Ultrastructure of "tubular body" in the endothelial cells of the ocular blood vessels

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Characteristic tubular bodies were detected with great regularity in the endothelial cells of the blood vessels of human eyes, normal and pathologic, as well as in growing vessels in rabbit corneas. These bodies in the mature form are shaped like a cylindrical rod with an internal tubular structure, bounded by a limiting membrane of unit membrane type. They are numerous in some instances of Behçet's disease. In the immature form they are often located in close proximity to the Golgi complex. It is probable that the tubular bodies are derived from the Golgi sac by budding and that they become more dense as they grow to maturity.

Key words: tubular bodies, endothelial cells, Behçet's disease, Golgi complex.

In 1964, Weibel and Palade reported a new rod-shaped cytoplasmic component present in the endothelial cell of the small arteries in various organs of rat and man. Weibel and his collaborators presumed that this organelle would be closely related to blood coagulation. Recently, Sengel and Stoebner also noted the same structure in the blood vessels of various human materials, emphasizing that it was derived from the Golgi complex.

The authors were able to observe a tubular body identical with that described by previous workers in the blood vessels of human eyes, normal and pathologic, as well as in growing vessels of rabbit cornea. The purpose of this paper is to describe the detailed morphology of this body and discuss a possible mode for its development.

Materials and methods

The material was obtained from the normal iris of two patients, 3 and 53 years old, whose eyes were removed because of orbital tumors. The iris from five patients and the choroid from one, all with Behçet's disease, were also used. The lacrimal gland of one patient with eosinophilic granuloma was also examined. Growing vessels were induced in rabbit cornea by external application of alloxan solution as reported previously. The corneas were removed 15 days after treatment. All tissues were immersed in 1 per cent buffered osmium tetroxide (0.1M osmium tetroxide solution in 0.1 M sodium cacodylate). The tissue was then dehydrated through a series of ethanol (95–100%) solutions and embedded in Spurr's resin. Ultrathin sections were cut with a diamond knife and stained with uranyl acetate and lead citrate. Observations were made with an Hitachi HU-12A electron microscope.
phosphate buffer, pH 7.4) for two hours. The tissues were cut into small pieces during fixation. Some of the tissues were prefixed in 2.5 per cent glutaraldehyde solution (phosphate buffer) for one hour. They were then dehydrated in graded ethanols and finally embedded in Epon. Thin sections were cut on an LKB ultrotome and examined with a Hitachi HU-11DS and a Hitachi HS-8 electron microscope following combined staining with uranyl acetate and lead citrate.

Observations

Human iris. In all instances investigated, characteristic tubular bodies were found with great regularity in the endothelial cells of capillaries, venules, and arterioles (Figs. 1 and 2). These bodies were rod-shaped, measuring 0.7 to 1.5 μ in length and 0.1 to 0.4 μ in width. They were bounded by a limiting membrane of unit membrane type, though it often appeared discontinuous when sectioned tangentially on the surface of the rod. Cross sections of these rods were circular or elliptical and exhibited varying numbers of ring-shaped profiles, about 100 A in inner diameter (Figs. 3 and 5). Longitudinal sections showed internal fine tubules of about 100 A in width disposed parallel to the long axis of the rod (Fig. 4). It may be reasonable to assume that these bodies are in the shape of a long cylindrical rod, usually straight, but sometimes bent. The internal tubules were embedded in a moderately dense matrix composed of fine particles and the interior of these tubules was generally clear. The wall of such tubules is about 60 A thick and the intertubular distance measured 50 to 150 A. The number of tubules contained in each rod was 10 to 30, depending upon the sectional area (Figs. 5 and 6).

In addition to the usual rods there were lucid tubular bodies, often located in close proximity to the Golgi complex. In shape, they were almost a flattened ellipsoid with an irregular outline. The tubules in the sacs were tortuous and had no dense particles around them (Figs. 6 and 7).

With regard to the developmental mode, a number of micrographs indicate the following sequence (Figs. 9 and 10). The Golgi sac puts forth a bud which, in time, contains one or more fine tubules which exhibit a tortuous or twisted course, though such a tubular structure is not clear at the root of the bud. The tubular bodies then occur in an electron-lucid form with an irregular outline and tortuous tubules. The tubular bodies are more numerous in the capillaries and venules than in the arterioles and they are markedly increased in some instances of Behçet's disease.

Other human ocular tissues. In both materials studied, i.e., lacrimal gland and choroid, the electron-dense tubular bodies were constantly detected in the endothelial cell of the blood vessels.

Growing vessels in the rabbit cornea. The tubular bodies were found with great regularity in electron-lucid form, in the endothelial cell of the growing vessels (Figs. 9 and 10). The more usual electron-dense form was limited to the limbus. The fine structure of these bodies was the same as in human iris.

Discussion

A new cytoplasmic component as reported by Weibel and Palade and others has not, to our knowledge, been reported in ocular blood vessels nor in growing vessels. The present study has revealed that such tubular bodies are always present in the endothelial cells of the blood vessels of human eyes, normal and pathologic, as well as in growing vessels of the rabbit cornea.

The essential structure of these bodies is in accordance with the description by others. The findings obtained indicate that these bodies are produced in the Golgi complex and distributed throughout the cytoplasm. A possible mode of their development is shown schematically in Fig. 11. The Golgi sac puts forth a bud. It then becomes tubulated and the tubular bodies occur in an electron-lucid form by separation from the sac. Their electron-dense mature form develops by deposition of dense particles in the matrix. In favor
Fig. 1. Cross section of a capillary in normal human iris. Endothelial cells (En) are occupied by two large irregular nuclei (N). In the cytoplasm around the nucleus there are tubular bodies (arrows) cut crosswise or longitudinally. (×16,500.)

Fig. 2. Tubular bodies (arrows) in the endothelial cell (En) of an arteriole in normal human iris. SM: smooth muscle, m: mitochondria, Lu: lumen of vessel. (×17,000.)
Fig. 3. Cross section of a vessel in the iris of beagles disease. A number of tubular bodies with a limiting membrane. P: pericyte, Lu: lumen of vessel, m: mitochondria. (×33,000.)

Fig. 4. Longitudinal section of an electron-dense tubular body. It is bounded by a limiting membrane of unit membrane type. The internal structure shows fine tubules of about 200 Å in width, running parallel to the long axis. (×147,000.)

Fig. 5. Cross section of an electron-dense tubular body. There are seen transverse figures of fine tubules (arrow), 100 Å in inner and 200 Å in outer diameter. (×168,000.)
Fig. 6. Endothelial cell (En) of the capillary in the iris of Behçet's disease. Near the Golgi complex (G) there are seen enlarged Golgi sacs containing several fine tubules (double arrows). Electron-dense tubular bodies (arrows) are found in the peripheral region. m: Mitochondrion, mv: multivesicular body, Lu: lumen of capillary. (×42,000.)

Fig. 7. Golgi complex (G) in the endothelial cell of the normal iris capillary. A protruded sac contains a fine tubule cut crossly (arrow). Double arrows indicate a fine tubule in the sacs running parallel to the long axis. (×60,000.)
Fig. 8. This electron micrograph shows the difference of the diameter between the fine tubule (arrow) and the vesicle of multivesicular body (mv). tb: Tubular body, m: mitochondria. (×142,500.)

Fig. 9. Golgi complex (G) in the endothelial cell of the growing vessel. Arrows indicate cross sections of fine tubules lined up in protruded Golgi sac. (×30,000.)

Fig. 10. Endothelial cell (En) of growing vessel. Many cytoplasmic organelles including Golgi complexes (G) are seen. Protruded sacs of Golgi complexes (arrows) contain fine tubules. (×39,000.)
of the above view, that an electron-lucid form is an immature one, is their extremely numerous occurrence in growing vessels in which the Golgi complex is very well developed. The observation on the growing vessels suggests that the tubular bodies do not become mature within two weeks under conditions employed.

It is probable that the tubular bodies play an important role in the endothelial cell of the blood vessel. The function of these bodies, however, still remains obscure, though a few attempts have been made to solve this problem. It is of interest that they are numerous in some instances of Behçet's disease in which circulatory disturbances are apt to occur. At any rate, the nature of these organelles needs further investigation.

REFERENCES