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SHORT COMMUNICATION

Can the power of mobile phones be used to improve tuberculosis diagnosis in developing countries?

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Summary The low-cost Microscopic Observation Drug Susceptibility (MODS) assay is a non-proprietary test that delivers rapid and accurate diagnosis of tuberculosis (TB) and multidrug-resistant TB. Although methodologically straightforward, implementation is challenging in isolated settings where personnel trained in plate reading are lacking. One affordable strategy to address this shortfall is the use of mobile phones, first to transmit images captured by an inverted microscope to a remote site where pattern recognition is performed by trained personnel, and second to receive the resulting output of this analysis. Such a system could be used for training of laboratory personnel through distance learning, resolution of equivocal appearances and quality assurance.

During the last few years, telemedicine with remote image viewing has emerged as a highly valuable and versatile tool, particularly suited to places where local expertise is limited. Of the available approaches for image transmission, the Internet and mobile phone telephony have been successfully used in a number of settings. In particular, mobile phones have been used for diagnosis, monitoring and medical management of several infectious and non-infectious diseases.[1–5]

We are evaluating the use of mobile phones as part of an integrated system to facilitate efficient diagnosis of tuberculosis (TB), a disease predominantly affecting developing countries although currently re-emerging in the industrialised world.

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Among the new tools being developed for the detection of TB and multidrug-resistant (MDR) TB is the low-cost Microscopic Observation Drug Susceptibility (MODS) assay for accurate and fast diagnosis and drug susceptibility determination. This test is based on visual recognition of a characteristic tangling growth pattern of mycobacteria in liquid media observed by inverted microscopy.[6,7] Extensive use in developing countries may be limited because pattern recognition requires trained personnel in order to achieve the best sensitivity and specificity. The fundamental basis of the MODS method makes it a suitable candidate for using the power of mobile phones both to transmit images to a remote site for expert analysis and then to receive the telephonically transmitted results of this analysis. To test the potential utility of mobile phones in TB diagnosis, we performed a study in which MODS culture images were transmitted using a mobile phone to a web server. An expert in reading MODS plates accessed and read the images online.

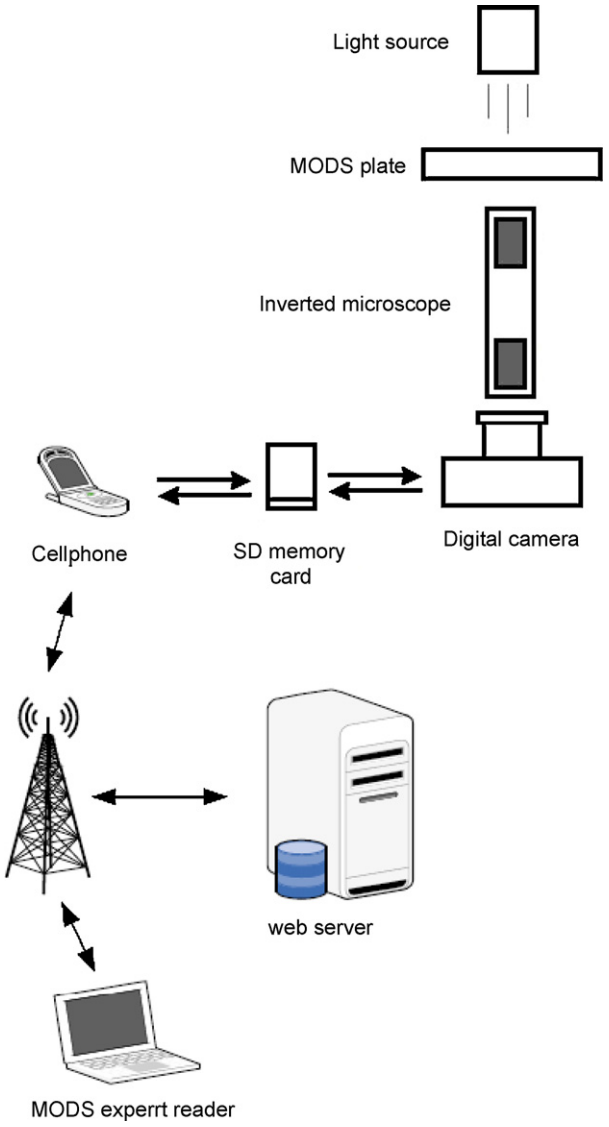

Figure 1 Diagram of the mobile phone-assisted Microscopic Observation Drug Susceptibility (MODS) pattern recognition system.

The system used to capture MODS images consisted of a commercial inverted light microscope (Nikon Eclipse TS100-F) using a 10× objective and 10× eyepiece, with a 4 megapixel digital camera (Olympus C-3030) adapted to the trinocular base. Images of MODS cultures were stored on a 256 Mb SD memory card. The original pictures were captured as PNG files with an average size of 750 kb each. To facilitate telephonic transmission, each image was transformed to a compressed JPG format with an average size of 130 kb.

The SD memory card was transferred from the digital camera to a mobile phone (Nokia 6110) with internet connection capability. JPG-compressed images were transmitted and uploaded to an ad hoc web server using the internet WAP protocol for mobile phones. A MODS plate expert reader remotely accessed the server and was able to analyse the images directly from the Internet browser by zooming up to its normal aspect. A scheme of the entire process is depicted in Figure 1.

To evaluate the efficacy of the mobile phone/web server system in TB diagnosis, 50 images of MODS cultures containing *Mycobacterium tuberculosis*, 20 images of MODS cultures of atypical mycobacteria and 5 culture-negative images were obtained using the Nikon system. The atypical mycobacteria included strains of *M. avium*, *M. kansasii*

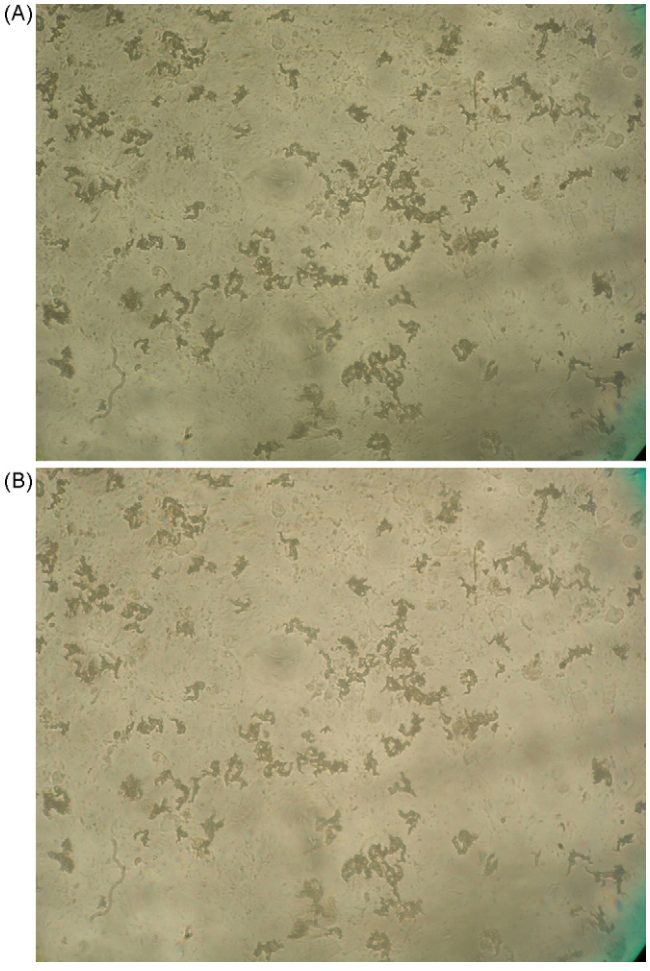

Figure 2 (A) Original image (750 kb) obtained by the Olympus digital camera. (B) Image downloaded from the web server after compression and upload using a mobile phone (127 kb).

and *M. chelonae*. *Mycobacterium bovis* strains were also included. Images transmitted by mobile phone were blindly read by the expert reader and results were compared with those made at the inverted microscope itself by a laboratory MODS technician. An example of a MODS pattern image transmitted and received by the web server is shown in Figure 2.

The concordance of readings between direct observation on the Nikon microscope and the mobile phone-transmitted image was 98.7% (74/75). The single discrepancy corresponded to an atypical mycobacterium that was misclassified as a contaminant after mobile phone transmission. It is important to highlight that for some atypical mycobacteria an important distinguishing characteristic from *M. tuberculosis* is the presence of small spine-shaped surface structures; these are not lost through file compression.

In conclusion, we propose that with a relatively minimal investment in mobile phones, it is possible to facilitate the diagnosis of TB and MDR-TB using MODS in remote settings where a lack of trained personnel may otherwise be a limitation.

Authors' contributions: MZ, WHC and DAJM developed the concept; MZ, JC, RHG, CGL, WHC and DAJM designed the study; JC and CGL read the images that were transmitted by MZ; MZ, JC, RHG, CGL, WHC and DAJM all contributed to the writing and editing of the manuscript. All authors read and approved the final version. MZ is guarantor of the paper.

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