Chemical imaging analysis of the brain with X-ray methods

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Abstract

Cells employ various metal and metalloid ions to augment the structure and the function of proteins and to assist with vital biological processes. In the brain they mediate biochemical processes, and disrupted metabolism of metals may be a contributing factor in neurodegenerative disorders. In this tutorial review we will discuss the particular role of X-ray methods for elemental imaging analysis of accumulated metal species and metal-containing compounds in biological materials, in the context of post-mortem brain tissue. X-rays have the advantage that they have a short wavelength and can penetrate through a thick biological sample. Many of the X-ray microscopy techniques that provide the greatest sensitivity and specificity for trace metal concentrations in biological materials are emerging at synchrotron X-ray facilities. Here, the extremely high flux available across a wide range of soft and hard X-rays, combined with state-of-the-art focussing techniques and ultra-sensitive detectors, makes it viable to undertake direct imaging of a number of elements in brain tissue. The different methods for synchrotron imaging of metals in brain tissues at regional, cellular, and sub-cellular spatial resolution are discussed. Methods covered include X-ray fluorescence for elemental imaging, X-ray absorption spectrometry for speciation imaging, X-ray diffraction for structural imaging, phase contrast for enhanced contrast imaging and scanning transmission X-ray microscopy for spectromicroscopy. Two- and three-dimensional (confocal and tomographic) imaging methods are considered as well as the correlation of X-ray microscopy with other imaging tools.

Keywords: synchrotron; metallomics; microscopy; spectroscopy; neurodegeneration

Graphical Abstract