptoms and signs have been described for the territories of ACA, MCA and PCA by Berman, Hayman and Hinck [1, 2, 6].

Finally, we would like to point out that in recent years, with CT and even more with MR, neuroradiologists have become aware of the high frequency of subcortical ischemic lesions that may affect the white matter quite extensively; the subcortical arteriosclerotic encephalopathy or Binswanger's disease is not at all rare, as was once believed [5]. The area that is mostly affected, where incomplete infarctions with demyelination, moderate loss of axons and gliosis are found, is a watershed area at the margins of the lateral ventricles. In fact, the periventricular white matter is the border zone between the territory of the LSAs and the territory supplied by the medullary arteries, i.e. branches which penetrate the white matter from the cortical vessels running over the convexity of the cerebral hemispheres.

In conclusion, despite the lack of accuracy due to the possible variations, and the incompleteness due to the representation only of the major territories, we hope that these diagrams will make for easier recognition of the vascular territories on CT scans and better definition of the areas involved in infarcts.

Sommario

Vengono presentate nove tavole illustranti schematicamente in sezioni trasversali i territori vascolari della fossa posteriore e delle regioni sopratentoriali. Variazioni e peculiarità dei territori e nei territori stessi sono brevemente discusse.

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