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Neuro radiology

A note on the cerebral arteries of Perissodactyla: the rete caroticum of *Diceros bicornis*

Dubious nomenclature of the internal carotid artery of horses

G. H. du Boulay

Institute of Zoology, Zoological Society of London, Regents Park, London, UK

Summary. The existence of a rete caroticum is reported in an adult black rhinoceros *(Diceros bicornis)*. Comparison of the arterial supply to the brain in other Perissodactyla, including the horse, suggests that what in them is generally called the "internal carotid" is the homologue of the ascending pharyngeal artery. This has far-reaching physiological implications.

Key words: Rete caroticum – Perissodactyla – *Diceros bicornis*

Since Thomas Willis (1684) [1], a clear distinction has been drawn between even-toed ungulates, all of which have retia carotica, and odd-toed ungulates, which have been thought to have a very different system. The cloven-footed (cattle, deer, antelope, pig, giraffe, hippopotamus) supply their cerebral arteries via complex networks of small arteries lying within the cavernous sinuses where they are bathed by venous blood. These retia are all supplied by branches such as the arteria anastomotica, the ramus anastomoticus or the ascending pharyngeal that originally derive from the external carotid. In many species the rete has been implicated as a heat exchanger in brain temperature regulation [2, 3]. du Boulay et al. [4] showed that, at least in the goat, the rete and branches that supplied it were also capable of autoregulation to favour the brain's blood supply during systemic arterial hypotension.

The theoretical advantage of an extradural method of autoregulation for long-legged, pronograde mammals has been previously propounded [4]. At that time the discovery that the adult black rhinoceros *(Diceros bicornis)* possessed a well-developed rete was also recorded, entirely against the preconception, following Willis [1], that Perissodactyla (odd-toed ungulates, the horse family) supplied their brains, like man via an undivided internal carotid artery.

The radiograph first demonstrating the rete caroticum of the rhinocerus has not been published until now.

Materials and methods

Single adult specimens of *D. bicornis* (black rhinoceros), *Equus caballus* (the horse), *E. burchelli* (zebra), and *Tapirus indicus* (tapir) were obtained as a result of death from natural causes. The heads were amputated and the cut ends of the common carotid arteries identified. Cannulae were tied into these and barium sulphate suspension (Micropaque) injected until adequate radiographs could be obtained showing the situation, branching and bony relationships of the major cerebral vessels. Stereoscopic views were usually used.

The head of *D. bicornis* was then deep frozen and divided in two by a single sagittal saw cut. After thawing, the two halves of the head were dissected by W. R. Cooke and G. H. du Boulay. The brain, with its barium-filled vessels, was subsequently radiographed on its own.

Results

Diceros bicornis

Radiographs. The rete caroticum is a symmetrical, more or less bilobed, very complex collection of interconnected vessels of irregular calibre, averaging about 1.2 mm in diameter. It lies astride the midline, embracing the basisphenoid, and receives its blood supply from two pairs of arteries. The smaller pair runs directly backwards from the facially-directed continuation of the maxillary artery and enters the rete at the anterolateral corners in a way very similar to the arteria anastomotica of, for instance, the goat. Each of the larger pair of supplying arteries is given off from the common carotid just proximal to the large occipital artery. It runs anteriorly, dorsally and medially in a gentle curve to a point immediately ventral to the rete, where it penetrates the skull base and enters the rete at its most lateral margin, two-thirds of the distance from the front of that structure.

Dissection. The vessels of the rete lay, as shown in the radiograph (Fig. 1), surrounded by the cavernous sinus. Anteriorly the vessels extended into the region of the orbital fissure; inferolaterally they lay adjacent to foramen lacerum, through which the larger artery of supply appeared to enter directly into the network. This artery could be followed directly from its origin in the neck; it lay in close proximity to the guttural pouch and then disappeared into the skull base at foramen lacerum. There was no internal carotid artery as seen in most mammals (other than Ungulates and Felidae), in which it enters the carotid canal close to the mastoid bulla and usually gives rise to the more or less well-developed stapedial artery; nor was there any other artery that might be considered the homologue of the ascending pharyngeal.

From the superior surface of the rete, both in the radiographs and on dissection, the paired anterior cerebral arteries, the middle cerebral and, on dissection, at

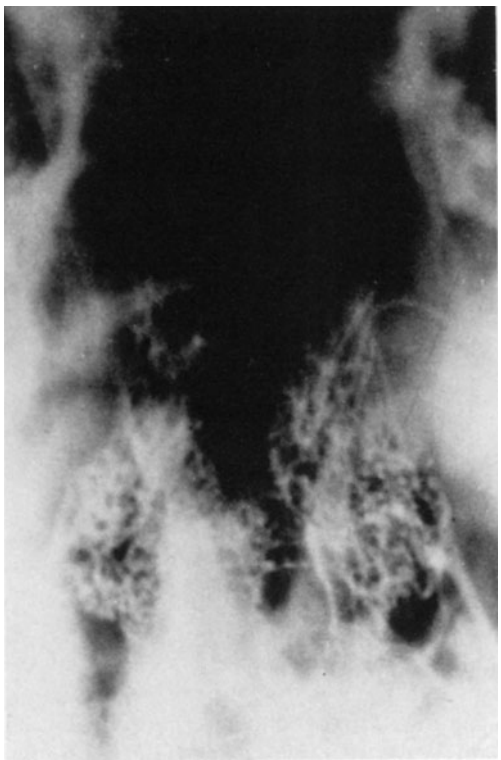

Fig. 1. Ventro-dorsal radiograph of the injected rete caroticum of the adult black rhinoceros

least two pairs of posterior cerebral arteries could be seen arising directly from the rete. There was no intracranial internal carotid artery but the cerebral vessels penetrated the dura directly from their origin in the retial network. Subsequent dissection and radiography of the brain showed in more detail the pial and perforating arteries, generally in line with the description by Garrod [5].

Equus caballus

Radiographs ([6], pp 238–241) show the similarity between horse and rhinoceros in the course of the main artery to the brain and particularly its point of entry into the cranial cavity. The intercarotid artery, an extradural anastomosis between the two brain-supplying arteries has been visualised.

The radiographs show how the occipital arteries (external carotid branches) are interposed between the major neck arteries (common carotid) and the cerebral vertebral arteries. There is little if any possibility of direct cervical vertebral-to-basilar artery blood flow.

Equus burchelli

Radiographs ([6], pp 242–243) show how the main vessel supplying the brain, close to a point where it perforates the fibrocartilaginous skull base, supplies a branch, not as in the horse to the opposite "carotid", but to pierce the dura mater, forming an anastomotic channel to supply the network of vessels on the ventral surface of the brain stem.

Tapirus indicus

Radiographs ([6], pp 244–245) show an arrangement more like the zebra than the horse.

Discussion

The demonstration of an elaborate rete caroticum in two single specimens of *D. bicornis,* one in an embryo [7] and the present adult, though the material is slight, establishes the likelihood that this is the pattern of arterial blood supply in the rhinoceros and unites the odd- and even-toed ungulates in way that might have been, but was not expected. Davies [7] does not seem to have realised the importance of his finding.

The anatomy of what has been thought and spoken of as the "internal carotid" of the horse by generations of zoologists and veterinary surgeons was described by Vaughan in 1892. Every feature, except its size, resembles the ascending pharyngeal artery of man, so familiar to neuroradiologists, including the perforation of the skull base by a meningeal branch. The works of Nanda and Getty [8, 9] on the arteria intercarotica caudalis and the arteria caroticobasilaris of the horse, although they give no consideration to the ascending pharyngeal, do emphasise the importance of dural and transdural anastomotic networks forming pathways to the brain stem, as our radiographs showed in the zebra and the tapir.

The vessel in *E. caballus* commonly called pharyngeal or ascending pharyngeal does not reach the skull base, but pursues a course like other pharyngeal branches of the external carotid artery in *Homo.*

The conclusion that all odd-toed ungulates share with even-toed ungulates the physiological advantages that may be derived from interposing smaller branches of the external carotid between the main arterial trunk of common carotid and the intracranial cerebral vessels seems inescapable.

In addition the rhinoceros possesses what is likely to be a highly developed heat exchanger to aid its brain temperature regulation.

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George H. du Boulay M. B., B. S., F. R. C. R.
Institute of Zoology
Regents Park, London, UK