

The Influence of Extracellular Vesicles on Immune Communication and Disease Regulation

Liora Venthan*

Department of Molecular Immunology and Translational Medicine, Crestview University, Singapore

DESCRIPTION

Extracellular vesicles have emerged as important mediators of communication between cells within the human body. These small membrane-bound structures are released by various cell types, including immune cells, epithelial cells, stromal populations, and malignant cells. They contain proteins, lipids, messenger molecules, and genetic materials that can influence the behavior of recipient cells. Research within cellular and clinical immunology has increasingly examined extracellular vesicles because they participate in immune regulation, inflammatory responses, tissue communication, and disease development.

Cells require continuous communication to coordinate biological activities. Traditional understanding of cellular interaction focused mainly on direct contact or soluble molecules released into surrounding environments. Extracellular vesicles represent an additional communication system that allows cells to transfer biologically active materials over short and distant ranges. Through this mechanism, cells can influence immune activation, differentiation, migration, and functional changes within complex tissue environments.

Extracellular vesicles are produced by many immune populations, including dendritic cells, macrophages, lymphocytes, and natural killer cells. Their composition reflects the characteristics and condition of the originating cell. During infection, injury, or inflammation, immune cells may release vesicles containing molecules that influence neighboring immune populations. These vesicles contribute to coordination of immune responses by transferring information between cells.

Dendritic cell-derived extracellular vesicles have received considerable attention because of their involvement in antigen presentation. These vesicles may contain molecules capable of stimulating immune recognition and influencing T-cell activity. Their ability to carry antigen-associated materials allows communication between antigen-presenting cells and lymphocytes.

This process contributes to regulation of adaptive immune responses and has been investigated in relation to vaccine research and immune-based therapies.

Macrophage-derived extracellular vesicles participate in communication within inflamed tissues. Depending on macrophage activation status, these vesicles may contain different molecular components that influence immune regulation. They can affect inflammatory mediator production, tissue repair processes, and interactions with other immune populations. In chronic inflammatory environments, altered vesicle production may contribute to persistent immune activation.

T lymphocytes also release extracellular vesicles that influence immune responses. Vesicles produced by activated T cells contain signaling molecules involved in communication with other immune populations. These structures may affect antigen-presenting cells, other lymphocytes, and tissue-resident cells. The ability of T-cell-derived vesicles to modify immune behavior demonstrates the complexity of cellular interactions during immune responses.

Natural killer cell-derived extracellular vesicles contribute to immune defense by carrying molecules associated with cellular elimination mechanisms. These vesicles may influence abnormal cells and participate in communication between immune populations. Research into their functions has expanded understanding of how immune cells exchange information during responses against infections and abnormal cellular changes.

Extracellular vesicles produced during inflammation can influence the behavior of surrounding tissues. Cells exposed to inflammatory conditions may release vesicles containing molecules that promote immune recruitment and cellular activation. These vesicles can contribute to communication between immune cells and structural components such as fibroblasts and endothelial cells. Their activity may influence whether inflammation resolves or becomes persistent.

Correspondence to: Liora Venthan, Department of Cellular Medicine and Immunology, Eastmoor University, Zurich, Switzerland, Email: liora.venthan@crestviewuni-sg.edu

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The role of extracellular vesicles in autoimmune disorders has gained increasing attention. In autoimmune conditions, vesicles carrying self-derived molecules may contribute to abnormal immune recognition. They may influence antigen presentation, lymphocyte activation, and inflammatory signaling. Changes in vesicle composition and release patterns have been observed in several autoimmune diseases, suggesting that they may serve as indicators of altered immune regulation.

Cancer represents another major area where extracellular vesicle research has expanded. Tumor cells release large numbers of vesicles containing molecules that influence surrounding immune populations and tissue environments. These vesicles can modify immune recognition, affect inflammatory responses, and alter communication between malignant cells and nearby tissues. Their ability to transfer information contributes to the complexity of tumor-associated immune regulation.

Tumor-derived extracellular vesicles can influence macrophage activity within cancer tissues. By transferring specific molecules, these vesicles may modify macrophage behavior and affect their interaction with malignant cells. They can also influence dendritic cell function and T-cell responses, creating changes in immune activity within the tumor environment. Understanding these interactions has become an important focus in cancer immunology.

The relationship between extracellular vesicles and infectious diseases is another active area of investigation. During infections, infected cells and immune populations release vesicles containing microbial components, host proteins, and signaling molecules. These vesicles may influence immune recognition and communication during infection. Depending on their contents, they may contribute to protective responses or assist pathogen survival.

The nervous system also uses extracellular vesicles for cellular communication. Neural cells, glial populations, and immune cells release vesicles that influence interactions within neural tissues. During neurological inflammation, these vesicles may carry molecules affecting immune activation and neuronal function. Research into neuroimmune communication has expanded understanding of how extracellular vesicles participate in neurological disease processes.

The cardiovascular system is influenced by extracellular vesicle activity as well. Endothelial cells, immune cells, and platelets

release vesicles that participate in vascular communication. During inflammatory conditions, changes in vesicle production may influence blood vessel function and immune cell recruitment. These processes have implications for cardiovascular disorders associated with chronic inflammation.

Extracellular vesicles are also influenced by metabolic conditions. Obesity, diabetes, and metabolic disturbances can modify vesicle production and molecular composition. Vesicles released from adipose tissue and immune cells may contribute to communication between metabolic organs and inflammatory pathways. These interactions provide additional information regarding the relationship between metabolism and immune regulation.

Technological progress has improved the ability to study extracellular vesicles. Advanced isolation methods, molecular analysis techniques, and imaging technologies allow researchers to examine vesicle composition and function in detail. Single-vesicle analysis approaches provide information regarding differences among individual vesicle populations. These developments have expanded understanding of how extracellular vesicles contribute to cellular communication.

Clinical applications involving extracellular vesicles continue to develop. Because vesicles contain molecules that reflect the condition of their originating cells, they are being investigated as potential indicators of disease activity. Their presence in biological fluids such as blood and other body fluids provides opportunities for non-invasive assessment. However, additional research is needed to establish reliable clinical applications and standardized analysis methods.

CONCLUSION

Therapeutic applications of extracellular vesicles are also being explored. Their natural ability to transport biological materials has generated interest in using them as delivery systems for medical interventions. Researchers are investigating how vesicles may be modified or utilized to influence immune responses. Careful evaluation remains necessary because vesicles can have different effects depending on their source and molecular contents.