UNIVERSITY of HOUSTON | ENGINEERING

Department of Biomedical Engineering

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PhD Dissertation Defense
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"Novel Microfluidic Devices for Diagnosis and Treatment of Blood Disorders in Vulnerable Pediatric Populations"

Abstract

Blood is a complex suspension made up of four main components: plasma, platelets (PLT), red blood cells (RBC), and white blood cells (WBC). The ability to separate blood into its individual parts is a critical first step for blood analysis, clinical diagnosis, and biological research. Conventional blood separation techniques typically require bulky instrumentation and complex procedures at prohibitive costs, making them less widely available in resource-limited settings with underdeveloped healthcare infrastructure and to some populations of high-risk pediatric patients. To address these limitations, this work focuses on the development of two novel microfluidic technologies capable of processing blood for diagnostic and treatment purposes. This dissertation first reports on a paper-based microfluidic device designed to enable universal newborn screening and rapid diagnosis of sickle cell anemia (SCA), a common inherited blood disorder causing lifelong morbidities. Our diagnostic device takes advantage of the structural difference between diseased hemoglobin, found within sickle RBC, and healthy hemoglobin to provide a distinct visual diagnosis for SCA rapidly and at a fraction of the cost of conventional approaches. The test kit can be prepared with easily accessible food-grade ingredients and has a long shelf-life, enabling its deployment even in remote resource-limited settings. The efficient and high-throughput separation of WBC directly from whole blood—typically performed using a process called leukapheresis—is crucial in many areas of medicine, including life-saving leukodepletion procedures and many novel cell therapies. Unfortunately, this established treatment method is not available to neonates and low-weight infants due to the large extracorporeal volume of the machines and significant risks associated with the procedures. This dissertation presents a small, microfluidic device capable of removing WBC from blood recirculating through a closed-loop circuit, with a separation efficiency and volumetric throughput on par with conventional, centrifugation-based leukapheresis. This device could provide a viable treatment alternative for underserved pediatric patients with leukemia, a common blood cancer for which leukapheresis is indicated. If adopted, the microfluidic tools discussed in this dissertation could drastically improve the quality and accessibility of clinical care for millions of individuals worldwide, regardless of socioeconomic status or patient size.