

Detection of Circulating Tumor Cells via Electrically-Charged Superparamagnetic Nanoprobos

Donglu Shi

Professor, The Materials Science and Engineering Program, Dept. of Mechanical and Materials Engineering and Dept. of Biomedical Engineering, College of Engineering and Applied Science, University of Cincinnati, Cincinnati, Ohio, 45221 USA

Yuxin Wang

The Materials Science and Engineering Program, Dept. of Mechanical and Materials Engineering and Dept. of Biomedical Engineering, College of Engineering and Applied Science, University of Cincinnati, Cincinnati, Ohio, 45221 USA

Neshwanth Kumar Tene

The Materials Science and Engineering Program, Dept. of Mechanical and Materials Engineering and Dept. of Biomedical Engineering, College of Engineering and Applied Science, University of Cincinnati, Cincinnati, Ohio, 45221 USA

Abstract:

We report a novel approach for the sensitive detection of circulating tumor cells (CTCs) using electrically-charged magnetic nanoprobos. Our recent findings indicate that negative surface charges on cancer cells are a biophysical manifestation of the Warburg effect, a hallmark of cancer cell metabolism characterized by increased glycolysis. Consequently, the cell surface charge serves as a direct measure of cancer metabolism governed by glycolysis rates. We have established a strong correlation between cancer cell lactate secretion and the presence of net negative electrical charges on cancer cell surfaces. These negative charges result from the cross-membrane movement of mobile ions, as the charge neutrality of most human cells is maintained by ion pumps through the plasma membrane. Superparamagnetic nanoparticles, functionalized to be positively charged, exhibit strong and specific binding to cancer cells. This charge-based targeting offers a new method for capturing and sensitively detecting cancer cells in clinical settings, particularly for detecting CTCs in whole blood. CTCs, which can detach from the original tumor and enter the bloodstream, are believed to play a crucial role in metastasis. We performed direct CTC detection on blood samples with highly encouraging results. Across different disease groups, our method captured CTCs with much higher sensitivity than previously published methods, confirming the efficacy of the charge-based strategy. Potential applications include early cancer diagnosis and evaluation of medical interventions by detecting circulating tumor cells.