Biomimetic Nanoparticles via Microfluidics: Advancing Precision Cancer Therapy

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Abstract
The precise delivery of therapeutic agents using nanoparticles (NPs) has revolutionized cancer treatment by improving diagnostic accuracy and therapeutic outcomes while reducing off-target toxicity. Recent breakthroughs in biomimetic strategies, where NPs are engineered to mimic cellular functions, offer new avenues for increasing selectivity toward tumors and their complex microenvironments (TME). [1] Biomimetic hybrid nanoparticles, particularly those combining bioactive cell membranes (CMs) with synthetic NPs, are emerging as powerful tools in cancer therapy. These nature-inspired systems enhance systemic circulation, improve targeting accuracy, and boost cellular uptake. [2]
In this keynote, I will present an innovative liposome-engineering approach that harnesses direct membrane fusion between synthetic liposomes and CMs derived from cancer cells, creating advanced hybrid liposomes. Traditional methods for fabricating biomimetic NPs, such as mechanical extrusion and ultrasonic processing, are labor-intensive and prone to inconsistencies between batches. To address these limitations, we developed a cutting-edge microfluidic sonication technique (Figure 1), which integrates active and passive mixing strategies to streamline nanoparticle production. [3] By leveraging the geometry of 3D-printed microfluidic devices for passive mixing and applying an external ultrasonic field for active mixing, we achieve efficient and consistent membrane fusion.
Through two case studies, I will demonstrate the success of our microfluidic method in fusing CMs with liposomes, with an emphasis on how active mixing significantly improves membrane fusion efficiency. Additionally, I will highlight how tumor-derived CMs enhance NP internalization in vitro, enabling homologous targeting—a key mechanism for precise drug delivery and optimized cancer therapy.
This microfluidic innovation not only simplifies the NP fabrication process but also offers new potential for clinical applications, ushering in a new era of precision cancer treatment.

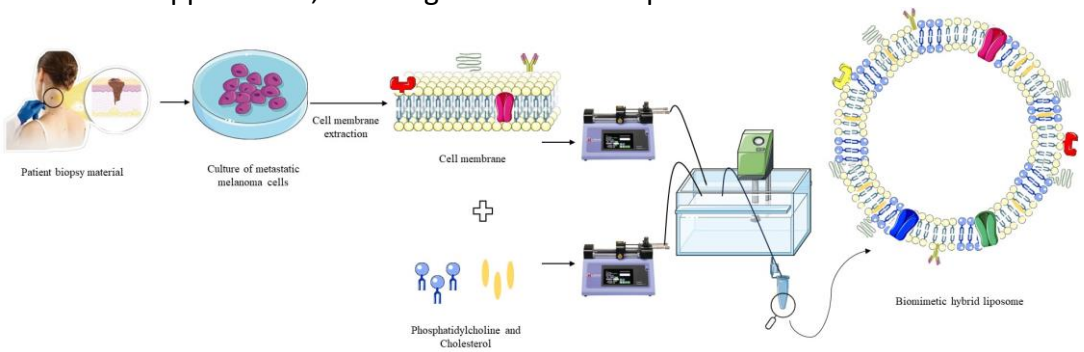

Figure 1: Schematic representation of the microfluidic fabrication of hybrid liposome.

References

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