The cranial venous system in the rat: anatomical pattern and ontogenetic development

I. Basal drainage

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Summary. The anatomical pattern and development of the venous system of the cranial base in the rat is described. The anatomy of the venous system was determined from observations of vascular casts in adult rats; the development of the vascular system was established by examination of ink-injected embryos. A transverse sinus system was found to be present in the basal venous system. The sinus connects the posterior facial veins; its middle section transverses the cranial base through the basisphenoid canal, and it receives the venae ophthalmicae within the basisphenoid bone. The venae ophthalmicae in turn are connected to the perioptic veins and to the sinus interperiopticus intracranially. Dorsally, the venae ophthalmicae anastomose with the paired sinus cavernosus. The term sinus transversus basalis is proposed for the venous connection between the posterior facial veins within the basisphenoid bone of the rat. The anlage of the sinus transversus basalis is established by vascular networks during the final prenatal period, its formation, however, is only completed postnatally. The anlages of the venae periopticae, the venae ophthalmicae, the sinus cavernosus and the rami intercavernosi are already established at early developmental stages. The characteristic pattern is formed before birth.

Key words: Cranial veins – Basal drainage – Development – Rat

Introduction

The anatomical pattern of the cranial venous system of the rat has yet to be clarified, especially that of the cranial base. Hebel and Stromberg (1986) briefly describe a pattern which is similar to that of man. Greene (1963) gives a more detailed description; nevertheless he writes: “No attempt has been made to work out the intricacies of the intercavernous sinus or the basilar plexus in such a small animal.” In particular, the detailed anatomy of the transverse sinus requires further investigation (Landsmeer 1951).

The developmental sequence of the cranial venous system in man has been described by Padget (1957). Recently, we have reported developmental and anatomical findings concerning the cranial venous system in the rat (Szabó 1987, 1989 a, b; 1990; Szabó and Mendoza 1988). The present studies were undertaken in order to elucidate in detail the anatomic connections contributing to the formation of the transverse basal sinus, and to determine the developmental sequence of the basal cranial venous system in the rat.

The anatomical nomenclature used in this manuscript is taken from the current edition of the Anatomy of the Laboratory Rat by Hebel and Stromberg (1986) and is generally consistent with that of the Nomina Anatomica Veterinaria (1983).

Materials and methods

Twenty-four adult albino rats (inbred Sprague-Dawley strain) weighing 150–250 g, and three each, 2-day-old and 14-day-old rats were anesthetized with Nembutal. The heads of the animals were perfused retrogradely through the descending aorta with Ringer’s solution and with low viscosity methacrylate casting medium (Mercox) or with Tardoplast (Farben- und Kunststoffvertrieb, H. Schum, Lindenweg 12, D-8160 Miesbach-Leitzach). Polymerization occurred in a hot water bath (60° C) overnight, then in warm water (40° C) for 5 days. Preparations were corroded in 10% KOH solution and washed in distilled water. Remnants of tissues were removed in 10% HCl solution. Vascular casts were partially dissected in distilled water under a dissecting microscope, freeze dried, then mounted on supports and examined in a Wild M 400 photomacroscope.

Ten albino rat fetuses (inbred Sprague-Dawley strain) were examined at each daily embryonic stage, beginning from the 12th gestational day (E 12) to birth. The onset of pregnancy was determined by vaginal smears. The day on which sperm were found in the smear was called day 0 (E 0). After Nembutal anesthesia...
of the pregnant rats, the embryos were removed together with the amniotic sac and placenta and injected with India ink according to Szabó and Gáspár (1981) as follows. The umbilical vessels were separated from the amniotic membranes under a dissecting microscope. A hypodermic needle (27 gauge), connected to a syringe via a plastic tube, was inserted into the umbilical vein. In order to maintain cardiac contractions during perfusion, the cardiac glycoside strophanthin-k was added into the umbilical vein. In order to maintain cardiac contractions the amniotic sac and placenta and injected with India ink according to the ink at a concentration of 0.25 mg per 30 ml ink. The progress of filling capillaries was monitored in the head region under a dissecting microscope.

Serial sections of celloidin-embedded (75–150 μm thick) or non-embedded (1–2 mm thick) embryos were cut in the horizontal, frontal and sagittal planes. Sections were cleared using the Spalteholz technique (Romeis 1948). Some of the celloidin sections were then stained lightly with hematoxylin and examined with a Wild M 400 photomacroscope.

Results

The bony cranial base

The present description emphasizes aspects of skull structure relevant to the angioarchitecture of the basal venous system. The body of the sphenoid bone is divided into a basisphenoid and a presphenoid part by the synchondrosis intersphenoidea (Figs. 1, 2, 4). Occipitally, the basisphenoid is also joined to the basioccipital by a synchondrosis (Figs. 1, 2). Laterally to the basisphenoid and the basioccipital the tympanic bulla is situated. It borders the fissura sphenopetrosa (foramen lacerum) occipitally (Figs. 2, 4) which has been described by Greene (1963) and Hebel and Stromberg (1986) as petro-tympanic fissure false; frontally the fissure is bordered by the alisphenoid. The basisphenoid is perforated by the basisphenoid canal transversely; the canal opens at the external cranial base near the pterygoid region (Figs. 1, 2; “interpterygoid foramen”, Greene 1963). The wing of the sphenoid (alisphenoid) extends laterally from the basisphenoid. It interdigitates with the temporal squama, the frontal bone and the orbitosphenoid. The latter encloses the optic canal (Figs. 4, 6). Occipital to the optic canal, the large oval fissura orbitalis superior (orbital fissure: Hebel and Stromberg 1986; anterior lacerated foramen: Greene 1963) perforates the cranial base (Figs. 1, 2, 4). It is bordered medially by the bodies of the basisphenoid and the presphenoid, frontally by the orbitosphenoid and dorsolaterally by the alisphenoid. The orbital fissure leads frontally though the foramen orbitoretundum (Hebel and Stromberg 1986; it is not listed in the Nomina Anatomica Veterinaria 1983, but is commonly used in veterinary anatomy, and is convenient in describing venous structure) into the orbit (Figs. 4, 6) and occipitally into the canalis basiphenoidideus (Fig. 1) and into the inner cranial base (caverno-ophthalmic canal, Fig. 4).

The venous system at the cranial base

The sinus transversus basalis is a transverse coursing sinus system, located at the cranial base, which connects the posterior facial veins of both sides (Fig. 1). It is composed of three developmentally different parts. Its unpaired middle section, the sinus basisphenoideus (Figs. 3, 5) is intraosseous, and is located in the basisphenoid canal (Fig. 1). The paired lateral sections, the sinus pterygoidei (Figs. 1, 3) are S-shaped and wide. They course along the fissura sphenopetrosa on the external cranial base (Fig. 2) to the posterior facial veins (Figs. 1, 3). The sinus pterygoideus receives the large maxillary vein frontally (Figs. 1, 3) curving around the medial aspect of the mandible. The sinus basisphenoideus receives a paired sinus-like vein, the vena ophthalmica (Figs. 1, 3, 5). The latter is formed in the orbit by the uniting of the perioptic vein with the superior orbital veins (Figs. 3, 5). Then the vessel passes through the foramen orbitoretundum (Fig. 4, 6) along the orbital fissure (Figs. 1, 2, 4), along the medial aspect of the trigeminal ganglion (extraosseal section of the ophthalmic vein; Figs. 3, 5). The ophthalmic vein receives the inferior orbital veins (Figs. 3, 5) in the orbit, and a branch from the sinus cavernosus transversing the basisphenoid dorsally to the occipital rim of the orbital fissure (Figs. 4, 5) which may be called vena cavernoophthalmica. The inferior orbital veins Anastomose infraorbitally with the sinus transversus basalis (10+11) connects the venae faciales posteriores (12) of both sides. Its middle section (sinus basisphenoides; 10) is located in the basisphenoid canal (arrows indicate the openings). The latter receive the venae ophthalmicae (5) and the sinus cavernosus (6); the lateral sections (sinus pterygoidei 11) receive the maxillary veins (13). The frontral part of the ganglion trigeminale (G) is situated at the lateral aspect of the ophthalmic vein in the orbital fissure.

Abbreviations (Figs. 1–6): A, alisphenoid; B, basisphenoid; BO, basioccipital; G, ganglion trigeminale; LC, lamina cribrosa; O, orbitosphenoid; P, presphenoid; TB, thympanic bulla; Z, zygomatic arch; a, canalis opticus; b, foramen orbitoretundum; c, fissura sphenopetrosa; d, foramen pterygopalatinum; arrows, openings of the basisphenoid canal; double arrow, arteria carotis interna; arrowhead, opening of the caverno-ophthalmic canal in the basisphenoid which contain the branch with the same name connecting the sinus cavernous with the ophthalmic vein.

(Figs. 1–17): 1, sinus interperiaticus; 2, vena perioptica; 3, superior orbital veins; 4, inferior orbital veins; 5, vena ophthalmica; 6, sinus cavernosus; 7, rami intercavernosi; 8, sinus petrosus superior; 9, sinus petrosus inferior; 10, sinus basisphenoides; 11, sinus pterygoideus; 12, vena facialis posterior; 13, vena maxillaris; 14, sinus petrosquamosus; 15, infraorbital anastomoses; 16, occasional anastomosis between the ophthalmic veins.