Aspects on Endolymphatic Sac Morphology and Function

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Summary. Morphological evidence indicate that the main function of the endolymphatic sac is to act as a reabsorptive and defensive mechanism for the inner ear. This activity is markedly enhanced in labyrinthine trauma, such as injection of foreign particles into the labyrinth, blocking of the endolymphatic duct, and cryosurgical destruction of vestibular sensory epithelia. Light and dark epithelial cells of the intermediate portion of the sac are capable of reabsorbing endolymph and digesting cellular debris respectively. The extensive capillary network surrounding the endolymphatic sac exhibits endothelial characteristics suggestive of active fluid transport. The "dynamic-flow theory" of endolymph circulation suggests that a radial-flow should be considered for energy metabolism and ion exchange around the sensory cell regions whereas a longitudinal-flow should be considered for reabsorption of endolymph and disposal of high molecular waist products and debris by the endolymphatic sac. The earlier concepts of endolymph circulation thus need not any longer be considered conflicting.

Key words: Endolymphatic Sac — Reabsorptive and Defensive Mechanism — Active Fluid Transport — Dynamic-Flow Theory.

Since the discovery of the aqueducts of the human inner ear by Cotugno (1774), and the first description of the endolymphatic sac proper by Boettcher (1869), it has been said to have many functions for the inner ear:

To be a rudimentary organ without any specific function (Siebenmann, 1919).
To produce endolymph (Boettcher, 1869; Seymour, 1954).
To resorb endolymph (Iwata, 1924; Guild, 1927; Lundquist, 1965 and others).
To act as a passive pressure regulator for the inner ear (Kolmer, 1923; Allen, 1964).
The first solid investigation based on histological analysis and experimental data was by Guild (1927). The following discussion and description is based on the first electron microscopical analysis of the endolymphatic sac by Lundquist and coworkers (1964, 1965) as well as later investigations.

Morphology

Gross Anatomy of the Endolymphatic Sac

The endolymphatic duct arises from the junction of the saccular and utricular ducts at the medial wall of the vestibule and continues running inside the vestibular aqueduct. In the posterior half of this duct, the true sac is formed as a dilatation extending through the external orifice of the vestibular aqueduct. The sac is at that part enclosed in a dural duplicature and ends in close contact with the sigmoid sinus (Fig. 1).

According to Guild (1927), the endolymphatic sac proper can be divided in three parts: The proximal constituting the first widening part inside the vestibular aqueduct. The intermediate, partly inside and partly outside the vestibular aqueduct. This latter part has also been called rugose (Bast and Anson, 1949) due to its irregular appearance with epithelial folds and crypts. The distal part is somewhat flattened and lies in close contact with the sigmoid sinus. It has a very narrow lumen without crypts or protrusions (Fig. 1).

Fine Structure

By electron microscopy a clear description can be given of the cellular appearance in the various parts of the endolymphatic duct and sac system.

Endolymphatic Duct: The epithelium is of a simple squamous or low cuboidal type resting on a smooth basement membrane.

The Endolymphatic Sac: The proximal portion. This gradually widening part of the sac has an epithelial lining which changes into a higher cuboidal cell type with small microvilliform protrusions on its endolymphatic surface (Fig. 2). The intermediate portion. This constitutes the main part of the sac. In the epithelial crypts and protruding papillae (Fig. 2) two distinct types of cells are recognized, the so-called light cell with a homogenous relatively pale matrix, richly abundant ribosomes and mitochondria, and on its fluid surface a presence of numerous microvilli and pinocytotic vacuoles (Fig. 3).

The basal part of this cell also exhibits an extensive infolding of its basal cytoplasm indicating an increased surface activity. The dark cell on the other hand is more wedge-shaped with a dense cytoplasm a fibrillous inappearance (Fig. 3). The distal portion exhibits a more cuboidal epithelial lining. Although the epithelial crypts and protruding papillae here disappears, the same basic cell types can still be recognized except in the extreme and where the cells are cuboidal in appearance.