Automated Doctors: Cell Phones as Diagnostic Tools

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“Here we are just playing Angry Birds,” says Wilson To. “How do we unlock [the] smartphone’s potential?”

To is trying to do just that at Caradigm, a joint health technology venture of GE Healthcare and Microsoft Corporation. To is the lead researcher and codeveloper of Lifelens, a mobile phone–based diagnostic tool. Lifelens is still in its visionary stage, but the hope is to change point-of-care (POC)3 diagnostics through the application of artificial intelligence and computer vision technologies. In the first iteration of this technology, Lifelens assesses blood samples for malaria. The Lifelens concept joins the innovations from at least a handful of other teams pushing forward in the field of cell phone–based malaria microscopy. We spoke to Dr. To about his team’s healthcare tool, as well as about the larger movement toward mobile phone–based diagnostic tools.

What Does This Technology Do?

Today, says To, most field diagnostic tools collect data, but ultimately a physician or trained healthcare worker needs to analyze the data to assess the finding. Instead, To has visualized something that does not require a trained healthcare worker. He wanted to create something foolproof—like a doctor in your hand—as well as something that brings the accuracy and clarity of the laboratory into the field: “Can we create a computer to look for signs of disease?” asks To.

In 2011, To’s group unveiled Lifelens, a smartphone diagnostic system that runs on the Microsoft Windows Phone 7 operating system and that its creators claim can take a picture of a blood sample and analyze it for malaria (Fig. 1). The geolocation of that blood sample, including when it was taken, can then be uploaded into the network cloud to provide real-time worldwide data about malaria outbreaks that Lifelens hopes will help the epidemiologist track—and prevent—disease.

How Does It Work?

To’s interdisciplinary team of a biologist, engineers, and computer scientists has created a system of both hardware and software. To enable the phone to “see” the blood sample, the team has created an attachable lens equivalent to that of a light microscope. At last year’s debut, the team showcased a plastic lens that magnified at 350×, but To says they are currently testing lenses of different materials that have magnification capabilities of 100× to 600×. If the device were to go to market with today’s technology, the lens would cost $50, “a one-time fixed cost” says To, and the team is hoping to lower that price.

When using the app to assess malaria, a healthcare worker would attach the lens over the mobile phone’s own camera. A blood sample would then be prepared via a standard protocol—draw the sample, smear it on a slide, and stain it. After the slide has developed, the worker would train the camera on the slide and take a photograph. A straightforward touchscreen interface features a button that when pushed launches the analysis software. To says the “onboard technology” looks at different fields of the sample, counts the number of red blood cells in each field, and locates any abnormal activity. When screening for malaria, the digital tool homes in on the parasite itself. According to To, a healthcare worker would walk away with a malaria diagnosis after about 2 min: Either you have the parasite or you don’t. The Lifelens team says the system has a 94% accuracy and a false-positive rate of 10%–15%, although the team has yet to publish any of their results. The equipment has not been deployed in the field; the team hopes to start clinical trials as early as the end of summer 2013.

Will It Work?

“How which of the five species is it?” asks Dr. Howard M. Shapiro, currently a lecturer in pathology at Harvard Medical School and who developed the first computer-
ized microscope with his colleagues in the late 1960s. Dr. Shapiro points out that the project cannot yet identify morphology elements critical to determining how best to medically treat a *Plasmodium* infection.

“Resolution of morphologic detail adequate to permit reasonably reliable identification of parasites and discrimination among parasite species requires use of a 100× oil immersion objective,” says Shapiro, who remains unconvinced about how well the new technology can reliably identify the presence of malaria, if at all.

To does not want the conversation to get too focused on malaria. He stresses Lifelens’ potential as a single digital tool that assesses many types of disease. “This is not a solution just for malaria; I wholeheartedly believe it can be a healthcare platform,” says To, whose project continues to move forward with funding from Microsoft via the Tides Foundation. He believes that the current weakness in developing POC devices, including the Lifelens system, is advancements that screen for only a single type of illness. “As a healthcare worker, I’m not taking 5 different mobile phones that test for 5 different things into the field,” says To.

But Shapiro’s skepticism goes even further. He believes the current weakness of POC digital development is not just its single-mindedness, as To says, but also its focus on resolution and magnification—and on mobile phones. “Stop trying to use cell phone cameras,” he says. “By putting microscopic lenses on cell phones, we’re starting in the wrong direction.” Shapiro points out that cell phone cameras have a low light sensitivity and a limited dynamic range. None can yet incorporate oil immersion. Under the current system of Good Manufacturing Practices (GMPs) for medical devices and components, manufacturers of cell phones and their components are not prepared to be part of the medical community. “To keep features competitive, new components and new phones are often brought out at intervals of a year and often less, meaning that even if components met GMP requirements, the new phones would [constantly] have to be approved,” says Shapiro.

Furthermore, no design that Shapiro has seen—including the one described by Lifelens and others coming out of the University of California Berkeley and elsewhere—adequately addresses the assessment of hundreds of high-power fields. As clinical chemists know, there are thousands of high-power fields on a slide of a single sample. If 20 parasites are spread out over 4000 fields, one would have to look at hundreds of fields to detect a single parasite. For this kind of application, a cell phone would require not only time, but also a way to focus in on fields that are only fractions of a millimeter in diameter.
“The most expensive component of the automated microscope is the platform that moves the slide around,” says Shapiro, and for good reason. He has not seen a company that has addressed this issue directly, although some companies have tried to ameliorate the problem with clips that attach slides to the phone. Having recently settled into laboratories in Washington state, To responded that his group is developing a “smartphone case” to hold the sample in place and that they have a unique approach that permits the analysis of multiple fields of view, which he could not explain because of intellectual property concerns.

Shapiro still maintains that when it comes to POC technology, there is too much of a focus on cell phones and their cameras. “It’s a poor camera and a good communicator,” he says. “But you could build a box that talks to the cell phone network that no one will steal.”

To and colleagues remain undeterred. They are working to continue the expansion of Lifelens into a “healthcare platform” with better computer vision and machine-learning algorithms so that they can move beyond malaria and target both chronic and communicable diseases, such as diabetes, sickle cell anemia, and “any parasite-based blood-borne illness.” To achieve this goal, they will need to continue expanding their digital technology. These plans include those for a system that not only takes pictures but also allows a user to take a video scan of the sample. They will also want to make sure that their technology is “foolproof,” says To. Today’s rapid-diagnosis tools are sensitive to temperature and humidity. To’s tool will need to have a long battery life and be resistant to sand, moisture, and other environmental elements.

In the war to advance POC hematology tools, the mobile phone appears not to have lost the battle yet, although many would argue that it is time to start asking harder questions. Says Shapiro, “There are fatal flaws of the cell phone microscope as a ‘platform technology.’”

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Please look out for a forthcoming opinion piece in Clinical Chemistry by Dr. Eric J. Topol, Director of Scripps Translational Science Institute, on the promise of microfluidics converging with smartphones.

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