Visualization of Inner Ear Morphologies

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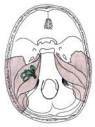
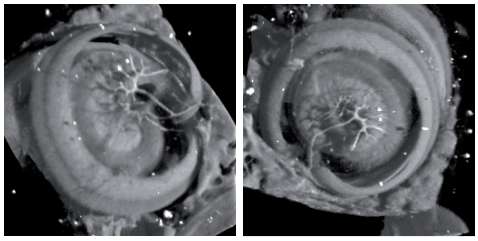
INTRODUCTION



The hearing organ belongs to the most complex structures in the human body. It is important to recognize its morphology on the microscopic level, because minor morphological deviations can result in crucial hearing deficiencies. Synchrotron radiation-based micro computed tomography (SRμCT) is a unique non-destructive, fully three-dimensional technique to visualize structures down to the subcellular level. Consequently, the fine membranes, the capillaries and cavities are quantitatively accessible.

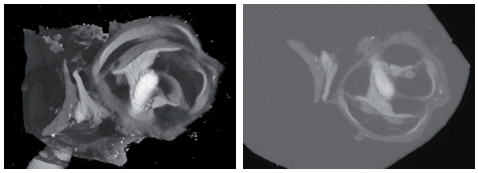
Staining the tissue using osmium, one can determine the osmium concentration with high precision substracting the tomogram acquired at the energy of 10.8 keV from that at 10.9 keV, because the Os-absorption at the L3 edges increases by more than a factor of 2.

CAPILLARIES

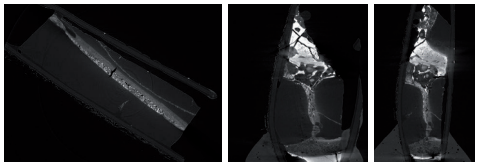


The 3D representation of blood vessels supplying the apical vascular network of the murine cochlea. One can see a branch of the inferior posterior cerebellar artery, which secures the vascular nutrition of the inner ear, supplying the apical vascular network of the cochlea. Below the vessel tree, one can recognize the apical winding of the cochlea. This 3D representation with a spatial resolution of about 5 μm is based on measurements using the photon energy of 10.8 keV. The voxel length corresponds to 2.82 μm. This spatial resolution allows the visualization of the smallest blood vessel, the capillaries.

MORPHOLOGY

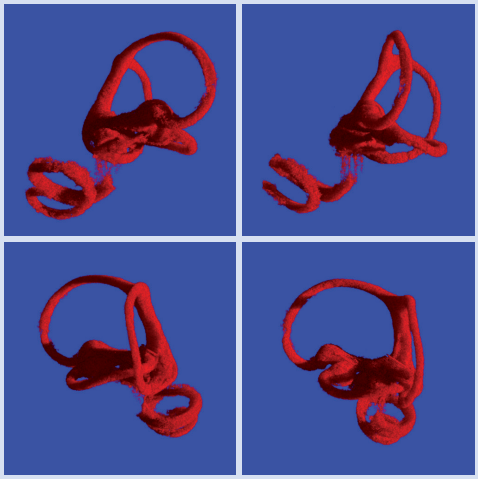


The chain of the ossicle: hammer, amboss and the little stapes (hardly to see). On the right, one can see the truncated modiolus and the spiral cochlear duct as 3D representation. On the left, a related slice is given.
HASYLAB at DESY, Germany, photon energy 10.8 keV

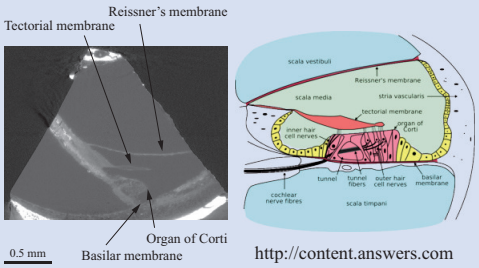


Neuronal ganglia cells on slices of three orthogonal directions. Again one can see the organ of Corti and the three membranes.
SLS at PSI, Switzerland, photon energy 12 keV

SEGMENTATION



The segmented endolymphatic space of the right murine labyrinth from different points of view. The 3D representations show the details of the endolymphatic space of the selected murine cochlea, namely the 3 orthogonal semicircular canals with their 3 ampullae, the saccule, the utricule, and the cochlear duct. Because the endolymphatic space exhibits a lower absorption than the surrounding tissues, it can be segmented semi-automatically. The visualization was carried out by VG Studio Max (Volume Graphics, Heidelberg, Germany).



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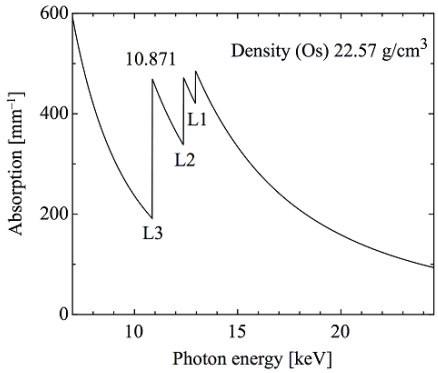
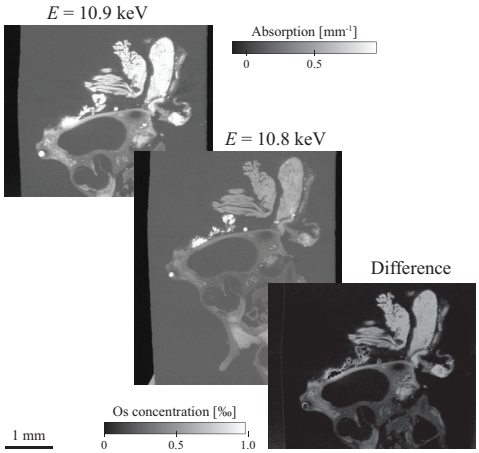
The organ of Corti and the three tiny membranes. The organ of Corti is the location, where the mechanical sound is transformed to chemical and neuronal impulses, respectively.
SLS at PSI, Switzerland, photon energy 10.8 keV

ABSORPTION EDGE



The X-ray absorption of osmium with a density of 22.57 g/cm³ versus photon energy. The absorption increases by more than a factor of 2 at the L3 line, which corresponds to the energy of 10.871 keV.



Slices obtained from the Os-stained murine cochlea. The tomogram measured at the photon energy of 10.9 keV shows many features of high contrast. The slice in the center exhibits much less absorption, although it is obtained using just a 100 eV lower photon energy. On the right, the slice is the difference image after rigid registration, which represents the local osmium distribution in the specimen.

CONCLUSION AND ACKNOWLEDGEMENT

SRμCT in absorption contrast mode allows imaging the cochlea and the adjacent tissues with isotropic spatial resolution down to the cellular level. Using osmium staining, one can take advantage of the L3 edge for differential absorption contrast. Thus, the spatial distribution of osmium is extracted. Concentration differences below 10^{-5} are detectable. The presented data of the cochlea allow visualizing the cochlear microstructure and therefore serve as the basis for a better understanding of hearing diseases. The data will also be used for the fabrication of 3D models of the murine and the human specimens for teaching purposes on a more detailed level than today.

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