



Intracellular Protein Tangles and Their Influence on Neural Integrity

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Description

Protein tangles within nerve cells are abnormal accumulations of filamentous material that disrupt normal cellular organization. These structures are most commonly associated with disorders affecting cognition and behavior, where they appear inside neurons and interfere with essential processes. Tangles are primarily composed of altered forms of tau protein, a molecule normally involved in stabilizing internal cellular transport systems. When tau undergoes chemical modification, it can lose its normal function and begin to assemble into dense, insoluble strands that occupy large portions of the neuronal interior. Under healthy conditions, tau binds to microtubules, which act as internal tracks for the movement of nutrients, signaling molecules and cellular components. This transport system is especially important in neurons because of their long extensions and high metabolic demands. Chemical changes such as excessive phosphorylation can weaken tau's attachment to microtubules. As a result, microtubules become unstable and tau molecules begin to associate with one another instead. Over time, these associations grow into twisted filaments that bundle together, forming tangles. The presence of tangles alters the internal environment of neurons. Crowding of abnormal protein structures interferes with transport pathways, limiting the movement of essential materials between the cell body and distant synapses. This disruption affects communication between neurons, as synapses rely on continuous delivery of proteins and energy sources. Even before neurons die, their ability to transmit signals can decline due to these internal blockages.

Tangles do not appear uniformly across the brain. Certain regions involved in memory, learning and emotional regulation tend to show earlier and more extensive involvement. The distribution of tangles often corresponds with the pattern of clinical symptoms observed during disease progression. Early accumulation in specific areas may explain why memory difficulties or changes in behavior can precede other neurological signs. As tangles spread to additional regions, a broader range of functions may become affected. The formation of tangles is influenced by multiple factors, including genetic background, metabolic state and cellular stress. Variations in genes related to tau production or modification can increase susceptibility to abnormal aggregation. Metabolic disturbances, such as impaired glucose use or oxidative imbalance, may further promote chemical changes in tau that favor aggregation. Aging also plays a role, as

cellular maintenance systems become less efficient over time, reducing the ability to clear altered proteins. Inflammatory activity within the nervous system is closely linked to tangle development. Support cells respond to abnormal protein accumulation by releasing signaling molecules that alter the local environment. While these responses aim to protect tissue, prolonged activation can create conditions that favor additional protein modification and aggregation. This feedback loop may contribute to the gradual increase in tangle burden observed over many years.

The relationship between tangles and neuron survival is complex. Some neurons containing tangles may persist for extended periods, suggesting that tangles themselves are not immediately lethal. However, their presence signals a state of severe cellular stress. Over time, the cumulative effects of impaired transport, altered signaling and metabolic strain can overwhelm neuronal coping mechanisms. Eventually, this may lead to loss of synapses and cell death, contributing to overall network dysfunction. Detection of tangles has traditionally relied on examination of brain tissue using specialized staining techniques. Advances in imaging and biomarker research now allow indirect assessment of tau-related changes in living individuals. These approaches help track disease progression and evaluate responses to therapy. Understanding when tangles first appear and how they expand provides valuable insight into the timing of intervention strategies.

Conclusion

Protein tangles illustrate how disruption at the molecular level can cascade into widespread functional impairment. They represent a convergence of altered protein chemistry, cellular stress and declining maintenance capacity. Studying tangles has deepened understanding of how neurons respond to long-term challenges and highlights the importance of maintaining internal cellular organization for sustained brain function. Efforts to address tangle-related pathology focus on multiple approaches. Some strategies aim to reduce abnormal chemical modification of tau, while others seek to enhance cellular systems responsible for protein clearance. Supporting overall neural health through management of metabolic conditions, sleep quality and physical activity may also influence the cellular environment in ways that slow abnormal protein accumulation.