Three-dimensional guinea pig and pigeon inner ear reconstruction
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Summary

By reconstructing (parts of) the inner ear of guinea pigs and pigeons in three dimensions we evaluated the morphology and possible physiology of the endolymphatic and perilymphatic spaces.

In chapter 1 the (human) inner ear anatomy is considered. The sensory epithelia of both the auditory as well as the vestibular system are located in the membranous labyrinth. This part is filled with endolymph. The main functioning part of both systems are the hair cells. Deflection of the cilia on the hair cells causes ion channels to open or close, resulting in de- or hyperpolarization of the cell membrane and a resulting neurotransmitter release.

Menière's disease, characterized by fluctuating, progressive, unilateral or bilateral, sensorineural hearing loss, unilateral or bilateral tinnitus and periodic episodes of vertigo was first described by Prosper Menière in 1861. Endolymphatic hydrops is presumed to be the histopathological basis of this disease. Can we learn something about the pathophysiology of Menière's disease from an evolutionary point of view?

In chapter 2 an overview is given on the changes seen in inner ear morphology in different animal classes. Immediate cause for doing this was the very detailed description of inner ears in almost one hundred animals by Retzius (1842-1919). (Das Gehörorgan der Wirbeltiere; morphologisch-histologische Studien, 1881, 1884). Bergeijk (1967) proposed, in the acousticolateralis hypothesis, the evolutionary origin of the inner ear from the lateral line organ. Both organs have the same kind of ciliated sensory hair cells. Others (Wever, 1974) believe that the lateral line system and the labyrinth have evolved parallel.

The membranous labyrinth of Fish is embedded in bone. It consists of seven sensory areas: the three cristae ampullares at the end of the semicircular canals, the utricular and saccular maculae, the lagener macula and the macula neglecta. The maculas are scattered with thousands of hair cells. The hair cells are covered by a large otolith plate in the utriculus, the saccule and lagena.

The endolymphatic duct is present in some fish, absent in others. In Elasmobranchs (sharks and rays) the endolymphatic duct/sac ends externally on the head of the fish.

The membranous labyrinth in Lizards is captured in the otic capsule. The labyrinth can be divided in an utricular and saccular part. The latter one exhibits a cochlear duct with a basilar papilla, likely the auditory part of the labyrinth. An equivalent of the endolymphatic duct/sac is seen in various lizards with various extensions.

In Amphibians the membranous labyrinth is also embedded in a protective bony labyrinth. Besides the three cristae ampullaris, the saccule, the utricle and the lagena, two other sensory areas are present: the amphibian and
basilar papilla. The endolymphatic sac has a large extension to the vertebral column. The exact function of the endolymphatic sac (endolymphatic pressure regulation among others) is not known.

In **chapter 3** three dimensional-reconstruction based on light microscopy is compared with 3D-reconstruction based on OPFOS-microscopy. OPFOS-microscopy-3D-reconstruction is superior to non-whole-specimen methods. Extensive 3D-reconstructions based on OPFOS microscopy, as well as on light microscopy, of the endolymphatic and perilymphatic spaces in guinea pig are presented. Measurements on the cochlear dimensions are given. The pro’s and con’s of OPFOS microscopy are discussed.

In **chapter 4** the 3D-reconstruction of the round window-cochlear aqueduct-complex shows that the round window membrane of the guinea pig has a pouch-like extension in de cochlear aqueduct. The entrance of the aqueduct is obstructed when the inner ear fluid pressure is low and the membrane is moving inwards (with a resulting high flow resistance in the cochlear aqueduct). The entrance is open when the inner ear fluid pressure is high and the membrane is moving outward. The resistance for fluid flow through the aqueduct is dependent on the position of the round window membrane.

In **chapter 5** a model is presented (Letter-to-the-Editor) in which the endolymphatic fluid pressure in the endolymphatic sinus is compared to the perilymphatic fluid pressure. When the perilymphatic pressure is increased to compress the sinus, the pressure inside the saccule will increase with the same amount. The fluid pressure from the saccule toward the sinus will precisely counteract the pressure that tries to compress the sinus. The response to this letter is also presented.

In **chapter 6** the 3D-reconstruction based on OPFOS microscopy of the Bast's valve-utricular duct-complex shows a rigid ‘arch-like’ configuration of the proximal end of the valve. The entrance of the duct is broad but small (funnel-like). This funnel quickly runs into a very narrow utricular duct. Furthermore the valve itself appears immobile and thus non-compliant. Opening and closure of the utricular duct is dependent on the membrane of the utricle and surrounding perilymphatic pressure.

In **chapter 7** the question is raised if pigeons also exhibit an equivalent of Bast's valve. 3D-reconstructions based on light microscopical slides show a valve-like structure at the utricular side of the utricular duct. Its functioning appears to be the same as in mammals.

In **chapter 8** the inner ear of the *Colomba Livia* (rock pigeon) is reconstructed in three dimensions. We used a combination of both OPFOS microscopy as well as conventional light microscopy. Both methods give
detailed three-dimensional reconstructions of pigeon inner ear anatomy. Accompanying volumetric and dimensional measurements of endolymphatic spaces are made.

In **chapter 9** the objectives of this thesis are discussed. Besides this the findings and hypotheses mentioned in the chapters are commented and discussed.