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Arachnoid Granulations and Arachnoid Villi in Mammals

by

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(With ten text figures)

There has been no general agreement regarding the presence of arachnoid granulations and arachnoid villi in mammals. This seems to have arisen from the fact that various workers have used different criteria in distinguishing between the two terms — 'granulation' and 'villus'. Luschka (1852) was the first to define the structure observed macroscopically as an 'arachnoid granulation', while for the microscopic structure he used the term 'arachnoid villus', a definition also used more recently by Turner (1958). It seems, therefore, that the only difference between these two structures is one of size, for it was Hassin (1930) who defined an arachnoid granulation as a hypertrophied villus consisting of several lobules, covered by a membrane and possessing a common stalk. Le Gros Clark (1920) regarded the structures seen with a hand lens also as granulations whereas Cooper (1958) used the term granulation to include all these structures irrespective of size.

Based more or less on the definition given by Luschka, Weed (1914) denied the presence of arachnoid granulations in animals but believed instead that villi were present in most mammals. Fankhauser (1962) described the presence of arachnoid granulations comparable to those of Man in horses, while Jayatilaka (1965 a) described them in sheep. In the present account, the terms 'arachnoid granulations' and 'arachnoid villi' will be retained to refer to the macroscopic and microscopic structures respectively, for although these terms have no exact meaning in so far as the basic structure of the two is the same, they are useful terms to retain when referring to structures of different size.

MATERIALS AND METHOD

Four adult human brains and four neonatal human brains with meninges, six adult brains each of cattle, dogs, cats, rabbits, guinea pigs and rats were taken for investigation.

The human brains were perfused through the basilar artery with 10% formol saline while in the others, perfusion was done through the common carotid arteries. After, perfusion, the brains were immersed in fresh 10% formal saline for 6 days. The superior sagittal sinuses, their parasagittal membranes and adjacent cortices were removed in all specimens and processed for embedding in paraffin wax. Sections were stained with haematoxylin and eosin.

RESULTS

Adult human

Arachnoid granulations were present in the lateral lacunae of all the superior sagittal sinuses examined. They were observed at sites of openings of cerebral veins into sinuses. These granulations in relation to venous channels, for purposes of description in this investigation will be referred to as Granulations type 1.

Arachnoid granulations were also observed over the surface of the cerebral cortices about half to one inch from the supero-medial border, but separate from the lateral lacunae of the superior sagittal sinuses, in the four specimens examined. These granulations were not associated with venous channels and will be referred to as Granulations type 2. Arachnoid villi of the optic nerve, with no relationship to venous channels and structurally similar to Granulations type 2, were reported by Jayatilaka (1967).

Microscopically, both types of arachnoid granulations were similar, being prolongations of the arachnoid membrane and its contained subarachnoid space into either the venous sinus as in Granulation type 1 or into the subdural space as in Granulation type 2. Arachnoid villi, with similar morphology to the granulations but with only a difference in size, were also observed in relation to the superior sagittal sinuses in all specimens.

A human arachnoid granulation possesses a body and a neck, through which there was communication with the subarachnoid space (Fig. 1.) Granulation type 1 has a covering of endothelium derived from the venous sinus while the Granulation type 2 has a covering of arachnoid mesothelial cells. Both types of granulations have cell aggregations of the covering epithelium at their summits (Fig. 4). These result in 'epithelial cell caps' (Turner, 1958), formed by a collection of round or oval cells. Similar cell aggregations were seen in the core of the granulation as well as in the arachnoid membrane over the cerebral cortex (Fig. 5). The presence of these cell collections in the core of a granulation made Kiss and Sattler (1957) postulate an endocrinal function to these structures but without convincing evidence.

In sagittal and coronal sections of Granulations type 1, crypts lined with endothelium were observed to dip into the core of granulations (Fig. 1). On serial study of transverse sections of a granulation, these crypts appeared to be continuous with endothelially lined tubules present in the core of the granulation (Fig. 2). These findings correspond with those of Trolard (1870) and Schaltenbrand (1955) in Man and of Jayatilaka (1965 a & b) in sheep. Apart from the tubules, the core of each granulation was made up of closely packed collagen bundles with small spaces between them (Fig. 2). These spaces were observed to communicate with similar spaces present in the subarachnoid space. Blood vessels were observed in the core of the granulation (Fig. 3) and these entered it from the dural collar surrounding the granulation at its entry into the venous sinus. By perfusion of the external carotid artery with coloured gelatine, Kolesnikov (1940) demonstrated that these blood vessels were derived from the middle meningeal artery. Corpora amylacea or psammoma bodies were observed in granulations (Fig. 3), a feature also observed in the cell aggregations of the arachnoid membrane.

EXPLANATION OF FIGURES

FIG. 1 Longitudinal section of adult human arachnoid granulation type 1 (AG), with crypt (Cr) and psammoma body, lying in lateral lacunae of the superior sagittal sinus (SS). SAS = subarachnoid space. H & E × 40.

FIG. 2 Transverse section of adult human arachnoid granulation type 1 showing tubule (T) found in its core. S = spaces between collagen bundles. H & E × 600.

FIG. 3 Longitudinal section of adult human arachnoid granulation type 1 showing blood vessel (BV) and psammoma body, (Ps). H & E × 400.

FIG. 4 Longitudinal section of adult human arachnoid granulation showing 'epithelial cell cap' (E). H & E × 400

FIG. 5 Coronal section of adult human cranial meninges showing dura mater (D) and arachnoid membrane (A). Note cell aggregations of arachnoid marked with arrows. H & E × 400.

Human Neonatus

No arachnoid granulations were observed but arachnoid villi were seen in all the serial sections of the superior sagittal sinuses examined microscopically. Structurally they resembled the arachnoid granulations of the adult in that there were 'epithelial cell caps', crypts, tubule-like spaces and spaces between collagen bundles (Fig. 6). In two of the specimens, psammoma bodies were observed. The cranial arachnoid membrane showed the presence of cell aggregations (Fig. 7).

Cattle

Arachnoid granulations and arachnoid villi were observed in all the superior sagittal sinuses examined. There was no difference in their structure to those described by Jayatilaka (1965) in sheep by light microscopy.

Dog

Naked eye examination of the superior sagittal sinuses showed minute pearly white bodies in the cerebral veins at their openings into the sinuses. These were granulations.

Microscopically, their structure was similar to the granulations in the adult human but 'epithelial cell caps' or crypts were not observed. In transverse sections of the core of these granulations, tubule-like spaces lined with simple squamous cells were observed (Fig. 9) but whether they corresponded to the tubules as seen in Man or in sheep was uncertain. Arachnoid villi were also present.

Cat

Only arachnoid villi were present in all the specimens examined. The villi were situated in the central part of the sinuses at the opeinings of cerebral veins. These villi showed 'epithelial cell caps' (Fig. 8).

Rabbit and Guinea Pig

No arachnoid granulations were observed in both these animals. However, arachnoid villi were present at the caudal end of each superior sagittal sinus, especially in the region where the pineal body was intimately related to the sinus (Fig. 10). The arachnoid villi in these two animals were similar to those observed in the dog and in the cat. Spaces lined by squamous cells were seen in the villi but again whether they corresponded to tubules as described in man and in sheep was uncertain.

Rat

No arachnoid granulations or arachnoid villi were observed in relation to the superior sagittal sinuses of all specimens examined.

EXPLANATION OF FIGURES

FIG. 6 Longitudinal section of a human neonatus arachnoid villus (AV) showing psammoma body (Ps). H & E × 200.

FIG. 7 Coronal section of human neonatus cranial meninges showing arachnoid cell aggregations (arrows) in arachnoid membrane

FIG. 8 Longitudinal section of cat arachnoid villus (AV) in cerebral vein (CV). Note 'epithelial cell caps' (E) in the villus. SS = superior sagittal sinus. H & E × 200.

FIG. 9 Transverse section of arachnoid granulation (AG) of dog, with tubule-like spaces (T), lying in cerebral vein (CV). H & E × 400.

FIG. 10 Longitudinal section of arachnoid villus (AV) of rabbit, with tubule-like spaces (T), lying in superior sagittal sinus (SS). B = brain, PB = pineal body. H & E × 600.

DISCUSSION

The suggestion has been made that, in sheep, arachnoid granulations and villi act as valves to permit unidirectional flow of fluid from the subarachnoid space to the venous system through tubules when the cerebrospinal fluid pressure was raised above a certain value (Jayatilaka, 1965b). Based on this suggestion it has been argued that arachnoid villi, with no association with venous channels situated in the optic nerve of Man, act as valves to allow cerebrospinal fluid to leak through them into the subdural space to be drained away by the perineural lymphatics (Jayatilaka, 1967).

Tubules similar to those described by Jayatilaka (1965 a) in the arachnoid granulations of sheep have been observed in human adult dog and cattle granulations and it is possible that they exist in the villi of other mammals. Shabo and Maxwell (1968) by electron microscopic studies, however, were unable to find similar tubules in the villi of the monkey. They have suggested that the endothelially lined tubules described in sheep granulations may have been capillaries although they themselves found no evidence of capillaries in the villi of the monkey. Further, their statement that the villi of the monkey "were so small that they could not be identified with certainty with the dissecting microscope" raises doubts as to the validity of their observations.

The presence or absence of granulations and villi in an animal seems to some extent be related to either the size or the posture of the animal. The larger animals like the adult human, cattle, sheep, dog have granulations while smaller animals like the human neonatus, cats, rabbits and guinea pigs have villi in their superior sagittal sinuses. These structures are usually situated at the highest point of their neuroaxes and may thus account for their presence only in the thoracic spinal region in the rat (Millen and Woollam, 1962), their highest neuroaxial point, rather than over the cerebral hemispheres. The adult human with an upright posture has granulations while the human neonatus with a reclining posture, for most of the time, has only villi. Le Gros Clark (1920) observed that granulations were first visible about the age of 18 months, the time at which a child was able to walk on his own. There seems to be some temporal relationship at least between the appearance of granulations and posture in the case of children.

The 'epithelial cell caps' of arachnoid granulations are formed from the cells of the surface epithelium that covers the granulation. The cell aggregations of the arachnoid membrane are similar. Some workers believe that formation and calcification of arachnoid cell aggregations was a phenomenon associated with old age but others have observed them in villi of infants e g. in this investigation. Chornyak (1948) found that in certain conditions of anoxaemia the cells of the arachnoid membrane proliferate and form typical cell clusters. It is likely that the 'epithelial cell caps' and arachnoid cell aggregations are produced by a similar condition though its nature is one of conjecture at the present time and falls outside the scope of this study.

SUMMARY

Cranial arachnoid granulations were present in adult humans, cattle and dogs while arachnoid villi were present in human neonatuses, cats, rabbits and guinea pigs.

Human arachnoid granulations were of two types, type 1 being associated with venous channels and type 2 without association with venous channels.

Human arachnoid granulations contained tubules within its core comparable to those observed in sheep.

There seems to be some relationship between the presence or absence of arachnoid granulations and villi with the size of the animal. In Man, there seems to be a relationship between the appearance of granulations and posture in the case of children.

It is suggested that 'epithelial cell caps', arachnoid cell aggregations and psammoma body formation in arachnoid granulations and villi were features not necessarily associated with old age.

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Fig. 1

Fig. 2

Fig. 3

Fig. 4.

Fig. 5.

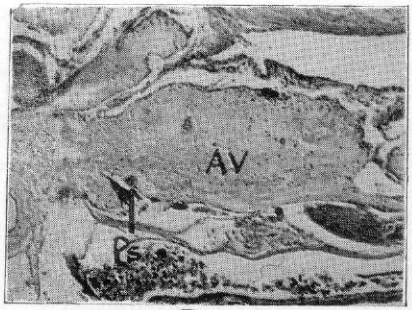

Fig. 6.

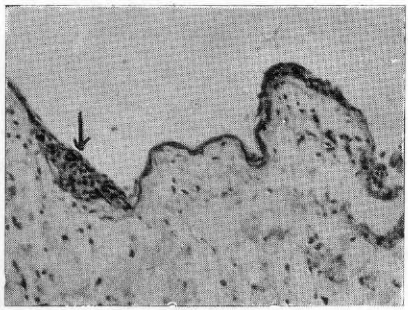

Fig. 7.

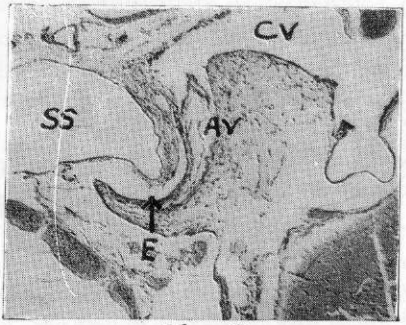

Fig. 8.

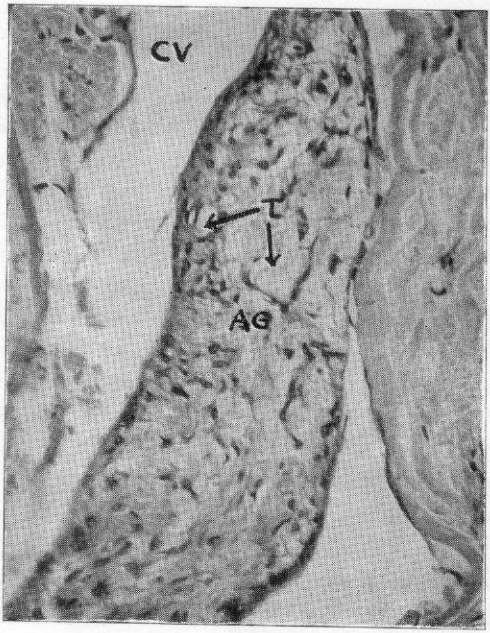

Fig. 9.

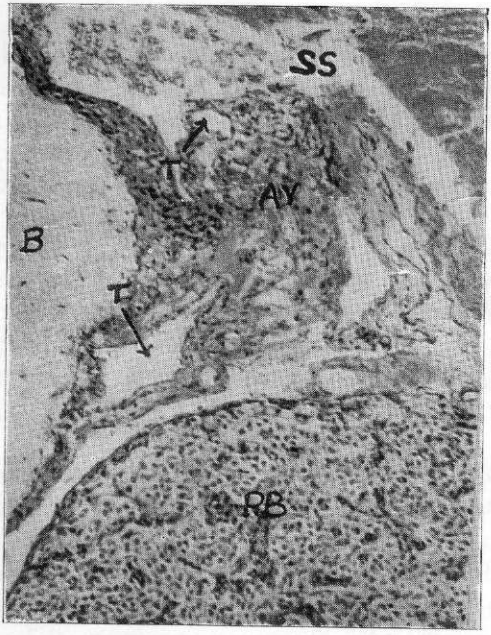

Fig. 10.