Name(s)
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Project Number
S0320

Project Title
Development of a Fully-Integrated Microfluidic System for Rapid Diagnosis of Infectious Diseases and Cancer

Abstract

Objectives/Goals
RNA analysis requires multiple lab processes that are expensive, tedious, susceptible to cross-contamination, and reliant on skilled operating. The goal of this project is to create a fully-integrated microfluidic system incorporating a 3D cartridge, battery-powered portable instrument, and smartphone-based fluorescent scanner that can perform nucleic acid sample preparation, separation and purification, amplification, and detection.

Methods/Materials
Individual technologies that were designed, tested, and optimized included 1) an electrochemical micropump, 2) wax microvalves, 3) acoustic micromixers, 4) reagent-storing blisters; 5) 3D layer stacking; 6) a portable battery-powered instrument for cartridge operations. The integrated system was tested with 4 cancer cell lines derived from cervical and breast cancer before being tested with clinical urine samples infected with Chlamydia Trachomatis and Mycoplasma Genitalium. Results were analyzed at each stage of the diagnostic process to optimize RNA extraction efficiency, RNA purity, and signal amplification. Comsol Multiphysics was used to study reactions in acoustic micromixing.

Results
The acoustic micromixing method significantly reduced sample preparation times from several hours to seconds. The electrochemical pump, wax microvalves, 3D design, and reagent-storing blisters were optimized for regulation and successfully facilitated fluid flow operations for maximization of RNA separation and purification. CFD models successfully validated acoustic interactions seen in cellular interactions to optimize sample preparation and RNA capture. The cell-phone-based fluorescent scanner successfully detected fluorescent signals in amplified samples. The integrated system performed sample-to-answer analysis on 6 different infectious diseases and types of cancer with diagnostic results comparable to modern-day-technologies, with an RNA extraction rate of 65% and production of high-purity RNA.

Conclusions/Discussion
The developed system produced consistent diagnostic results among 6 different types of diseases that were comparable to those of modern-day-technologies. It displays the potential to diagnose hundreds of other infectious diseases and cancer-causing mutations for use in everyday households and at the point-of-care. Many of the engineering components are transferable to a variety of microfluidic platforms for other biotech and analytical applications.

Summary Statement
My project is about the development of a fully-integrated microfluidic system for sample-to-answer diagnostics consistently demonstrated successfully among 6 different infectious diseases and types of cancer.

Help Received
Lab equipment was provided by Dr. Eva Mcghee. Results and future directions were discussed with Dr. Eva Mcghee and Mohammad Agahmoo.