Advancing the Characterization of Circulating Tumor Cells with High-Dimensional Mass Cytometry

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Circulating tumor cells (CTCs) are rare cancer cells released from primary or metastatic sites into the bloodstream, and their detection holds great potential for diagnosis, prognosis and therapy monitoring. However, reliable methods for CTC isolation and characterization remain limited. This study explores the application of mass cytometry for CTC detection and characterization, leveraging its unique strengths in high-dimensional single-cell analysis. Cytometry by time of flight (CyTOF) offers high resolution, high sensitivity and the ability to simultaneously quantify more than 40 parameters without spectral overlap, making it ideally suited for detecting rare cell populations such as CTCs.

To enable robust identification of CTCs, an antibody panel was established by extending the standard Maxpar® Direct™ Immune Profiling Assay (MDIPA) framework with cancer- and proliferation-associated markers, including Ki-67, EpCAM, and pan-cytokeratin. Building on this panel design, antibody titration experiments were performed for selected markers to determine optimal staining concentrations.

CyTOF-based detection was compared with the DEPArray system, an independent single-cell technology that enables imaging and physical isolation of single cells. While DEPArray allows precise recovery of single, viable or fixed cells for downstream analysis, it is limited in throughput and panel complexity. In contrast, CyTOF provides high-content, high-throughput, population-level analysis, although it does not enable downstream analysis of individual cells.

Together, these data demonstrate that CyTOF represents a powerful and scalable platform for multiparametric CTC profiling, paving the way for clinical applications in precision oncology.