

Microfluidic Approaches to Hemorheology: Engineering Perspectives on Age Reversal

Jihee You¹, Chae-A Park², Ae-Kyeong Kim³, Hye Ran Jeon³, Dong-Ik Kim^{3*}, Sehyun Shin^{1,2*}

¹School of Mechanical Engineering, Korea University, Seoul, Republic of Korea

²Engineering Research Center for Biofluid Biopsy, Seoul, Korea

³School of Medicine, SungKyunKwan University, Suwon, Korea

†Email address for correspondence: lexerdshinr@korea.ac.kr

Abstract

Red blood cell (RBC) deformability is closely linked to aging and holds promise as an indicator of biological age. However, current hematological techniques lack the sensitivity to accurately discern the subtle differences in deformability associated with aging. To overcome this limitation, we developed an ultrasensitive microfluidic device inspired by the spleen's filtration mechanism. The device features a porous section created by packing 25 μm beads into a tube with a diameter of 400 μm and a length of 2 mm. RBCs with higher deformability traverse this porous region more rapidly, covering longer distances and achieving higher velocities. Hematocrit levels were meticulously standardized to ensure measurement consistency. In murine models, statistically significant differences in RBC deformability were observed across age groups (1, 6, 12, and 18 months). For human samples, cell aggregation was minimized by diluting the specimens to approximately 60% and adjusting the osmolarity to 170 mOsm, which allowed for a clear distinction in deformability between the young group (median age: 30 years, range: 12–40 years) and the older group (median age: 72 years, range: 65–90 years). Using a cutoff speed of 0.9 mm/s to differentiate the two groups, the diagnostic performance demonstrated an area under the curve (AUC) of 0.84, a sensitivity of 78.3%, and a specificity of 73.9%, indicating moderate diagnostic accuracy. These findings confirm that RBC deformability is a reliable marker for age-related physiological changes, and the method could be further applied to estimate physiological age, assess systemic aging, and evaluate oxygen delivery efficiency.

Keywords: RBC, deformability, ageing, diagnosis, microfluidic

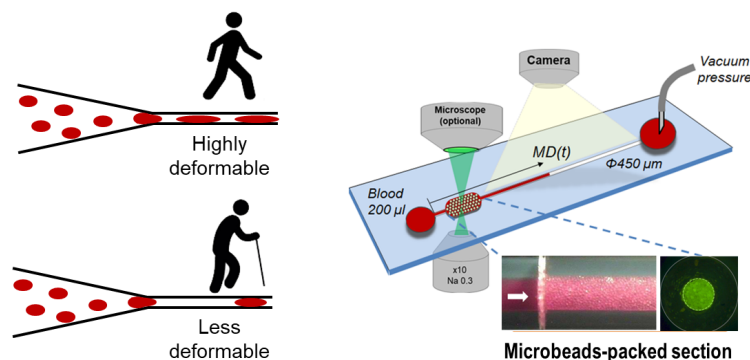


Figure 1. Schematic of the AnyDeform assay for distinguishing elderly from young individuals.

Acknowledgments

This project was conducted with the support of the Alchemist Project of the Korea Evaluation Institute of Industrial Technology (KEIT 20018560/NTIS 1415184668) funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea) and National Research Foundation of Korea (NRF) Grant funded by the Korean Government, MSIP (RS-2023-00207833).