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[The Pocket Doctor – Laboratory Results Using A Smartphone]

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Researchers have recently invented a device they call a "dongle," which is in short, a diagnostic test that is based on microfluidics that runs strictly on the power from a smartphone headphone jack. The dongle runs a complete immunoassay and tests for HIV and syphilis by searching for specific antibodies in the patient's blood. Researchers put it to the test most recently in Rwanda as a blind experiment in which health care workers used the dongle to obtain results in 15 minutes or less on the app, which is synced with the tool. The given results from the dongle rivals gold standard laboratory-based tests without a doubt, seeing as their sensitivity and specificity compete neck-and-neck with one another. Because of this, there is proof that with advancing technology and coupling microfluidics, clinics and communities who are poor in resources might soon be able to provide laboratory-like diagnostics to a population that otherwise wouldn't typically receive that type of advanced care. Soon, this might all be done through a pocket-sized device ran on the common smartphone.

Introduction

The distribution of smartphones is universally widespread, developing countries included, and their communication abilities as well as their developed software and sensors make them the perfect candidate to be an on-the-spot treatment and diagnostic tool on a molecular basis. Typically, the health and medical field in terms of the smartphone haven't strayed far from the typical data analysis, processing and communication. However, this is now all changing with the introduction of the molecular level, laboratory quality diagnosis that smartphone tools are enabling paired alongside their coordinating app.

The dongle is a microfluidics-based device that is strictly and solely powered by the smartphone when plugged into a headphone jack. The microfluidics-based approach can be described as manipulation and exact control of fluids in micro-sized channels on a relatively miniscule scale. This smartphone accessory runs a complete immunoassay with laboratory-like quality with only a simple pinprick of the patient's finger for their blood. An immunoassay is a test that is utilized in order to identify the existence or the number of a substance, in this case antibodies, depending on the antibodies' ability to act like an antigen. (1) This is done in order to test for not only a HIV antibody, but also for treponemal-specific antibodies (meaning any type of anaerobic spirochetes related to the *Treponema* genus, which are ultimately parasitic and pathogenic in humans) for syphilis, as well as nontreponemal antibodies for it too. (1) The goal of the dongle is to perform and have the effectiveness of that of a ELISA, or enzyme-linked immunosorbent assay, which is used in ordinary labs. However, the dongle is a compact diagnostic tool that has the capability of attaching to a smartphone instead of a bulky tool used in a gold-standard laboratory. The dongle is every bit of an ELISA, however it runs the assays on disposable plastic cassettes that have reagents already loaded into it, so that disease-specific areas would enable healthcare workers with an objective readout. In contrast to the ELISA model, the dongle has an amplification step that is performed by gold nanoparticles and silver ions rather than enzymes and substrates. (1) The dongle experiment uses the standard immunoassay in which the gold-labeled IgM antibodies distinguish HIV and syphilis antigens, and then the silver reagents follow so as the amplify the resulting signal. This is all done with 2 µL of blood, or in other words a simple pinprick on the finger with results flashing on the screen of the app within 15 minutes or less. In reference to the smartphone as a use of power to enable the diagnostic tool to run, the audio jack connection allows for a high frequency kHz audio signal

to be sent from the smartphone to the dongle to be converted into Voltz, thus powering the dongle as a result and enabling it to run the test.

Recent Progress

Continuing the idea of a molecular diagnostic tool using the smartphone, countless companies have been delving deeper into the research needed to make the smartphone a suitable application to run tests for other diseases. Branching out from HIV and syphilis, there is another similar device that has a "diffraction-based approach" which allowed for the screening of precancerous/cancerous cells in cervical specimens as well as to identify human papillomavirus DNA. (2) Instead of a dongle, this process uses a snap-on module covering the smartphone's camera, equipped with both a light source and area to insert the sample. In short, the whole idea consists of digital diffraction diagnostics (or D3), which can be defined as a computational analysis of distinct diffraction patterns generated by microbeads that bind to biological targets of interest. (2) Through their model, they ultimately analyzed cancer cells by profiling them with the immunomicrobeads. These microbeads generate a specific diffraction pattern, allowing them to be detected by the camera in the smartphone in a bright-field type of setting. Digital processing was the able to fully reconstruct these images of the cells bound to the beads in order to recover molecular information. The only issue with the module was that it did not have a high specificity in regards to identifying the human papillomavirus DNA, although it did around 50% of the time. Through experimentation, scientists were able to reliably diagnose patients with high risk for a malignancy in cervical cancer and continued other experimentation that proved to be consistent with what the module's purpose is. They go on to prove that the snap-on module has a high specificity and sensitivity comparable to laboratory-based diagnosis, however still have countless alterations to go before the module can be implemented as a 100% guarantee to screen precancerous/cancerous cells in cervical specimens.

Discussion

One day–in the near future, it is hopeful that the direction of consumer-oriented medical accessories in smartphones will lean more towards that of clinical diagnostics and molecular bases rather than the run of the mill smartphone apps that are available today, such as those that help you determine weight loss or vital signs. From what the above trials have described, there is supporting evidence that these tech accessories provide justifiable responses and evidence to their success with patients and their diseases. There is much to discover in terms of the furtherment of molecular diagnostic testing, and hopefully a more wide range of tests will someday be available whether that be drugs, pregnancy, malaria, Zika, Ebola or even cancer. Rather than just a "high" specificity or sensitivity to prove their competence, these tests might someday have 100% in these categories as well as be available worldwide. The science behind each of these assays have to be furthered and understood both in a qualitative and quantitative way in order to stray away from the laboratory field and into more of a place that is available anytime, anywhere. This is all to say, that somewhere along the way, accurate and efficient medical diagnostic tests might at some point in the future become available to those people that wouldn't normally be given the opportunity, especially in resource-limited communities and underdeveloped countries.

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