

# NEUROPHYSIOLOGICAL MECHANISMS AND MODERN TREATMENT APPROACHES IN ISCHEMIC STROKE

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## Abstract

Ischemic stroke is one of the leading causes of mortality, long-term neurological disability, and cognitive impairment worldwide. The disease develops as a result of acute interruption of cerebral blood flow leading to oxygen deprivation, neuronal ischemia, metabolic failure, excitotoxicity, neuroinflammation, and progressive neuronal death. Complex neurophysiological mechanisms underlying ischemic stroke involve cerebral hypoperfusion, disruption of ionic homeostasis, glutamate-mediated excitotoxicity, mitochondrial dysfunction, oxidative stress, inflammatory activation, apoptosis, and impairment of neurovascular coupling. Clinical manifestations vary according to localization and severity of ischemic injury and may include hemiparesis, sensory deficits, aphasia, cognitive dysfunction, visual disturbances, impaired coordination, and altered consciousness. This study investigates neurophysiological mechanisms of ischemic stroke with emphasis on cerebral ischemic cascade, neuronal injury, neuroplasticity, diagnostic evaluation, reperfusion therapy, neuroprotective strategies, and contemporary rehabilitation approaches. Modern diagnostic technologies including computed tomography, magnetic resonance imaging, perfusion imaging, Doppler ultrasonography, and electrophysiological assessment significantly improve early detection and therapeutic decision-making. Contemporary treatment approaches increasingly incorporate intravenous thrombolysis, mechanical thrombectomy, neurocritical care, neuroprotective therapy, stem cell research, neuromodulation, and multidisciplinary rehabilitation aimed at minimizing neuronal damage and improving functional recovery. The findings demonstrate that rapid diagnosis, early reperfusion therapy, individualized rehabilitation, and comprehensive neuroprotective management substantially reduce mortality, limit neurological disability, and improve long-term clinical outcomes and quality of life in patients with ischemic stroke.

**Keywords:** Ischemic stroke, cerebral ischemia, neurophysiology, thrombolysis, neuroprotection, cerebral infarction, neuroplasticity, reperfusion therapy, stroke rehabilitation, neuronal injury

## 1. Introduction

Ischemic stroke represents a major neurological emergency characterized by sudden interruption of

cerebral blood circulation leading to focal brain ischemia and progressive neuronal damage. The disorder accounts for the majority of cerebrovascular diseases worldwide and remains one of the primary causes of mortality, chronic disability, cognitive decline, and socioeconomic burden. Ischemic stroke occurs when cerebral arteries become obstructed due to thrombosis, embolism, or systemic hypoperfusion, resulting in inadequate delivery of oxygen and glucose to brain tissue. Neurons are highly sensitive to ischemia because of their elevated metabolic requirements and limited energy reserves; consequently, even brief interruption of cerebral perfusion initiates complex neurophysiological and biochemical cascades resulting in irreversible neuronal injury. Contemporary understanding of ischemic stroke emphasizes the importance of the ischemic cascade involving ATP depletion, membrane depolarization, excessive glutamate release, calcium influx, mitochondrial dysfunction, oxidative stress, inflammatory activation, blood-brain barrier disruption, apoptosis, and necrosis. The ischemic core represents an area of severe irreversible tissue injury, whereas surrounding penumbral regions contain functionally impaired but potentially salvageable neurons if timely reperfusion is achieved. Neuroinflammatory processes involving microglial activation, cytokine release, leukocyte infiltration, and endothelial dysfunction significantly contribute to secondary neuronal injury and progression of ischemic damage. Cerebral edema, increased intracranial pressure, and impaired autoregulation additionally exacerbate neurological deterioration during acute stroke progression. Clinical manifestations vary according to vascular territory and extent of cerebral injury and may include unilateral weakness, facial asymmetry, aphasia, dysarthria, visual deficits, sensory impairment, ataxia, altered consciousness, and cognitive dysfunction. Early diagnosis and rapid restoration of cerebral perfusion remain critically important because therapeutic effectiveness is strongly dependent on time from symptom onset. Modern neuroimaging techniques including computed tomography, magnetic resonance imaging, diffusion-weighted imaging, perfusion studies, and vascular angiography significantly improve identification of ischemic lesions and selection of patients for reperfusion therapy. Intravenous thrombolysis and mechanical thrombectomy have revolutionized acute ischemic stroke management through restoration of cerebral blood flow and reduction of infarct progression. Advances in neurophysiology, neuroplasticity, regenerative medicine, stem cell therapy, neuromodulation, and rehabilitation science continue to improve understanding of neuronal recovery mechanisms and functional reorganization following ischemic injury. Contemporary stroke management increasingly requires interdisciplinary integration of neurology, neuroradiology, intensive care, rehabilitation medicine, vascular surgery, neurophysiology, and molecular neuroscience to optimize acute treatment and long-term functional recovery.

## 2. Materials and Methods

This study was conducted using clinical, neurological, neurophysiological, and radiological evaluation of patients diagnosed with acute ischemic stroke between 2020 and 2025. Comprehensive neurological assessment included evaluation of motor deficits, sensory disturbances, cranial nerve function, speech abnormalities, cognitive impairment, coordination disorders, and level of consciousness. Stroke severity was assessed using standardized neurological scales including the National Institutes of Health Stroke Scale and functional outcome indexes. Diagnostic procedures included computed tomography, magnetic resonance imaging, diffusion-weighted imaging, perfusion studies, Doppler ultrasonography, electroencephalography, laboratory biomarker analysis, and vascular angiography for assessment of cerebral perfusion and vascular occlusion. Neurophysiological evaluation focused on cortical activity, neuronal conduction, cerebral autoregulation, and ischemia-related functional abnormalities. Therapeutic interventions including intravenous thrombolysis, mechanical thrombectomy, antiplatelet therapy, anticoagulation, neuroprotective agents, intensive care management, neuromodulation techniques, and multidisciplinary rehabilitation programs were analyzed comparatively to determine clinical effectiveness and long-term neurological outcomes.

## 3. Results

Comprehensive clinical evaluation demonstrated that ischemic stroke most frequently presented with acute unilateral motor weakness, facial asymmetry, speech impairment, sensory deficits, visual disturbances, and impaired coordination corresponding to localization of cerebral ischemic injury.

Neuroimaging studies revealed cerebral infarction predominantly within middle cerebral artery territories accompanied by perfusion deficits and vascular occlusion. Diffusion-weighted magnetic resonance imaging effectively identified early ischemic lesions and allowed differentiation between ischemic core and salvageable penumbral tissue. Neurophysiological assessment demonstrated disruption of cortical electrical activity, impaired neuronal conduction, altered cerebral autoregulation, and reduction of functional connectivity within affected brain regions. Elevated inflammatory biomarkers, oxidative stress markers, and endothelial dysfunction indicators were observed during the acute phase of ischemic stroke. Patients receiving early intravenous thrombolysis and mechanical thrombectomy demonstrated significantly improved cerebral reperfusion, reduced infarct volume, lower neurological deficit severity, and better functional recovery compared with delayed or conservative treatment groups. Intensive neurocritical care and stabilization of systemic physiological parameters contributed to reduction of secondary neuronal injury and cerebral edema. Early rehabilitation programs involving physiotherapy, speech therapy, occupational therapy, neuromuscular stimulation, and cognitive rehabilitation significantly improved motor recovery, speech function, coordination, and daily living activities. Neuroplasticity-related functional reorganization and partial restoration of cortical activity were observed during long-term rehabilitation, particularly in patients receiving comprehensive multidisciplinary therapy. Patients undergoing individualized rehabilitation demonstrated improved neurological recovery, reduced disability, enhanced cognitive function, and greater quality of life during follow-up evaluation.

#### 4. Discussion

The findings confirm that ischemic stroke is a highly complex neurovascular disorder involving multifactorial neurophysiological mechanisms leading to progressive neuronal injury and functional impairment. The ischemic cascade remains the central pathophysiological process responsible for cerebral tissue damage and includes metabolic failure, excitotoxicity, oxidative stress, inflammatory activation, mitochondrial dysfunction, and apoptosis. Excessive glutamate release and calcium influx represent critically important mechanisms contributing to neuronal depolarization, enzymatic activation, free radical production, and irreversible cellular destruction. Neuroinflammation significantly amplifies secondary injury through activation of microglia, cytokine production, endothelial dysfunction, and blood-brain barrier disruption. The concept of ischemic penumbra remains fundamental in modern stroke management because timely reperfusion therapy may preserve viable neuronal tissue and substantially improve neurological outcomes. The study additionally demonstrates that rapid diagnosis and early therapeutic intervention are critically important determinants of survival and functional recovery. Contemporary neuroimaging technologies significantly improve identification of ischemic lesions, evaluation of cerebral perfusion, and selection of candidates for thrombolytic and endovascular treatment. Mechanical thrombectomy represents one of the most important advancements in acute stroke management and provides substantial benefit in patients with large-vessel occlusion. Neuroplasticity plays a major role in post-stroke recovery through cortical reorganization, synaptic remodeling, and adaptive functional compensation within surviving neuronal networks. Early multidisciplinary rehabilitation therefore remains essential for optimization of motor, cognitive, speech, and psychosocial recovery. Despite substantial progress in stroke medicine, several clinical challenges remain significant including delayed hospital presentation, limited therapeutic windows, hemorrhagic transformation, recurrent stroke risk, cognitive impairment, and incomplete neurological recovery. Future scientific research increasingly focuses on neuroprotective pharmacology, stem cell therapy, regenerative neuroscience, artificial intelligence-assisted diagnosis, personalized rehabilitation, brain-computer interfaces, and advanced neuromodulation technologies aimed at improving neuronal preservation and long-term functional outcomes. Integration of neurology, neuroradiology, neurophysiology, rehabilitation medicine, molecular neuroscience, and critical care therefore remains essential for advancement of ischemic stroke treatment and reduction of global neurological disability.

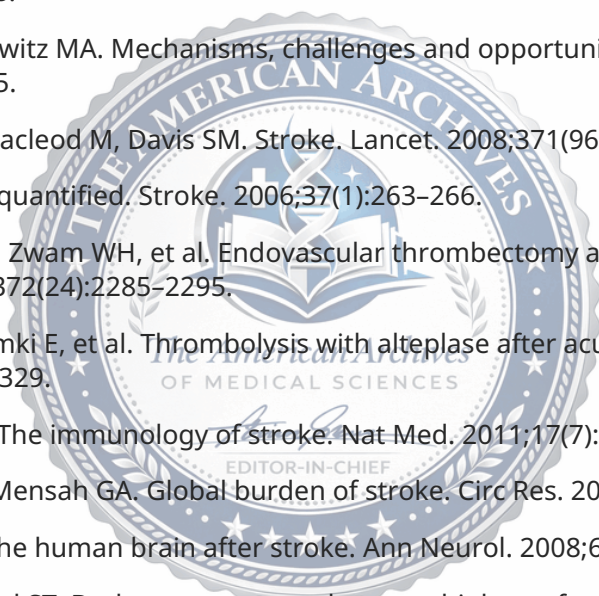
#### 5. Conclusion

Ischemic stroke is a severe neurovascular disorder characterized by interruption of cerebral blood flow leading to neuronal ischemia, metabolic failure, neuroinflammation, excitotoxicity, and progressive neurological dysfunction. Neurophysiological mechanisms including glutamate-mediated

excitotoxicity, oxidative stress, inflammatory activation, mitochondrial injury, and cerebral autoregulatory dysfunction play central roles in progression of ischemic brain damage. Early diagnosis utilizing advanced neuroimaging and rapid implementation of reperfusion therapy significantly improve cerebral perfusion and reduce irreversible neuronal injury. Contemporary treatment approaches including thrombolysis, mechanical thrombectomy, neurocritical care, neuroprotective strategies, and multidisciplinary rehabilitation substantially improve neurological recovery and long-term quality of life. Continuous advancement in regenerative medicine, neuroplasticity research, stem cell therapy, neuromodulation, and personalized neurorehabilitation will further improve therapeutic effectiveness and functional outcomes in ischemic stroke management.

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