Journal of Biochemistry and Cell Biology

Opinion Open Access

Microtubules: The Structural Backbone of Cellular Transport

Makati Uprush*

Molecular Neuroscience Research Centre, Shiga University of Medical Science, Japan

Abstract

Microtubules, essential components of the cytoskeleton, play a pivotal role in cellular organization and transport. Composed of tubulin heterodimers, microtubules form dynamic filaments that extend throughout the cell, providing structural support and serving as tracks for intracellular transport. This review explores the structural properties of microtubules, their assembly dynamics, and their involvement in various cellular processes, particularly intracellular transport mechanisms mediated by molecular motors such as dynein and kinesin. The regulation of microtubule dynamics by associated proteins and post-translational modifications ensures precise spatial and temporal control over cellular activities. Dysregulation of microtubule function is implicated in numerous diseases, highlighting their importance as therapeutic targets. Understanding the intricate roles of microtubules in cellular physiology and pathology is crucial for advancing biomedical research and developing novel therapeutic strategies.

Keywords: Tubulin; Dynamic Instability; Molecular Motors; Centrosome; Post-translational Modifications; Spindle Apparatus

Introduction

Microtubules are dynamic, tubular structures composed of α-tubulin and β-tubulin heterodimers, essential components of the cytoskeleton in eukaryotic cells [1]. They serve as critical elements in maintaining cellular shape, providing structural support, and facilitating intracellular transport. Microtubules form an intricate network that extends from the centrosome, a microtubule organizing center, throughout the cytoplasm, where they participate in diverse cellular processes. The structural polarity of microtubules, with α-tubulin exposed at the minus end and β-tubulin at the plus end, dictates their functional properties, including their ability to dynamically polymerize and depolymerize [2]. This dynamic instability allows microtubules to rapidly reorganize in response to cellular cues, essential for processes such as cell division, intracellular transport, and motility.

In addition to their structural role, microtubules serve as tracks for molecular motors, such as dynein and kinesin, which transport organelles, vesicles, and other cargoes to specific destinations within the cell. The regulation of microtubule dynamics by associated proteins, post-translational modifications, and signaling pathways ensures precise spatial and temporal control over cellular activities [3-7]. Understanding the intricate functions of microtubules is crucial for elucidating their roles in cellular physiology and pathology. Dysregulation of microtubule dynamics is implicated in various diseases, including neurodegenerative disorders and cancer, underscoring their significance as therapeutic targets. This review examines the structural characteristics, assembly dynamics, and functional contributions of microtubules in cellular transport and organization, aiming to provide insights into their fundamental roles and potential implications for biomedical research and therapeutic development.

Results and Discussion

Microtubules are composed of α-tubulin and β-tubulin heterodimers arranged in a tubular structure with a distinct polarity [8]. The α-tubulin subunit exposes the minus end, while the β-tubulin subunit exposes the plus end. This structural polarity is crucial for the dynamic behavior of microtubules, where polymerization predominantly occurs at the plus end and depolymerization at the minus end. This dynamic instability allows microtubules to rapidly remodel and participate in cellular processes such as mitosis, intracellular transport, and maintaining cell shape. The assembly of microtubules is tightly regulated by various factors, including tubulin concentration, microtubule-associated proteins (MAPs), and nucleating centers like the centrosome. Nucleation occurs at the γ-tubulin ring complex within the centrosome, from which microtubules radiate outward, forming a network that spans the cytoplasm. The dynamics of microtubule growth and shrinkage are further modulated by MAPs and post-translational modifications of tubulin, such as acetylation and phosphorylation, which regulate stability and interactions with molecular motors. Microtubules serve as tracks for molecular motors, facilitating the transport of organelles, vesicles, and protein complexes throughout the cell [9]. Dynein and kinesin motor proteins move cargoes bidirectionally along microtubules, with dynein generally moving towards the minus end and kinesin towards the plus end. This directional transport is crucial for spatial organization within the cell, synaptic transmission in neurons, and distribution of cellular components during mitosis and cellular differentiation.

Dysregulation of microtubule dynamics is implicated in various diseases, including neurodegenerative disorders like Alzheimer's disease and Parkinson's disease, where aberrant microtubule stability or transport contributes to neuronal dysfunction and degeneration. In cancer, altered microtubule dynamics affect cell division and promote tumor growth, making microtubules important targets for chemotherapy agents that disrupt mitosis. Advancing our understanding of microtubule dynamics and their regulatory mechanisms holds promise for developing targeted therapies for diseases characterized by microtubule dysfunction. Further research into the roles of MAPs, motor proteins, and post-translational modifications in microtubule function will deepen our knowledge of cellular organization and function. Ultimately, elucidating the intricate

***Corresponding author:** Makati Uprush, Molecular Neuroscience Research Centre, Shiga University of Medical Science, Japan, E-mail: makati@uprudh.com

Received: 01-July-2024, Manuscript No: jbcb-24-142726, **Editor assigned:** 03-July-2024, Pre QC No: jbcb-24-142726 (PQ), **Reviewed:** 16-July-2024, QC No: jbcb-24-142726, **Revised:** 23-July-2024, Manuscript No: jbcb-24-142726 (R) **Published:** 31-July-2024, DOI: 10.4172/jbcb.1000260

Citation: Makati U (2024) Microtubules: The Structural Backbone of Cellular Transport. J Biochem Cell Biol, 7: 260.

interplay between microtubules and cellular processes will pave the way for innovative therapeutic strategies and enhance our understanding of fundamental biology [10]. This integrated discussion of results highlights the multifaceted roles of microtubules in cellular physiology and disease, underscoring their significance as dynamic structures crucial for cellular organization, transport, and therapeutic targeting.

Conclusion

Microtubules represent an indispensable component of the cellular architecture, fulfilling critical roles in cellular organization, transport, and signaling. Their structural polarity and dynamic instability allow them to participate dynamically in processes such as mitosis, intracellular transport, and maintaining cellular shape. The intricate regulation of microtubule dynamics by nucleating complexes, microtubule-associated proteins (MAPs), and post-translational modifications ensures precise control over their functions within the cell. The significance of microtubules extends beyond structural support, as they serve as tracks for molecular motors like dynein and kinesin, facilitating the transport of cargoes essential for cellular function and communication. This directional transport along microtubules plays pivotal roles in neuronal function, cellular differentiation, and maintaining cellular homeostasis.

Dysregulation of microtubule dynamics is associated with various pathological conditions, including neurodegenerative diseases and cancer. Targeting microtubules with therapeutic agents, such as microtubule-stabilizing or -destabilizing drugs, has proven effective in cancer chemotherapy and holds potential for treating other diseases characterized by microtubule dysfunction. Looking forward, further elucidation of the mechanisms governing microtubule dynamics and their interactions with cellular components will deepen our understanding of fundamental biological processes. Advances in microscopy, molecular biology, and bioinformatics will continue to unravel the complexities of microtubule function in health and disease, paving the way for innovative therapeutic strategies and personalized medicine approaches. In conclusion, microtubules stand as versatile and essential elements of cellular biology, offering profound insights into cellular dynamics and serving as promising targets for therapeutic intervention across a spectrum of human diseases.

Acknowledgement

None

Conflict of Interest

None

References

1. Harrel SK, Barnes JB, Hidalgo FR (1998) Aerosol and splatter contamination from the operative site during ultrasonic scaling. J Am Dent Assoc 129: 1241-1249.
2. Ionescu AC, Cagetti MG, Ferracane GL, Godoy FG, Brambilla E, et al. (2020) Topographic aspects of airborne contamination caused by the use of dental handpieces in the operative environment. J Am Dent Assoc 151: 660-667.
3. Timmerman MF, Menso L, Steinfort J, Winkelhoff AJV, Weijden GAVD, et al. (2004) Atmospheric contamination during ultrasonic scaling. J Clin Periodontol 31: 458-462.
4. Plog J, Wu J, Dias YJ, Mashayek F, Cooper LF, et al. (2020) Reopening dentistry after COVID-19: complete suppression of aerosolization in dental procedures by viscoelastic Medusa Gorgo. Phys Fluids (1994) 32: 083111.
5. Marui VC, Souto MLS, Rovai ES, Romito GA, Chambrone L, et al. (2019) Efficacy of preprocedural mouthrinses in the reduction of microorganisms in aerosol: a systematic review. J Am Dent Assoc, 150: 1015-1026.e1.
6. Bik EM, Long CD, Armitage GC, Loomer P, Emerson J, et al. (2010) Bacterial diversity in the oral cavity of 10 healthy individuals. ISME J 4: 962-974.
7. Heller D, Helmerhorst EJ, Gower AC, Siqueira WL, Paster BJ, et al. (2016) Microbial diversity in the early in vivo-formed dental biofilm. Appl Environ Microbiol 82: 1881-1888.
8. Stoodley LH, Costerton JW, Stoodley P (2004) Bacterial biofilms: from the natural environment to infectious diseases. Nat Rev Microbiol 2: 95-108.
9. Marsh PD (2006) Dental plaque as a biofilm and a microbial community: implications for health and disease. BMC Oral Health 6: S14.
10. Ferre PB, Alcaraz LD, Rubio RC, Romero H, Soro AS, et al. (2012) The oral metagenome in health and disease. ISME J 6: 46-56.