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Automated disease diagnostics for low-resource areas using mobile phones

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Background: Technology that enables disease diagnosis is fundamentally complex. In low resource areas, the degree to which a diagnostic technique can shield the user from that complexity largely determines its usefulness. RDTs, which convert an intricate chemical reaction into an easy-to-visualize readout, have become widespread and popular. Diagnostic microscopy, which is needed for both screening and confirmation of many diseases, continues to be limited by the need for support from a well-equipped clinical environment. While a microscope sufficiently simplifies the act of *microscopy* it does not adequately address the complexity of performing a *diagnostic*, as experts are needed to both acquire and analyze images before a result can be provided to a patient, dramatically reducing the impact that diagnostic microscopy could have in disease diagnosis and elimination efforts in low-resource settings. It is time to rethink how we perform diagnostics with microscopy.

Methods: Our approach is to use automation and algorithms to construct fully integrated microscopy-based diagnostics. By leveraging the mass production of consumer electronics such as mobile phones, we can design inexpensive automated devices with extremely low recurring costs for low-resource areas. By using state-of-the-art algorithms, we can provide rapid, quantitative diagnoses without the need for expert microscopists. And by analyzing large quantities of data collected by the automated devices, we can continuously improve the algorithms to provide quality-controlled diagnostic capabilities.

Findings: Here we present an approach that utilizes automation and integration to quantitatively diagnosis *Loa loa* infection at the point-of-care to allow resumption of MDA campaigns. We use hobby electronics to actuate a sample of whole blood in a glass capillary, and a mobile phone mated to inexpensive optics to both image and analyze the sample, providing a quantitative diagnosis in only 2 minutes.

Interpretation: These devices illustrate a framework for the expanded use of diagnostic microscopy in low-resource areas that we are extending to tuberculosis, malaria, soil-transmitted helminths, and other infectious and noncommunicable diseases.

Funding: This work was supported in part by the Bill and Melinda Gates Foundation, the Blum Center for Developing Economies at University of California (UC) Berkeley, U.S. Agency for International Development through the Development Innovation Lab at UC Berkeley, the Purnendu Chatterjee Chair fund, and the Division of Intramural Research of the National Institute of Allergy and Infectious Diseases.

Abstract #: *1.013_TEC*

Implementation of an electronic surgical registry in a low-middle income country: Assessing organizational readiness using the theoretical domains framework approach

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Background: While the benefits of using electronic health records (EHRs) in both developed and low-middle income countries (LMICs) are known, the barriers and facilitators to implementing EHRs in LMICs have not been characterized. Through an implementation science approach, we assessed organizational readiness for EHR implementation on a surgical service in an urban LMIC hospital.

Methods: 6 semi-structured focus groups were conducted with 4 hospital administrators, 3 faculty surgeons, 20 surgical residents, 6 interns, 10 nurses, and 12 medical students in a large urban hospital in Paraguay. Focus groups were conducted over the course of three weeks during the pre-implementation phase to identify barriers and facilitators to implementation. Focus group data was coded using the Theoretical Domains Framework (TDF), which are 12 validated domains related to behavior change, in order to evaluate organizational readiness for adaptation of the EHR tool in place of paper records. The study was approved by the University of Pittsburgh IRB.

Findings: Reinforcement, environmental context and resources, and roles and responsibilities were the three most relevant TDF domains that emerged from the data. Residents asked fewer questions about technical aspects of the tool than interns and students. Department heads were more confident about successful, widespread use of the tool than junior-level trainees. Residents, interns and students were more uncertain than faculty and department heads about who would enforce the use of the tool in place of paper charting. Triage nurses were more concerned than other stakeholders about the feasibility of learning to use the novel tool given the frequently rotating shifts among triage nurses. Internet quality was a concern raised by all groups.

Interpretation: Uncertainties about reinforcement, roles and responsibilities for using the novel EHR tool are important potential barriers to be addressed in the pre-implementation phase of introducing an EHR to an LMIC surgical service. Concerns about environmental context and resources, including hospital workflow and Internet quality, were key points raised. The findings are limited to implementation of an EHR on a surgical service of an LMIC hospital, and generalizability may vary based on hospital and country.

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Abstract #: *1.014_TEC*

Point-of-care drop-based microfluidics platform using isothermal amplification for the quantitative detection of *Mycobacterium tuberculosis*

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Background: Tuberculosis (TB) is a serious global health problem with 9 million new cases and approximately 1.5 million deaths worldwide every year. A majority of TB deaths are caused by late or unavailable diagnosis. Given the availability of effective treatment strategies for TB and the extremely frequent airborne transmission of the pathogen *Mycobacterium tuberculosis*, it is vitally important

to detect TB at an early stage in patients. Current diagnostic tests, including sputum sample microscopy and the Mantoux skin test, are very slow and characterized by many false-positive results. Thus, a rapid point-of-care diagnostic for TB remains an unresolved challenge.

Methods: Nucleic acid amplification tests (NAATs) have shown great promise in quickly detecting genes of interest with high specificity and sensitivity. This study employs the combination of a drop-based microfluidics platform and isothermal DNA amplification to create a breakthrough technology that enables the detection of TB bacteria from the bloodstream or sputum. Advantages of drop-based microfluidics include reduced sample size and reagent consumption, short processing times, and enhanced sensitivity. In our device, TB DNA is rapidly encapsulated in microfluidic drops (water-in-oil emulsions), amplified using loop-mediated isothermal amplification (LAMP), and detected via fluorescent signal.

Findings: The method allows for all steps, including emulsification with a pipette, amplification at a single temperature, and quantitative-detection from a reservoir, to be done on-chip in less than 1 hour. Imaging and quantification of fluorescent drops (indicating the presence of TB DNA) can be achieved by a simple color camera.

Interpretation: Such a microfluidic technique would allow for rapid TB diagnosis to be done directly from the blood/sputum in resource-poor locations of the developing world.

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Abstract #: *1.015_TEC*

The development of a novel local area network based EMR utilizing handheld devices to serve resource-limited clinics

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Program/Project purpose: Our project describes a practical electronic medical record (EMR) for global use in areas lacking Internet access or significant informational technology (IT) experience. We seek to provide better clinical communication, improved patient safety, and more coordinated and efficient patient care while maintaining patient privacy at resource-limited locations. We designed and beta-tested our new EMR at a remote clinic site with the above challenges. Our system provides an economical, practical, secure, and mobile EMR system useful for a myriad of global health settings.

Structure/Method/Design: We pair a low-cost, commercially available wireless router/hard drive combo with unique software to create a dynamic system not requiring Internet access during encounters. Our portable EMR utilizes an Apple Airport Time Capsule that serves as a wireless hard drive and full-featured Wi-Fi base station. The Time Capsule generates a secure local area network allowing multiple on-site providers to sync with the server and access the chart in real time. Dynamic portable document format (PDF) templates are organized within the iOS application "*PDF Expert*" providing an individual patient record. The patient PDF template outlines the encounter using free text, check boxes, and drop down selections that may be customized depending on clinic context. The resulting system allows health providers to share and analyze secure and confidential health information with local stakeholders including hospitals, governmental agencies, or patients themselves.

Outcome & Evaluation: We beta-tested our EMR in the spring of 2015 at a remote health post in the Andes to better understand the individual challenges and aspects of the EMR. The system efficiently managed and securely stored tablet-generated simulated "patient encounters" on the Airport Time Capsule server. The EMR simulation demonstrated a promising model to enhance clinic flow, patient documentation, and medical record communication with local health officials.

Going Forward: While no one template could meet every system's needs in documentation, ours may be easily adapted for site nuances or research data collection applications. Limitations include tablet and phone connectivity only for iOs devices. Our system offers a technically viable EMR solution in resource-limited settings with potential applications for global health service and research.

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Abstract #: *1.016_TEC*

Adoption of Information and communication technologies for early detection of breast and cervical cancers in low- and middle-income countries

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Purpose: In response to the growing burden of breast and cervical cancers, low- and middle-income countries (LMICs) are beginning to implement national cancer prevention programs. We reviewed the literature on information and communication technology (ICT) applications in the prevention of breast and cervical cancers in LMICs in order to examine their potential to enhance cancer prevention efforts.

Methods: Ten databases of peer-reviewed and grey literature were searched using an automated strategy for English language articles on the use of mHealth and teleoncology in breast and cervical cancer prevention (screening and early detection) that were published between 2005 and 2015. Articles that described the rationale for using these ICTs and/or implementation experiences (successes, challenges and outcomes) were reviewed. Bibliographies of articles that matched the eligibility criteria were reviewed to identify additional relevant references.

Results: Out of the initial 285 citations that were identified, eight met the inclusion criteria. Of these, four used primary data, two were reviews and two were commentaries. Articles described the potential for mHealth and teleoncology to address both demand and supply side challenges to cancer prevention such as awareness, access, and cost in LMICs. However, there was a dearth of evidence to support these hypotheses.