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Ultrastructure of the Arachnoid Membrane in Man

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Summary. The arachnoid membrane in man is formed of two layers of cells. Those of the outermost layer are very electron dense and have long interweaving processes containing numerous vacuoles. Spaces which may appear empty or contain granular material may separate these cells and their processes. Beneath this outer layer is an inner layer consisting of groups of less electron dense cells, their interweaving processes and collections of collagen fibres and fibrillar material. Desmosomes are frequent between the cells. Occasional electron dense cells occur amongst the clear cells and desmosomes occur between them. The internal aspect of the layer of dark cells is covered by an interrupted layer of basement membrane and a space may occur between it and basement membrane overlying the outer aspect of the clear cells. In places, however, only a single layer of basement membrane separates the dark and clear cells or they may be in close contact, desmosomes being present between them. Basement membrane separates the superficial dark cells from the collagen fibres of the inner layer of the arachnoid membrane and amongst the collagen occur elongated electron dense cells similar to fibroblasts. Macrophages occur within the subarachnoid space.

Sometimes the arachnoid and the pia mater are in contiguity and the subarachnoid space is not apparent. Evidence of bulk flow of cerebrospinal fluid into the subdural space via the arachnoid membrane was not found.

Key words: Ultrastructure of Arachnoid — Dark and Clear Cells.

Introduction

The ultrastructure of the lemptomeninges and particularly that of the arachnoid membrane has been studied in different animals by Pease and Schultz (1958), Nelson *et al.* (1961), Andres (1966, 1967), Wolff (1966), Waggener and Beggs (1967), Klika (1967, 1968), Anderson (1969), Akashi (1972), and Tripathi (1973), and in man by Ramsey (1965), Thomas (1966), Anderson (1969) and Rascol and Izard (1972). Few authors attempt to correlate the ultrastructure of the arachnoid membrane with its permeability to various substances.

The structure of the pia mater in man and its relationship to the outer part of the cortex has been reported previously (Lopes and Mair). The present investigation was undertaken to establish the ultrastructure of the arachnoid membrane in man and to seek evidence concerning its role in the absorption of cerebrospinal fluid.

Materials and Methods

Arachnoid membrane was obtained from 6 patients undergoing surgical treatment for deeply seated cerebral gliomas. The fragments of arachnoid membrane taken from different sites of the cerebral hemisphere were immersed for 2 h in cold 3% glutaraldehyde, buffered at pH 7.4. They were then cut in small pieces and post-fixed in buffered 1% osmium tetroxide (pH 7.4). The tissue was washed in distilled water, dehydrated in ascending grades of alcohol

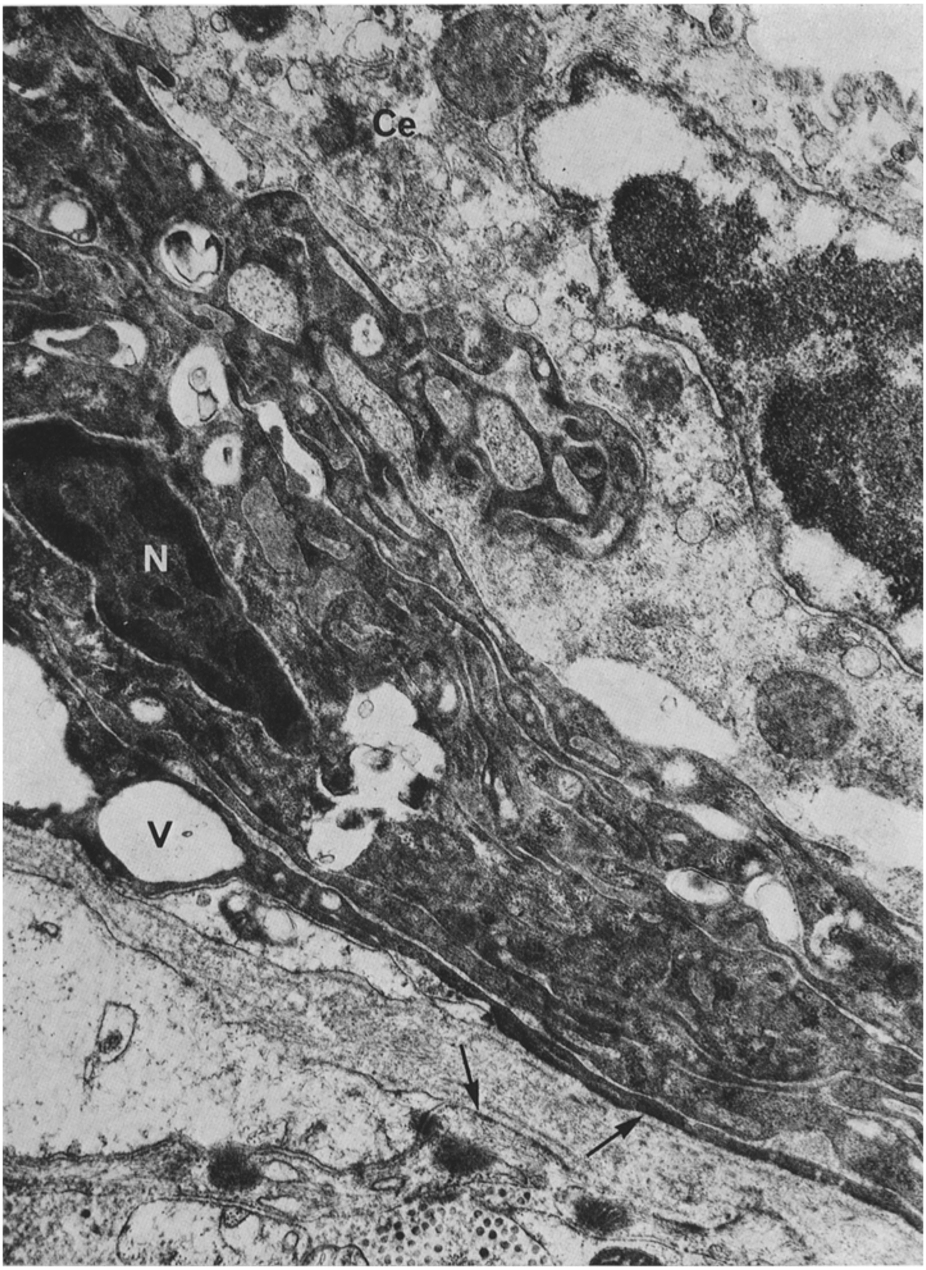

Fig. 1. The outer part of the arachnoid membrane is formed of several layers of very electron dense cells with an elongated nucleus (*N*). Vacuoles (*V*) of considerable size and centrioles (*Ce*) may occur in them. Basement membrane (arrowed) may be present on the inner aspect of this layer of cells and a space may occur between it and another layer of basement membrane which may cover the outer aspect of the underlying clear cells. × 10500

and embedded in epon. Thick sections were stained with toluidine blue and examined by light microscopy. From selected regions of the blocks thin sections were cut and stained with lead citrate and uranyl-acetate and examined in an Elmiskop 1.

Results

The arachnoid membrane consists of two parts, an outer part formed by several layers of dark cells and an inner part by groups of clear cells, their processes and bundles of collagen fibres and fibrillar material. A space may occur between the two layers.

The cells of the outermost part are very electron dense. Desmosomes and also spaces are present between them; the spaces may appear to be empty or may contain granular material. The nucleus is elongated or pear-shaped and very electron dense with the chromatin around its margin or in masses throughout it. The cells have numerous slender branching processes (Fig. 1). The cytoplasm presents large vacuoles, mitochondria, occasional lipid droplets and membranous bodies: centrioles may also be present. Basement membrane is not present on the outer aspect of this layer of cells nor between them but an interrupted layer of basement membrane is sometimes present on its internal aspect.

Beneath this outer layer there is an inner layer formed by groups of clear cells, trabeculae of their interweaving processes and collections of collagen fibres and fibrillar material. An interrupted layer of basement membrane covers the outer surface of the groups of clear cells. A space up to 250 nm wide containing amorphous material and occasional collagen fibres is often seen between the basement membranes of the dark and clear cells (Fig. 1). In places there is no intervening space but a single layer of basement membrane may separate the dark and clear cells or these cells may lie in contiguity with desmosomes between them. The clear cells (Fig. 2) have a relatively large amount of cytoplasm containing varying numbers of small vacuolated mitochondria, cisterns of the rough endoplasmic reticulum and some granular material. Some cells contain fine filaments but vesicles are infrequent. The nucleus is oval and the chromatin disposed in irregular clumps throughout it. Desmosomes occur between adjacent cells which occur in groups separated by variable amount of collagen and fibrillar material. Occasionally, fragments of basement membrane separate the cells from the nearby collagen fibres. At irregular intervals beneath the layer of dark cells and at right angles to them occur trabeculae of interweaving processes of the clear cells (Fig. 3). The processes contain many vacuolated mitochondria. Numerous desmosomes are present between the processes. A discontinuous layer of basement membrane sometimes separates the trabeculae from the collagen fibres surrounding them and is present at intervals on the internal aspect of the clear cells bordering the subarachnoid space. Amongst the clear cells occur very occasional cells which are more electron dense and present desmosomes between them and the clear cells. In addition there occur in the arachnoid membrane occasional elongated cells with large cytoplasmic projections. Such cells when in close proximity do not exhibit desmosomes on their adjacent cell membranes: their appearance would suggest that they are fibroblasts.

In the subarachnoid space are found collagen fibres, granular material and macrophages (Fig. 4).

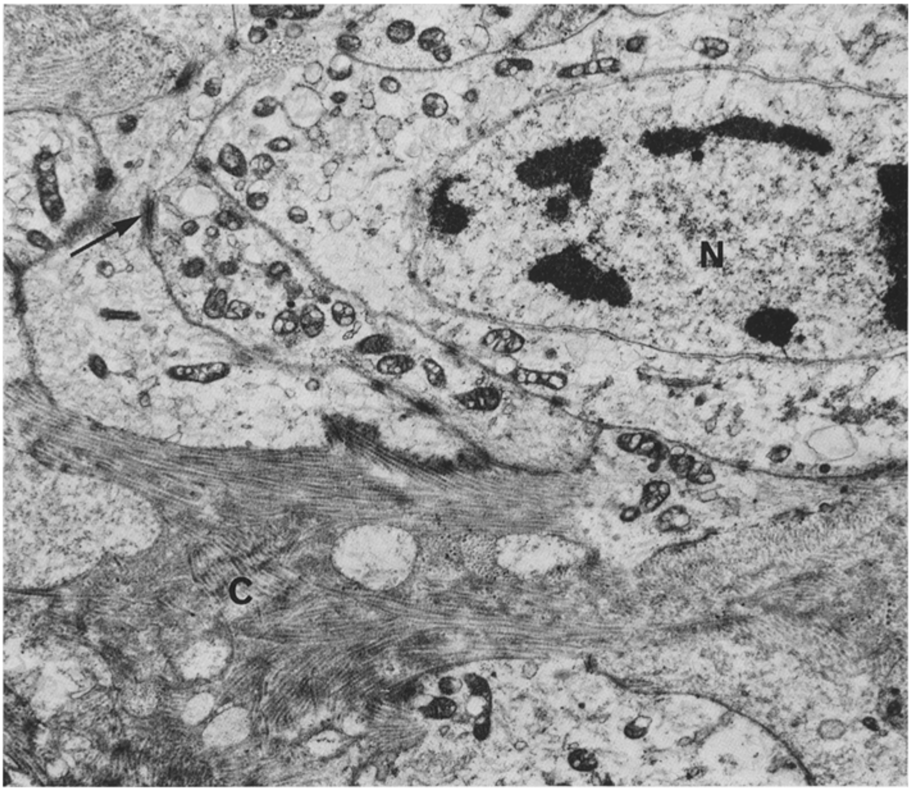

Fig. 2. The clear cells of the inner part of the arachnoid membrane have an elongated nucleus (*N*) and a large amount of cytoplasm containing small mitochondria and relatively few organelles. Desmosomes (arrowed) occur between adjacent cells which lie in groups separated by collagen fibres (*C*). × 7000

Discussion

There are numerous reports on the ultrastructure of the arachnoid membrane from different sites of the central nervous system of different animals. In man it is said to be formed by several layers of meningothelial cells and collagen fibres. These meningothelial cells correspond to the clear cells of the present report. Desmosomes are frequent between these clear cells. The dark cells of the outer layer have been regarded as mesothelial cells which line the inner surface of the dura mater (Pease and Schultz, 1958). However in the present investigation the arachnoid membrane was examined and not the dura mater. The dark cells are therefore assumed to form part of the arachnoid membrane; this agrees with the view of Klika (1967, 1968). The dark cells present desmosomes between them and between them and the clear cells when these layers are in direct contact.

The frequency of collagen fibres in relation to the clear cells would suggest that they elaborate collagen fibres. Collagen fibres may also be elaborated by the occasional electron dense elongated cells which appear to be fibroblasts.

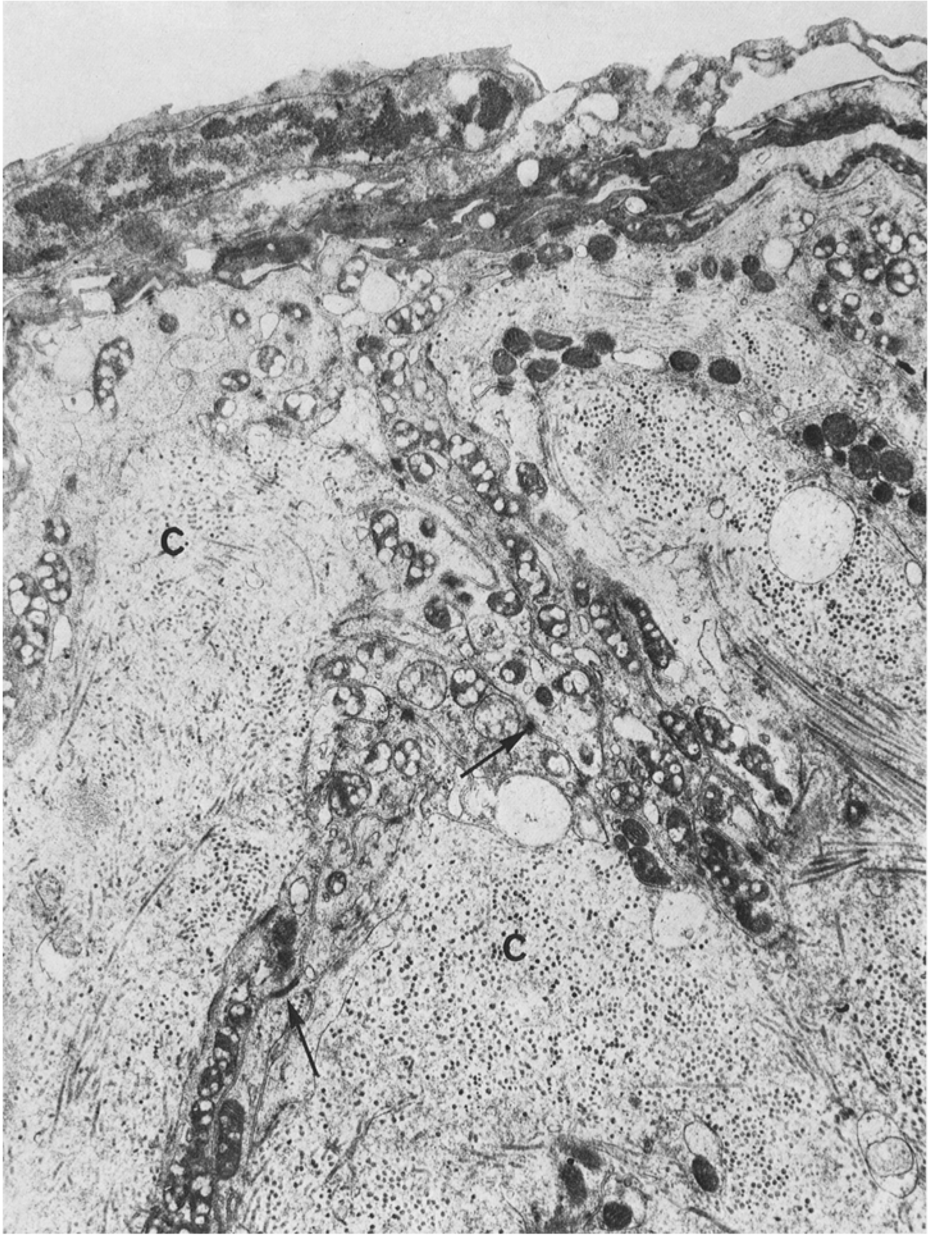

Fig. 3. Interweaving processes of the clear cells, with desmosomes (arrowed) between them, form trabeculae extending inwards amongst the collagen (*C*) of the arachnoid membrane. × 8700

Regarding the drainage of cerebrospinal fluid from the subarachnoid space, Tripathi (1973) discussed its similarity with the aqueous outflow of the eye. He described very large vacuoles in the outer cells of the arachnoid membrane

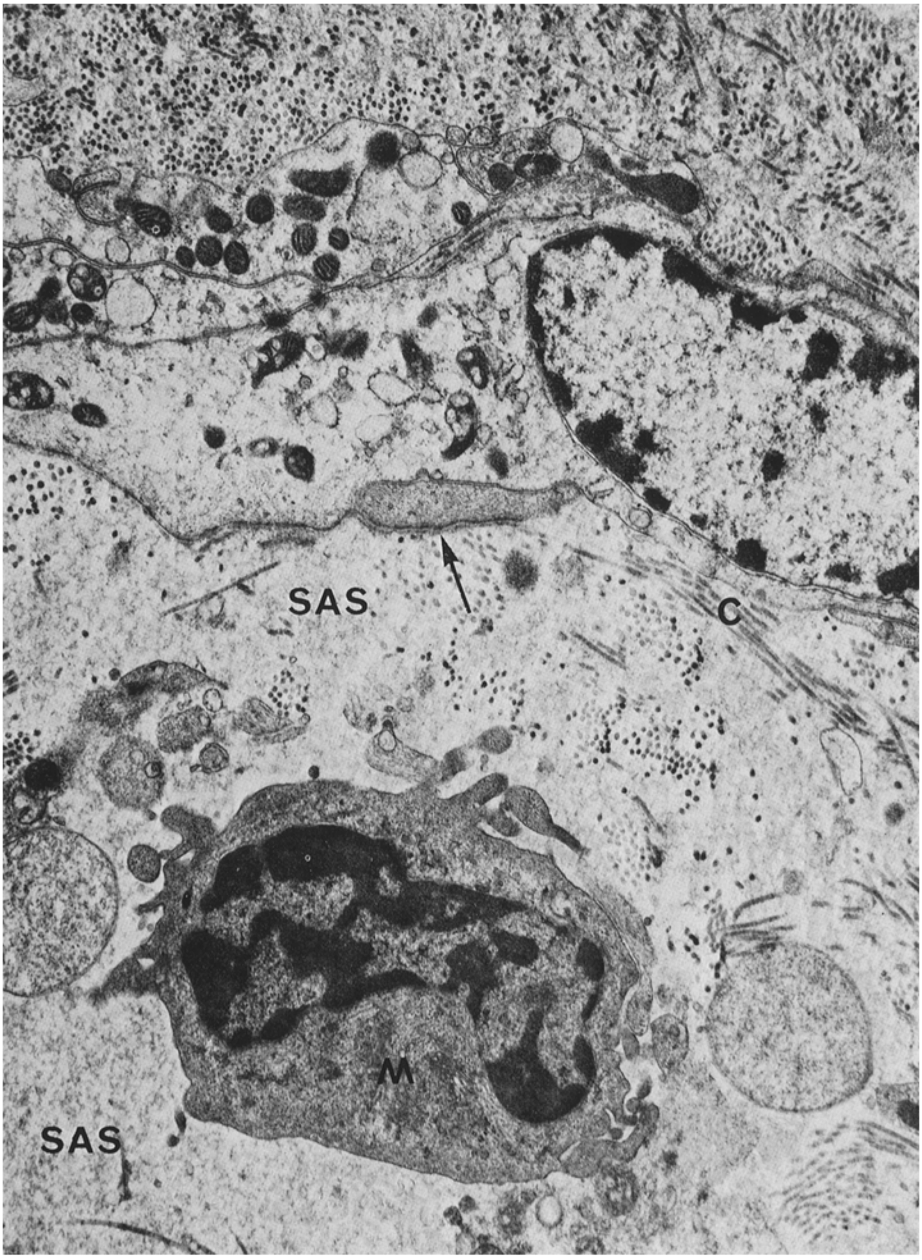

Fig. 4. The arachnoid cells bordering the subarachnoid space (*SAS*) present an interrupted layer of basement membrane (arrowed) on their inner aspect. Macrophages (*M*), collagen fibres (*C*) and granular material lie in the subarachnoid space. × 8700

from the parasagittal region of monkeys and postulated that these vacuoles are a stage in the formation of transcellular channels by which the cerebrospinal fluid drains into the subdural space. However in the human material examined in the present study while large vacuoles were present in some of the dark superficial cells of the arachnoid neither large vacuoles nor collections of pinocytotic vesicles were seen in the clear cells. Hence there was no evidence to suggest that in man bulk flow of cerebrospinal fluid occurs through the arachnoid membrane into the subdural space.

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