

調控腦內出血損傷：從血腫清除機制到免疫代謝之間的交互作用

## **Modulating Intracerebral Hemorrhage Injury: From Hematoma Clearance to Immunometabolic Crosstalk**

### **Abstract**

Intracerebral hemorrhage (ICH) is one of the most devastating forms of stroke. It has high rates of morbidity and mortality, and there are limited therapeutic options. Recent insights emphasize the importance of both timely hematoma clearance and precise immunometabolic modulation in mitigating secondary brain injury. Our latest findings demonstrate that cerebral dopamine neurotrophic factor (CDNF) significantly enhances erythrophagocytosis mediated by microglia and macrophages, thereby expediting hematoma resolution. The Nrf2–HO-1 signaling pathway, a key regulator of cellular redox homeostasis, orchestrates this phagocytic process. Additionally, surgical hematoma aspiration provides neuroprotection by preserving mitochondrial function, restoring bioenergetic balance, and promoting the polarization of microglia toward an anti-inflammatory M2 phenotype. These interventions suppress oxidative stress and neuroinflammation collectively, highlighting a novel therapeutic strategy. Integrating mechanical hematoma evacuation with targeted immunometabolic reprogramming holds promise for enhancing neuroimmune recovery and improving functional outcomes in intracerebral hemorrhage (ICH) patients.