Morphology of the endolymphatic space in the murine cochlea uncovered by micro computed tomography using synchrotron radiation

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The hearing organ belongs to the most complex structures in the human body. It is very important to recognize its morphology on the microscopic level, because already minor morphological deviations may result in crucial hearing deficiencies. Current methods such as histological sectioning are very powerful, but destructive, may lead to preparation artefacts and only provide the necessary spatial resolution in two dimensions. Consequently, it is highly desirable to complementarily apply a non-destructive, fully three-dimensional technique, as synchrotron radiation-based micro computed tomography (SRμCT).

For the feasibility test we have chosen the mouse cochlea, since it is known to be an appropriate model system for the human hearing organ. Furthermore, it is easier to investigate the mouse cochlea because it is smaller by a factor of two with respect to the human one. The preparation procedure includes explantation, removal of the Petrous bone, fixation in 1% OsO_4-solution and embedding in SPURR [1, 2]. The SRμCT measurements were performed at the beamline BW 2 (HASYLAB at DESY) using the standard set-up for tomography in absorption contrast mode. The photon energy was set to 10.8 keV. The spatial resolution corresponds to 5.2 μm at a pixel size of 2.8 μm [3]. Three tomograms out of 721 projections each and 1536 x 1024 pixels, respectively, were co-registered using a rigid registration algorithm [4].

Figure 1 shows the entire segmented endolymphatic space of the selected right murine labyrinth from different points of view. Because this space exhibits a lower absorption than the surrounding tissues, it can be easily segmented semi-automatically. The segmentation as well as the visualization of the endolymphatic space has been carried out by means of the software VG Studio Max (Volume Graphics, Heidelberg, Germany).

The endolymphatic space is a fluid-filled compartment that is rich of potassium. The positively charged ions lead to a potential difference between the endo-lymphatic and the surrounding peri-lymphatic compartment. As the reaction to mechanical stimuli the endolymphatic space is responsible for the deflection of the hair cells and the consecutive opening of ion channels. Consequently, it plays the key role in the transduction of mechanical to chemical-neuronal/electrical impulses. The endolymph is produced in the middle scale (stria vascularis). There is almost no way for the outflow except diffusion. Therefore, physiological and non-physiological constrains are of crucial importance. Minor deviations from the generic morphology can lead to severe consequences for the quality of hearing.

The upper parts of the four images in Figure 1 show the three semicircular canals. As easily recognized they are orthogonal to each another. The spiral cavity is the cochlear duct also termed the *scala media*. It is the part of the cochlea that is used to perceive the different acoustic impulses. In the images, a few artefacts are present, namely some missing volume on the posterior semicircular duct, especially visible in the second image, which results from a conglomeration of osmium particles. The tiny connections are hardly seen since they coincidence with the gate of the nerve fibres and the vascular structures. These structures have absorbed relatively high amounts of osmium and exhibit absorption values that make their differentiation from the endolymphatic space difficult. Nevertheless, the morphology of the endolymphatic space is imaged with equidistant

resolution in the three orthogonal directions and unattained precision. The SRμCT data are available to be presented as movie for teaching purposes.

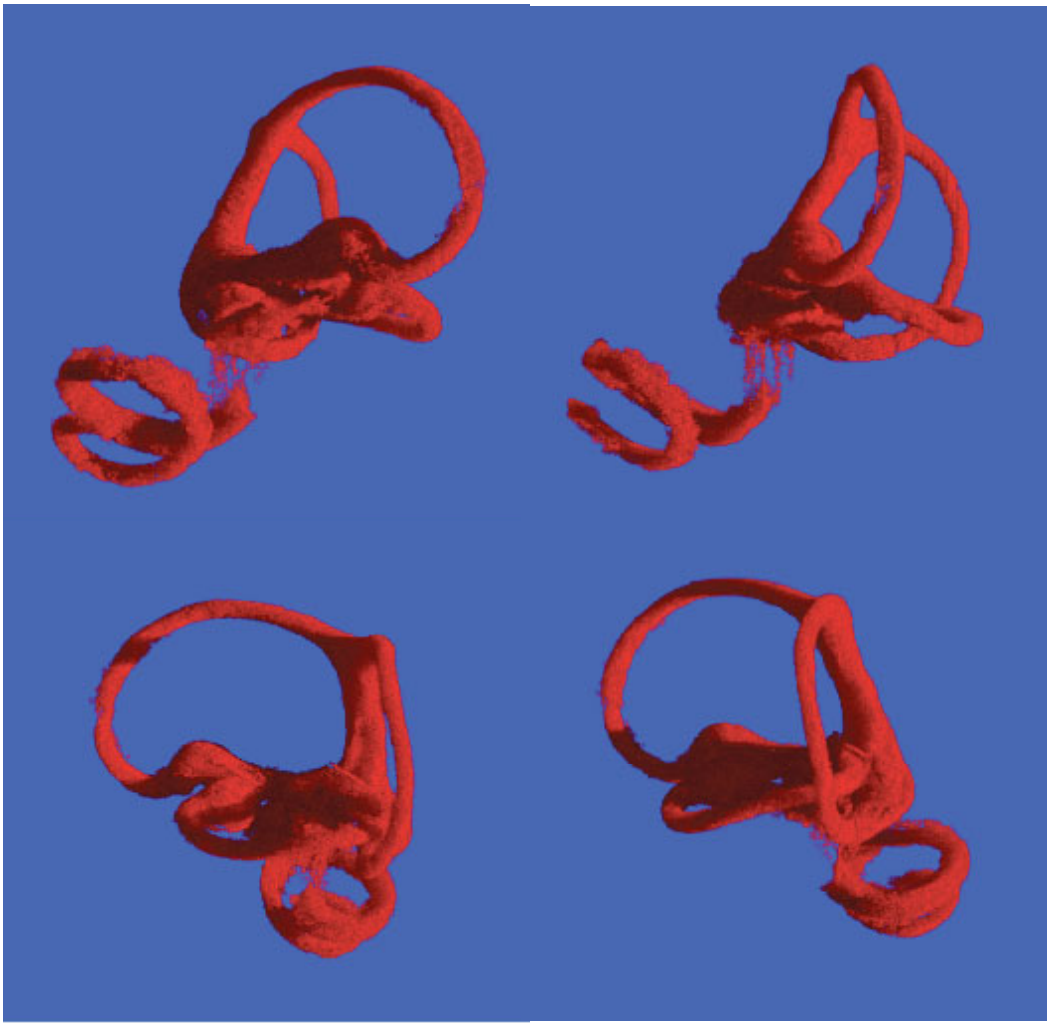

Figure 1: The four different three-dimensional representations show the details of the segmented endolymphatic space of the selected murine cochlea, namely the three orthogonal semicircular canals with their three ampullae, the saccule, the utricle, and the cochlear duct.

References

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