A Scanning Electron Microscopic Observation of the Choroid Plexus in Rats

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Summary. Scanning electron microscopy of the choroid plexus in white rats gave the following results:

1. The choroid plexus consists of tortuous capillary blood vessels, an epithelial cell layer uninterruptedly covering their surface and the interjacent connective tissue which is not seen from the surface. The contour of each epithelial cell is recognizable from the ventricular surface as a low, round hill.

2. Each epithelial cell has numerous microvilli on its free surface. They are neither branched nor fused; they are variable in shape, sometimes with a swollen tip. Their thickness is inconstant even in a single microvillus. The distribution of microvilli seems more dense and conglomerated at the top of the hill than at the periphery of the cell.

3. Clusters of longer protrusions which possibly correspond to groups of cilia are scattered on the epithelial surface covered with microvilli. A cluster which consists of about ten or less cilia is seen in only one per several cells. Occasionally two or three such clusters occur on a single cell.

Electron microscope studies on the structure of the choroid plexus have been performed by various investigators (Breemen and Clemente, 1955; Dempsey and Wislocki, 1955; Millen and Rogers, 1956; Maxwell and Pease, 1956; Ladman and Roth, 1958; Murakami, 1961; Pontenagel, 1962; Carpenter, 1966; Oksche and Vaupel-von Harnack, 1969; Dohrmann and Bucy, 1970; Dohrmann and Herdson, 1970; Dohrmann, 1970a). These studies confirmed that the basic structure of the choroid plexus consists of a single layer of cuboidal epithelial cells, an interposed layer of connective tissue and the innermost capillary blood vessels as observed by the light microscope, and they revealed the occurrence and fine structure of epithelial microvilli. Maxwell and Pease (1956) stated that "pedicles" of various sizes were thought to be labile structures and described them as "irregular and greatly variable in form." Dohrmann and Bucy (1970) classified these microvilli into symmetrical finger-like ones and relatively shorter, rounded or club-shaped ones. On the other hand, cilia were found in the choroidal epithelium by Millen and Rogers (1956) and later confirmed by Ladman and Roth (1958), Murakami (1961), Pontenagel (1962), Carpenter (1966), Oksche and Vaupel-von Harnack (1969), Dohrmann and Bucy (1970) and Dohrmann and Herdson (1970). Among them Dohrmann and Herdson (1970) described that the cilia exist as tufts at the apex of the epithelial cell. Although these observations have enabled, to a certain extent, a visualization of the three dimensional structure of the choroid plexus, especially of the microvilli and cilia growing there, no report on this subject using scanning electron microscopy seems available as far as the author knows.
The purpose of this paper is to describe the fine detail of scanning electron microscopic observation of the choroid plexus in white rats.

Materials and Methods

Brains of adult white rats weighing 150-250g were used. Animals were fixed by the perfusion fixation technique for transmission electron microscopy (Yamadori and Saito, 1970). The perfusate used was phosphate buffered 2.5% glutaraldehyde which contains 7.5% sucrose (Tokunaga, Harada and Matsumoto, 1970). Soon after the perfusion the brains were taken out and the choroid plexuses, separated from the fourth and lateral ventricles with or without the tissue of the ventricular floor to which the plexus attaches, were flooded with the same glutaraldehyde for 12 hrs. The specimens were then flooded in a fresh fixative for the next 12 hrs. Some of the choroid plexuses, after being fixed by the perfusion and flooded for more than 1 hr in glutaraldehyde, were washed briefly by the buffer solution and then flooded with 1% osmic acid (Palade, 1952) for 3 hrs like the specimen for transmission electron microscopy. The fixed specimen was dehydrated through an ascending series of acetone and dried in the air (Barber and Boyde, 1968; Fujita, Inoue and Kodama, 1968). The specimen surfaces coated by vacuum evaporation of carbon and gold (Barber and Boyde, 1968) were observed and photographed in a JSM-U3 type scanning electron microscope. The accelerating voltage used was 6-26 kv.

Observations

Under low magnification, the choroid plexus of rat ventricles appears as tortuous swellings covered by an epithelial cell layer (Fig. 1, 2). It is evident by a longitudinally

![Fig. 1. Choroid plexus of the lateral ventricle. The area outlined in the square is enlarged in Figure 3. ×150](image_url)
torn view that under the epithelial cell layer there are blood vessels (Fig. 8). However, the connective tissue layer which must exist between the epithelial layer and the blood vessel is not evident. Only the rugged endothelial cell surface of the blood vessel is observable. The individual epithelial cells can be seen by higher magnification as low, round hills which have a sponge-like surface (Fig. 3). The fine detail of the cell surface shows many small serpentine protrusions (Fig. 4). Although these protrusions seem somewhat depressed and conglomerated at the apical or central area, the protrusions at the peripheral area seem more prominent. Those depressed and conglomerated forms may probably be the products of fixation and dehydration procedures. The enlarged view of the cell surfaces shows that the small protrusions are so-called microvilli which have tortuous forms and considerable length (Fig. 5). Winding and twisting of these microvilli as well as contact with each other are also seen in high magnifications, but branching is not observable. Frequently the tip of the microvilli swells up into a bulbous structure, so that the thickness of these microvilli varies even in a single microvillus (Fig. 5).

Besides these small protrusions which are called microvilli or brush border, longer protrusions are recognized as scattered bright spots on the epithelial surface (Fig. 1–4). By larger magnification each bright spot is seen as a cluster of long and

Fig. 2. Choroid plexus of the lateral ventricle. Clusters of longer protrusions are seen as bright spots. ×420
slender protrusions which have almost the same thickness as the neighboring microvilli (Fig. 6, 7). Although it is impossible to identify them definitely as cilia, it is deducible both by Dohrmann and Herdson’s description (1970) that the cilia of the choroid plexus exist as tufts at the apical surface of the epithelium, and by the scanning electron microscopic observation of cilia in the tracheal and olfactory mucosa (Barber and Boyde, 1968). As these probable cilia always cluster and form a glomerulus or flower-like structure, the number of cilia composing a cluster is hard to guess. However, they are probably around ten or less (Fig. 6, 7). The cell which has one, occasionally two or three, of these clusters is seen in only one per several epithelial cells. The distribution of these clusters seems generally greater in concave areas than in convex areas in some fields (Fig. 3, 4). However, in occasional fields they seem to be distributed evenly as in Figure 2, which clearly shows the distribution of the bright spots.

Fig. 3. The area marked in Figure 1 at a higher magnification. The contour of each epithelial cell is recognizable as round hills. Clusters of longer protrusions are indicated by arrows. ×1,250

Fig. 4. Choroid plexus of the fourth ventricle. Microvilli and possible cilia (arrows) are more prominent. The area in the square is enlarged in Figure 5. ×3,900

Fig. 5. The area marked in Figure 4 in a higher magnification. The tortuous structure of microvilli is clear. ×12,500
Fig. 6 and 7. Enlarged view of clusters of possible cilia. ×15,000

Fig. 8. Choroid plexus of the lateral ventricle. A longitudinally torn blood vessel and its inner surface is observable. ×390
Discussion

There are a number of reports on the choroid plexus of various animals as seen by transmission electron microscopy. Particularly descriptions of the epithelial cell including the morphology of microvilli and cilia are precise. It is said that the existence of brush border on the free surface of the epithelial cell had been described by Kalwaryjski in 1924 (Dohrmann, 1970b), but the occurrence of microvilli there was first recognized with the electron microscope by Breemen and Clemente (1955) and Dempsey and Wislocki (1955) in their experimental and morphological studies on the hematoencephalic barrier. Breemen and Clemente (1955) described the bleb-like structure covering the epithelial cell surface in the choroid plexus, while Dempsey and Wislocki (1955) documented bulbous protoplasmic projections of the plasma membrane. A detailed electron microscopic observation of microvilli was first performed by Millen and Rogers (1956) who described them as a consistent and well defined element forming the brush border of the choroidal epithelium. Maxwell and Pease (1956), on the other hand, stated that the cell projections were thought to be labile and might actually be pinched off and contribute to the secretory product. The microvilli or brush borders are thought to be seen in the choroidal epithelium of almost all species except a lizard, Gecko japonicus, which was studied by Murakami (1961). Dohrmann and Bucy (1970) divided the microvilli of the choroidal epithelium into two groups: symmetrical finger-like ones and relatively shorter, rounded or club-shaped ones. The present scanning electron microscopic observation clearly shows the occurrence of these microvilli in rats and indicates that they are not short, club-shaped ones but more slender and finger-like. They seem considerably long and frequently have a swollen tip (Fig. 5), but it can not easily be inferred that a part of them are pinched off and contribute to the secretory product as Maxwell and Pease (1956) stated.

The structure of cilia was reported by Millen and Rogers (1956), Pontenagel (1962), Carpenter (1966), Dohrmann and Bucy (1970) and Dohrmann and Herdson (1970) by observation with the transmission electron microscope. The morphological criteria of cilia established in the studies of thin sections are naturally unavailable for the identification of cilia by scanning electron microscopy. Because Millen and Rogers (1956), Dohrmann and Bucy (1970) and Dohrmann and Herdson (1970) described cilia as clusters of longer protrusions, scattered groups of longer protrusions are assumed to be cilia (Fig. 1–4). This can also be inferred from the report of Barber and Boyde (1968) who observed the tracheal and olfactory cilia by scanning electron microscope. By larger magnifications (Fig. 6, 7), the detail of these longer protrusions become somewhat clear. However, their thickness seems to be variable compared with the typically uniform shape of cilia observed by transmission electron microscope. It may be possible to attribute this inconsistent thickness to the fixation and drying procedures. It is an interesting fact that they have a tendency to cluster by inward folding and make a form of glomerulus or flower among the irregularly twisting microvilli.

As for the fixation methods in this study, there seems to be no great difference between fixation with 2.5% glutaraldehyde only (Fig. 1–5) and double fixation using glutaraldehyde and osmic acid (Fig. 6–8) except that a slight unevenness of the
surface of the microvilli is recognized in the case of the single glutaraldehyde fixation (Fig. 5). However, whether this can be actually ascribed to the single fixation, or to insufficient washing of specimen surfaces or some other causes was not clear in this study.

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シロネズミ脈絡巣の走査電子顕微鏡による観察

山鳥 崇

成熟シロネズミの側脳室と第四脳室の脈絡巣を走査電子顕微鏡で観察し，次の結果を得た。

1. シロネズミの脈絡巣は迂曲曲転した小血管（毛細血管）と，結合組織を介してその上をくまなくおおう上皮細胞の層から出来ている。そして個々の上皮細胞は脳室側から観察すると，円形のやや低い小丘として認められる。

2. 上皮細胞は表面に数多くの微鉄毛をもつ。微鉄毛は分枝したり融合したりはしないが，その形態は変化にとどめ，末梢が膨大しているものもしばしば認められる。従ってこの直径は たとえ単一の微鉄毛の場合でも一定していない。微鉄毛の分布は小丘の中央隆起部ではその辺縁部より密で，しかもたがいにより合ってかたまっているようにみられる。

3. 微鉄毛でおおわれる これら上皮細胞の中に，微鉄毛より長い，繊毛と思われるもののを持つ細胞が散在している。"繊毛" は およそ 10 本ないしそれ以下のものが ひとつの群をなして微鉄毛の中に存在し，この様な "繊毛群" は たいてい ひとつの "繊毛所有細胞" について 1 個存在するが，まれには 2 ないし 3 個みとめられる。

References

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