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Histologic changes in the ageing spiral tract

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Abstract

To investigate the influence of ageing on the morphology of the bottom of the internal auditory meatus, we analysed 150 undecalcified pyramids of human temporal bones. In most of the histologic sections examined, we found pointed bony spicules in the region of the spiral tract. These develop from layers of active and resting osteoid, reach their final morphologic shape in the fourth decade of life and then protrude into the internal auditory meatus, compressing the cochlear nerve fibers.

Introduction

The bottom of the internal auditory meatus is made up of a tiny bony wall containing openings and canals through which bundles of nerve fibers and blood vessels pass. The spiral tract (area cribrosa basis modioli) occupies the largest part of the bottom of the internal auditory meatus, and consists of a lot of coiled, placed openings. By entering these openings, the cochlear nerve fibers reach the cochlea, passing through irregular and tortuous bony canals (Fig. 1).

Extensive research has been carried out on the effect of ageing in the auditory system, but most of these investigations have been focussed on the organ of Corti, the ganglionic cells and their nerve fibers, the cerebral auditory pathways and centers and on blood vessels. Fewer studies, however, have been conducted on the influence of ageing on the bony ear structures.

In 1934 Crowe, Guild and Polvogt found that the typical lesion in ears with a gradual high tone loss was a partial atrophy of the cochlear nerve supply in the osseous spiral lamina of the basal turn.

The most comprehensive investigations of the spiral tract have been performed by Šercer and Krmpotić (1958) and later by Krmpotić-Nemanić and her colleagues (1969, 1971, 1972, 1976). In macerated skulls of advanced age, they found hyperostotic changes in the internal auditory meatus and its bottom, which are mostly developed in the basal coil of the cochlea. These changes lead to the closure of the openings through which the fibers of the acoustic nerve pass and their damage is consequently responsible for the disappearance of ganglionic cells. Hyperostotic changes occur with ageing and result in senile deafness or presbyacusis in advanced age. Examining series of decalcified histologic specimens Krmpotić-Nemanić *et al.* (1972) found in older persons, osteoid and bone tissue

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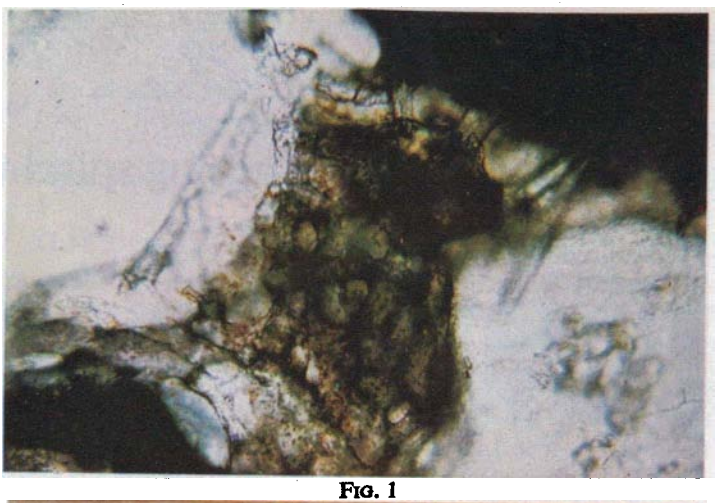


FIG. 1

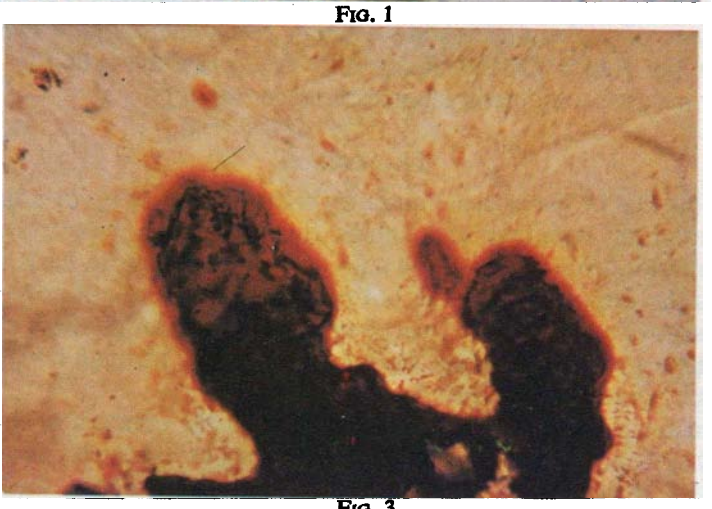


FIG. 3

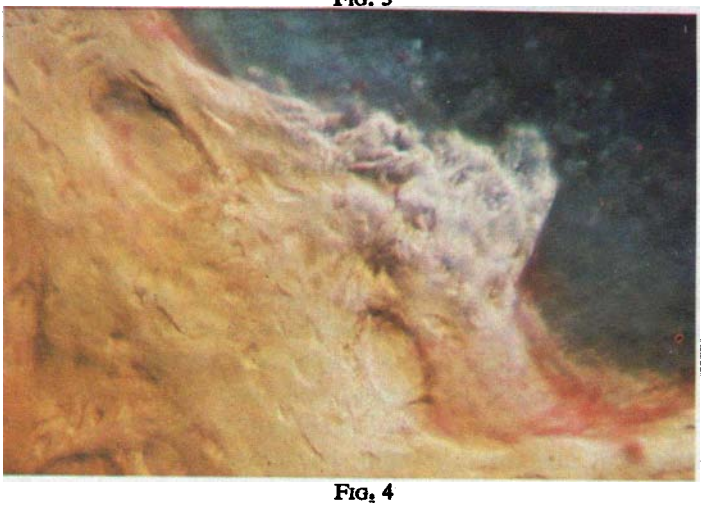


FIG. 4

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FIG. 5A

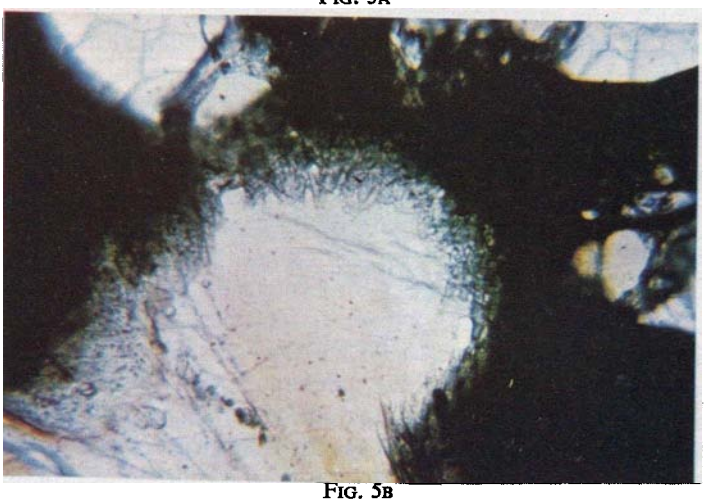


FIG. 5B

FIG. 1

Cribriform lamina of modiolus with openings for cochlear nerve fibers, ×32.

FIG. 3

Blunt bony spicules of the spiral tract protruding into the internal auditory meatus. Layer of osteoid is present around the margin, while the lower parts are completely mineralized. Dahl's stain, ×450 (64 years).

FIG. 4

Pointed bony spicule in the region of the spiral tract completely formed and mineralized; tetrachrome stain, ×400 (61 years).

FIG. 5

The entire surface of the spiral tract is covered with pointed and mineralized bony spicules, which protrude into the internal auditory meatus (39 years).
FIG. 5A tetrachrome stain, ×200; FIG. 5B tetrachrome stain, ×32.

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covering the openings of the spiral tract's nerve canals, whose apposition makes the surface of the bottom rough. Between 80 and 90 years, the nerve fiber canals become, finally, nearly or completely closed.

In this study we have investigated the influence of ageing on the spiral tract in undecalcified histologic sections, in order to obtain an understanding of the nature of the bone substance and the dynamics of this process.

Material and methods

We investigated 75 pairs, i.e. 150 undecalcified pyramids, of temporal bones of various ages, ranging from 1 month to 83 years (36 female and 39 male). The bones were obtained at autopsy and fixed in 95 per cent ethanol. The pyramids were sawn to a size of $2 \cdot 5 \times 2 \times 3$ cm, to preserve all parts of the internal ear and acoustic nerve, and then embedded in methyl methacrylate (Štern-Padovan *et al.*, 1978, 1979). Histologic sections of pyramids from newborn to three years of age were obtained by hard-tissue microtome (Jung K, 10 μ), while the other sections were prepared according to a slight modification of Frost's procedure (30 μ). The sections were dyed without prior removal of the methacrylate, with the following stains: Dahl's calcium stain, hematoxylin-eosin, von Kossa stain and tetrachrome stain (Villanueva, 1974; Štern-Padovan, 1978).

Results

In persons up to 16 years of age no changes were found in the region of the spiral tract in any of the investigated pyramids, except for enlargement proportional to growth. The openings for the nerve fibers were wide, were similar in diameter and had entirely smooth margins.

In the majority of specimens from persons between 17 and 25 years, we found active osteoid on the margins of the nerve fiber openings. At the same time, active osteoid appeared on the surface of the bone partitions which separated individual openings. This is actually a very thin layer of osteoid which does not surround the entire opening equally, but is irregularly distributed.

The most intensive ageing activities occurred between 26 and 40 years. In addition to active osteoid, there are also resting layers and transitional forms of osteoid on the margins of the spiral tract openings and on the bony partitions between them. Mineralization of osteoid begins in the deeper layers and gradually reaches the superficial layers. The diameter of the spiral tract openings gets smaller, and at the same time, these openings become irregularly shaped. The bony partitions between the openings of the spiral tract, which originally had smooth surfaces, protrude towards the internal auditory meatus and gradually change from a blunt to a pointed form (Fig. 2). Staining the sections according to Villanueva, we confirmed the development of active osteoid which is then followed by the appearance

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FIG. 2

Development of pointed bony spicules in the region of the spiral tract from layers of active and resting (R) osteoid seams.

of increasing amounts of resting osteoid layers. Mineralization of osteoid layers in the majority of specimens begins at the base of the osteoid, progressing towards the superficial layers which now protrude into the internal auditory meatus as pointed bony spicules (Figs. 3, 4). Therefore, two types of change occur during mineralization of the osteoid: at first the shape and diameter of the spiral tract openings change; and secondly, spicules appear on the bony partitions between the openings of the spiral tract. We found the first completely formed bony spicules in a person 37 years old.

In most of the specimens from persons between 41 and 65 years of age, we were able to confirm that this is the period when the processes of formation and mineralization of osteoid have already started in the spiral tract openings and their bony partitions continue, but the process is slower. The same changes as those mentioned above appear now in tortuous bony canals, extending to the cochlear side of the spiral tract. The openings of the spiral tract are irregular and different, and the diameters are much smaller. The bony partitions between the openings therefore become more massive and pronounced. The decrease in size of the openings certainly contributes to the development of pointed bony spicules, which at this time protrude into the internal auditory meatus, pressing on the fibers of the cochlear nerve. In the specimens investigated, however, there were differences in the appearance, size and distribution-density of the pointed bony spicules.

We found these processes continuing in 50 per cent of specimens from persons older than 65 years while, in the rest of the pyramids, osteoid seams were rarely observed.

We have found no significant sex differences, and the changes were nearly the same throughout the various age-groups in both males and females.

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Discussion

Our findings have confirmed that aging of the bony inner ear structures does not affect all persons of the same age in the same manner, but varies from individual to individual. For this reason, we divided all the specimens investigated into approximately 20-year age-groups. However, in spite of individual variations in the occurrence of these changes, our findings proceed that this process affects the bony structures at the bottom of internal auditory meatus in all persons.

Belal (1975) found in decalcified histologic sections of the middle and inner ear from persons with normal and disturbed audiograms, two ageing phenomena which affect the human ear. The first is physiological and includes all structures of the middle and inner ear, except the basilar membrane, and has been called 'auditory senility'. Belal examined only the auditory ossicles and found increased diameters of the Haversian system and osteoporosis, manifested by the appearance of cavities of different forms and shapes. This process involves all parts of the auditory mechanism equally. The second phenomenon is pathological and has been termed 'auditory decay'. It involves only the perceptive system and results in different types of clinical presentations.

Based on our findings in undecalcified sections, the bone structures of the bottom of internal auditory meatus are not affected by osteoporosis and atrophic processes in persons of advanced age. That means that degenerative and atrophic changes are not the only morphologic manifestations of the ageing process of the bony structures in the auditory system. However, during the process of osteoid mineralization, the spiral tract increases its surface by forming pointed bony spicules which protrude into the auditory meatus and take space away from the cochlear nerve fibers. In the majority of specimens, the first appositions appeared between 17 and 25 years of age, but such initial changes could also be found in persons around forty years of age. However, regardless of whether these pointed bony spicules form earlier or later, they do start developing between 17 and 40 years of age. We found the first completely formed bony spicules in a person 39 years old (Fig. 5). However, in patients with acoustic neurinoma, there may be severe degeneration of the cochlear nerve without significant hearing loss (Schuknecht and Woellner, 1955; Jerger, 1960), while on the other hand Neff (1947) reported a high-frequency hearing loss when more than 50 per cent of the nerve fibers were severed.

Some authors have observed the appearance of new bone in the ageing process of bony structures of the temporal bone and inner ear. Fowler (1944) found hyperostoses in the pyramid of the temporal bone, while patchy or widespread atrophy were not present. Covell (1952) observed osteitis in the bottom of the internal auditory meatus of the human temporal bone at the point of exit of the cochlear nerve fibers. Describing the histologic changes of the cochleas of senile guinea pigs as compared to

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those of young animals, Covell and Rogers (1957) found osteitis of the bony wall of the modiolus, increasing with age.

The macroscopic and microscopic investigations of Krmpotić-Nemanić *et al.* (1969, 1971, 1972, 1976) have proved that with ageing the bone piles up in the bottom of the internal auditory meatus, making the surface of the fundus uneven and rough.

In our previous study, casts of the internal auditory meatus (107 macerated skulls) showed that during life the meatus narrows from its porus towards the bottom. In advanced age, the casts showed ridges and grooves, but never along the spiral tract. These grooves correspond to the findings of microscopic hyperostoses in the auditory meatus (Štern-Padovan, 1977, 1978).

Kelemen (1958) attributes the findings of irregular exostoses in the bottom of the auditory meatus to a long list of other congenital malformations in cases of autopsied premature infants.

None of the authors who have reported the microscopic findings of new bone formation in the internal auditory meatus, however, have described the formation of similar pointed bony spicules in the region of the spiral tract. Our investigations of undecalcified histologic specimens embedded in methacrylate have revealed that the formation of osteoid in different periods of life goes through various phases of development, leading thus to the previously described microscopic hyperostotic changes morphologically defined already at 40 years. In decalcified sections the only morphological changes observed were a rough bottom of the internal auditory meatus, which corresponds only to the specific developmental phase of the bony hyperostoses of the spiral tract, as we have shown in undecalcified histologic sections. This is quite understandable, since we were also unable to preserve the pointed bony spicules in undecalcified but unembedded pyramid specimens.

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