News Release

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New insights into neurodegenerative diseases:

New X-ray CT method with molecular sensitivity

Researchers including members from the Technische Universitaet Muenchen (TUM) have developed a new method for visualizing previously invisible brain structures. The new method exploits the fact that different molecular structures affect the detailed signature of the x-ray scattering pattern. The new approach can map, for example, the myelin sheaths of nerve cells, and can provide valuable information for research on multiple sclerosis and Alzheimer's disease. The results have been published online ahead of print in the scientific journal, NeuroImage.

The myelin sheaths of nerve cells in the human brain are lamellar membranes surrounding the neuronal axons. The myelin layers are important to the central nervous system as they ensure the rapid and uninterrupted communication of signals along the neuronal axons. Changes in the myelin layers are associated with a number of neurodegenerative disorders such as cerebral malaria, multiple sclerosis, and Alzheimer's disease.

"The development of these diseases are still not fully understood," says Franz Pfeiffer, Professor for Biomedical Physics at TUM, "but are thought to be related to the damage of the myelin layers, so that messages from the brain reach the various parts of the body poorly or not at all. It is like an electric cord where the insulating material has been damaged and the current short circuits. In order to find methods to prevent or treat the diseases it is important to understand the connection between the myelin changes and the diseases."

The new development is based on conventional X-ray computed tomography (CT). The principle is well established – CT scanners are used every day in hospitals and medical practices for the diagnostic screening of the human body. In the process the human body is X-rayed while a detector records from different angles how much radiation is being absorbed. In principle it is nothing more than taking multiple X-ray pictures from various directions. A number of such pictures are then used to generate digital 3D images of the body's interior using image processing.

"The new aspect of our molecular X-Ray CT method", explains TUM researcher Dr. Martin Bech, "is that we do not only measure the overall beam intensity absorbed by the object, but also those parts of the X-ray beam that are deflected in different directions – 'scattered' in the language of physics. Such a scattering pattern is generated for every point in the sample and every angular projection. This supplies additional information about the molecular structure in every volume element of the reconstructed CT image."

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The scattering patterns are then processed using an algorithm developed by the team. Torben Jensen, researcher at the Niels-Bohr-Institute and lead author of the article, explains: “We developed an image reconstruction algorithm that generates a high-resolution, three-dimensional image of the sample using typically several hundred thousand x-ray scattering patterns. This algorithm takes into account not only classical X-ray absorption, but also the scattering signature of X-rays that reflect the molecular structure.”

A showcase example of the new technique was the examination of the brain of a laboratory rat – with surprisingly exact results. “We can see the myelin sheaths of the neuronal axons and we can distinguish the layers which have a thickness of 17.6 nanometers”, details Prof. Robert Feidenhans’l from the Niels-Bohr-Institute in Copenhagen. “Up until now, you had to cut out a little sample in order to examine the layers in one area and get a single measuring point. With the new method we can examine 250,000 points at once without cutting into the sample. We can get a complete overview over the concentration and thickness of the myelin and this gives of the ability to determine whether the destruction of the myelin is occurring in spots or across the entire sample”, he explains.

The research has been carried out in an international collaboration with researchers in Germany, Denmark, Switzerland, and France. The experiments took place at the cSAXS synchrotron beamline of the Swiss Light Source at the Paul Scherrer Institute in Switzerland. In future the technique shall also be transferred to novel, laser-based X-ray sources, such as the ones currently under development at the cluster of excellence “Munich-Centre for Advanced Photonics” and at the recently approved large-scale research project “Centre for Advanced Laser Applications” on the TUM campus Garching.

Original publication:

Molecular X-ray computed tomography of myelin in a rat brain
T.H. Jensen, M. Bech, O. Bunk, A. Menzel, A. Bouchet, G. Le Duc, R. Feidenhans'l and F. Pfeiffer, NeuroImage, Advanced online publication, 13 April 2011
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