Review Mol Neurobiol. 2025 Jan 28. doi: 10.1007/s12035-025-04712-z. Online ahead of print.

Central Nervous System Response Against Ionizing Radiation Exposure: Cellular, Biochemical, and Molecular Perspectives

Ravi Kumar [1], Pratibha Kumari [1], Raj Kumar [2]

Affiliations

PMID: 39875779 DOI: 10.1007/s12035-025-04712-z

Abstract

Gamma radiation is known to induce several detrimental effects on the nervous system. The hippocampus region, specifically the dentate gyrus (DG) and subventricular zone (SVZ), have been identified as a radiation-sensitive neurogenic niche. Radiation alters the endogenous redox status of neural stem cells (NSCs) and other proliferative cells, especially in the hippocampus region, leading to oxidative stress, neuroinflammation, and cell death. Planned (i.e., radiotherapy of brain tumor patients) or unplanned radiation exposure (i.e., accidental radiation exposure) can induce nonspecific damage to neuronal tissues, resulting in chronic or acute radiation syndrome. Although anatomical alterations in the neuronal tissues have been reported at higher doses of gamma radiation, biochemical and molecular perturbations may be evident even at much lower radiation doses. They may manifest in the form of neuronal deficits and cognitive impairment. In the present review, several molecular events and signaling pathways, such as oxidative stress, neuroinflammation, apoptosis, cognition, neuroplasticity, and neurotoxicity induced in neuronal cells upon ionizing radiation exposure, are reviewed. Furthermore, brain-specific radioprotectors and mitigators that protect normal neuronal cells and tissues against ionizing radiation during radiotherapy of cancer patients or nuclear emergencies are also discussed.

Keywords: Acute radiation syndrome (ARS); Apoptosis; Ionizing radiation; Nervous system; Neuroinflammation; Oxidative stress.