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Encapsulated nerve corpuscles in the human tympanic membrane

T. Nagai and T. Tono

Department of Otolaryngology, Miyazaki Medical College, Kiyotake, Miyazaki, 889-16 Japan

Summary. Encapsulated nerve endings were found in both the subepidermal connective tissue and the lamina propria of a human tympanic membrane. The structure of the corpuscles was round or oval and contained a number of axon terminals with mitochondria and Schwann cell processes. Amorphous materials were present in the intercellular space. These features appear to be advantageous in transmitting mechanical forces on the capsule to the axon terminals and are comparable to the function of a mechanoreceptor. Resultant changes in the shape and stiffness of the tympanic membrane as the result of its dislocation indicate similar changes in the pressure on the corpuscle. The arrangement of the sensory corpuscles suggests that they may play a role in detecting pressure changes in the middle ear cavity.

Key words: Tympanic membrane – Ultrastructure – Sensory receptors – Nerve endings

Introduction

Wilson [5] in 1911 studied nerve distribution in the human tympanic membrane and reported the presence of free nerve endings in the intraepidermal, subepidermal and submucosal layers. He mentioned them as nociceptive organs that were sensitive to the pain. He also noted a peculiar structure resembling the modified Vater-Pacinian corpuscle at the peripheral area of the tympanic membrane.

However, its physiological significance was not elaborated and there have since been no available reports dealing with its fine structure. Among our collections of tympanic membranes removed from patients with various middle ear disease, we encountered nerve endings resembling the modified Vater-Pacinian corpuscle reported by Wilson. This report deals with its fine structure and discusses its significance in possibly regulating middle ear pressure.

Offprint requests to: T. Nagai

Materials and methods

The patient whose tympanic membrane was examined for the present study was a 16-year-old girl with an atelectatic ear. The specimen was obtained from the second quadrant of the tympanic membrane where a ventilation tube was placed. The specimen was immediately fixed in 3% glutaraldehyde for 1 h and post-fixed in 1% osmium tetroxide for 1 h. It was dehydrated in a series of methanol solutions, immersed in propylene oxide, and embedded in Epok 812. Semi-thin sections were cut and then stained with toluidine blue solution for examination under a light microscope. When a nerve corpuscle was found, further ultrathin sections were cut with a diamond knife attached to a Porter-Blum type I microtome. These sections were doubly stained with uranyl acetate and lead citrate and examined under a JEM-100B and 200CX electron microscope.

Results

Six encapsulated nerve corpuscles were found in the tympanic membrane specimen. Four of these corpuscles were located in the subepidermal connective tissue and the remaining two corpuscles were present in the lamina propria near the epidermis. These corpuscles were oval or round with diameters that were about 40 μm. They were completely surrounded by a single layer of capsular cells and were clearly differentiated from the surrounding tissues except where a fine axon occasionally passed through the capsule (Fig. 1). The intracapsular space was filled with a number of poly-

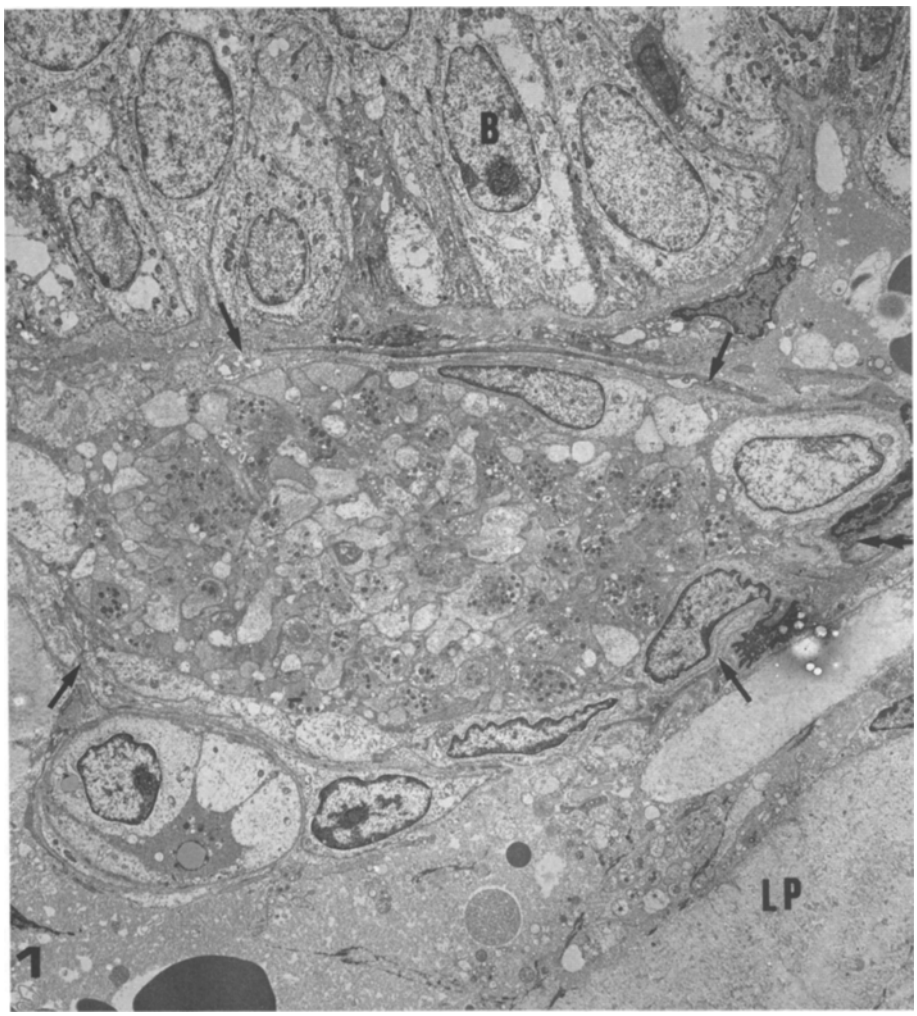

Fig. 1. The overall structure of the encapsulated nerve ending (with its margin indicated by *arrows*) of the human tympanic membrane. Nerve fibers enter the corpuscle from the left side and a fine fibril comes out at the opposite side (indicated by the *double arrow*). *B*, Basal cells of epidermis; *LP*, lamina propria. × 2250

gonal processes of clear and dark cells (Fig. 2). These processes were in close proximity to each other and were spearated by distances of only 200 Å–0.1 μm. However, such contact devices as desmosomes, which are often found in lamellated mechanoreceptors, were not observed. An amorphous ground substance was seen to fill the spaces between the processes. The clear cells appeared to be either axons containing intermediate filaments and microtubules or axon terminals with aggregations of mitochondria (Fig. 3). The dark cells were apparently Schwann cell processes which contained fine reticulate filaments, mitochondria, endoplasmic reticulum and lysosomes. No cell body of the Schwann cell was found in the corpuscle. The capsular cell contained cytoplasmic filaments (Fig. 4). In spite of the continuity of the each capsule, junctional complexes were not found between the capsular cells. A bundle of non-myelinated nerve fibers occasionally entered into each corpuscle (Fig. 5) and free nerve endings were also encountered around the corpuscle (Fig. 6).

Discussion

Wilson's initial report [5] indicated that capsulated endings resembling modified Vater-Pacinian corpuscles consisted of a complex interlacement of nerve fibers. Our electron microscopic observations revealed that the intracapsular space was filled with a number of axons and Schwann cell processes.

The encapsulated sensory receptors in the cutis are the Meissner corpuscle and the pacinian corpuscle [1]. They are distinguished by layers of thin lamellar cells around the axon terminals. The interlamellar space is filled with a basement-membrane-like substance and collagen fibers. When compared to these receptors, the Schwann cell of the corpuscle studied by us does not possess such specialization as lamellated structures. However, the presence of amorphous materials in the corpuscle studied by us is a common observation with the lamellated corpuscles.

When considering the function of the corpuscle in the tympanic membrane, interlacement of the Schwann

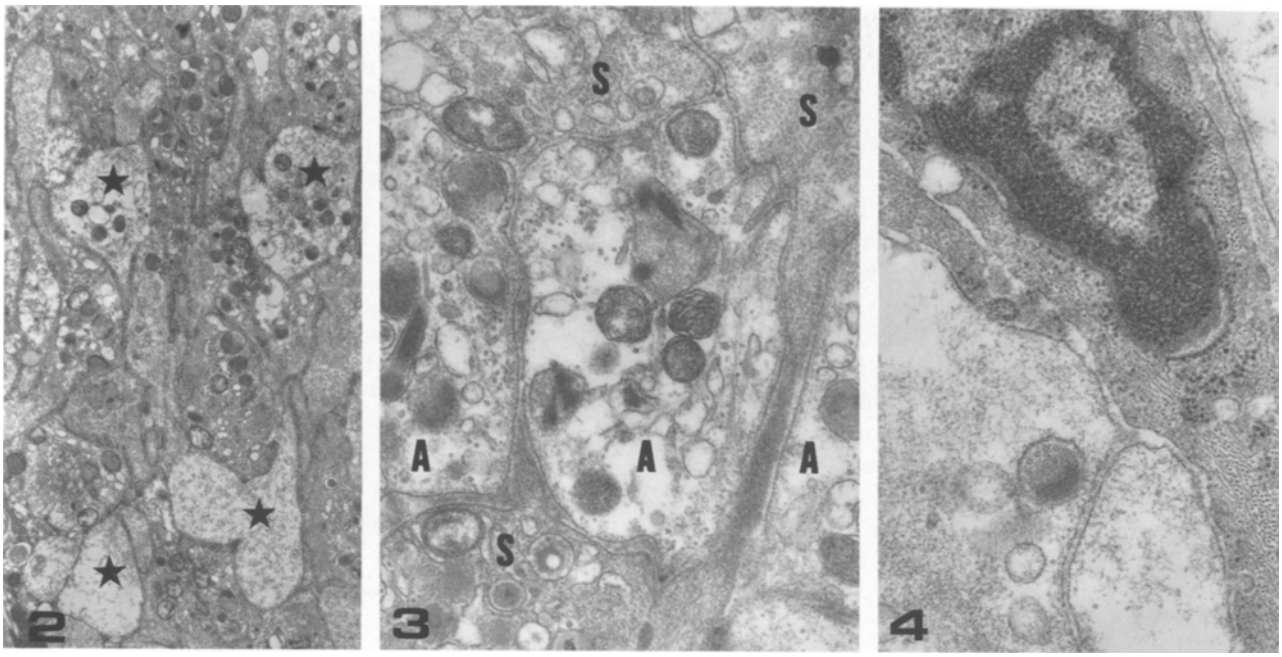

Fig. 2. Axons (indicated by *asterisks*) and processes of a Schwann cell fill the intracapsular space. × 6750

Fig. 3. Axon terminals *(A)* containing mitochondria and Schwann cell processes *(S)* containing fine reticulate filaments. × 21750

Fig. 4. Capsular cell containing cytoplasmic filaments. × 30000

cell processes with axons provides a desirable structure for the transmission of mechanical forces on the capsule to the axon terminals. According to the theory of mechanoelectric transduction in the pacinian corpuscle [4], the amorphous materials in the intercellular space are necessary for generating a viscous pressure.

Free nerve endings frequently encountered in the subepidermal connective tissue seemingly respond to pain, as Wilson [5] reported. However, the structure of the corpuscle seen in the tympanic membrane is not suitable for a pain receptor because its capsule is so configured to prevent the axon terminals from coming into direct contact with the chemical mediator released by any inflammation or trauma.

The nerve endings in the tympanic membrane were located in the subepidermal connective tissue and lamina propria layers, which are mainly composed of dense collagen fibers intermingled with some elastic fibers [2, 3]. The tympanic membrane changes its shape

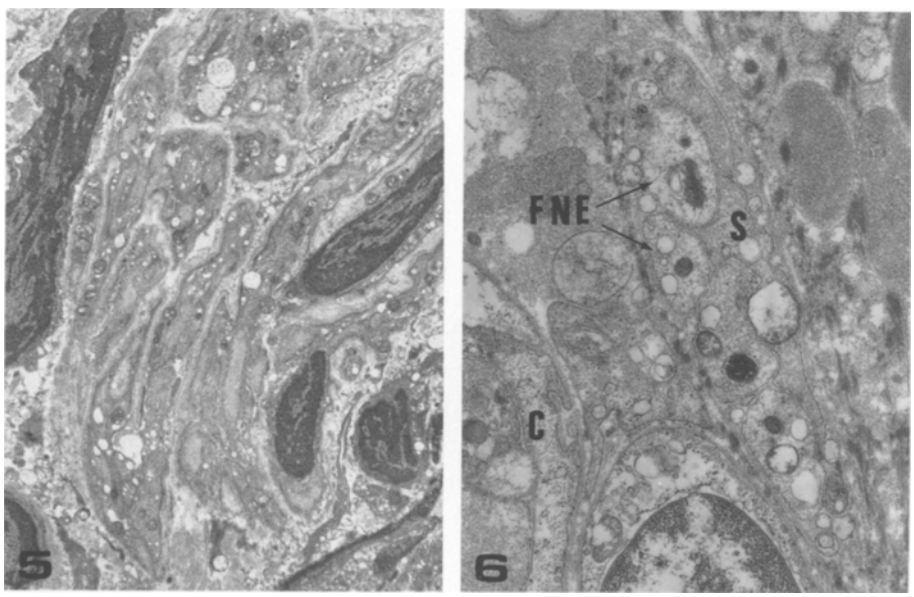

Fig. 5. A bundle of non-myelinated nerve fibers innervating the corpuscle. × 5100

Fig. 6. Free nerve ending *(FNE)* near the corpuscle. *S*, Schwann cell; *C*, capsule. × 12200

and stiffness in relation to pressure differences between the external acoustic meatus and the tympanic cavity. The resultant increased tension of the tympanic membrane may then press the corpuscle. It is our concept that the encapsulated nerve corpuscles are sensitive to any dislocation of the tympanic membrane and then play a role in directing subsequent pressure changes in the middle ear.

Some inflammatory changes were observed in portions of our present specimen. These included alterations of the fine stucture of mitochondria, edema of the cells and the presence of lysosomes in the Schwann cells. However, no serious pathological changes were not found in the fundamental organization of the cell components within the corpuscles studied. These observations remain to be confirmed in the normal tympanic membrane (in the absence of middle ear disease).

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