Delivering Better HIV Care in Sub-Saharan Africa Using Phone-Based Clinical Summaries and Reminders

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Abstract

Despite the effective use of computerized clinical summaries and reminders in high-income countries to increase the quality of care, the difficulties of implementing and deploying such systems in low-income countries have hindered their adoption. To become viable in these settings, clinical summaries and reminders systems must reliably deliver information while enabling healthcare providers to explore relevant data.

This paper begins by explaining the need for summaries and reminders and how they might increase the efficiency of care. It then discusses the challenges similar systems have overcome and how those lessons learned apply to the context of providers in Sub-Saharan Africa. Finally, we describe the development of a phone-based clinical summaries and reminder system designed to increase the quality of Human immunodeficiency virus (HIV) care in Sub-Saharan Africa. In our evaluations, we will show through instrumentation and user studies that such a system is more available and can lead to more compliance with HIV testing guidelines.

1 Introduction

Of the 33 million people globally who have HIV [1], 22 million live in Sub-Saharan Africa where their clinical outcomes are worsened by strained healthcare systems [2]. While Sub-Saharan Africa has 25% of the global burden of disease, it only has 3% of the world's healthcare workers [3]. Given this disproportional allocation of resources [4] and high attrition rates of existing health providers [5], it is no surprise that the region accounted for 72% of the world's AIDS-related deaths in 2008 [6].

There has been a push to use information communication technologies (ICTs) to strengthen existing healthcare systems. Broad categories of interventions include informing populations about health issues [7, 8], providing medical consultation remotely [9, 10, 11], and enabling health data collection and retrieval [12, 13, 14]. It is this latter category of health data management that is explored in this work.

For most patients in these regions, human immunodeficiency virus (HIV) status is first determined in a clinical or community visit. In such visits, the patient is counseled about HIV and tested to determine status. If the patient is confirmed positive in an HIV status test, a cluster of differentiation 4 (CD4) test is performed to determine how much damage the virus has caused. Generally, if the CD4 count is under 200 cells/mm^3, the patient is enrolled on an antiretroviral (ART) drug regimen [15].

ART drug regimens are not a cure for the disease, but instead control the HIV-1 RNA levels (viral load) in the body. The combination drugs must be taken daily for the rest of the patient's life. As the virus evolves or opportunistic infections develop, healthcare providers modify the combination to ensure patients stay healthy. Regimens also change if side-effects from the drugs become too much for the patient to bear [15].

Widely followed care guidelines specify that patients on ARTs be evaluated monthly for changes in CD4 count and viral load – the important indicators for HIV patient health. In the monthly evaluations, providers must monitor and document laboratory results, regimen changes, clinical status, and any adverse events. With a small number of HIV positive patients in a clinic, this data can be monitored using detailed paper records, but as the number of patients increase, the relevant data quickly grows to unmanageable levels. With search and retrieval limited to paper, critical information is not readily available to providers at the point of care.

Increasingly, electronic medical records (EMRs) systems are being used in low-income regions to help manage patient data [16, 17]. In clinics where EMRs are being used, the process of using patient data is still primarily paper-based [18, 19, 20]. When providers see patients, they complete paper forms that document the encounter. These forms are eventually added to a paper record (see Figure 1). Every few days, the encounter (along with laboratory data) is manually entered into an electronic system and then returned to the patient's record. Upon a return visit, the provider reviews the patient's record on paper using past encounters and lab results to guide decision making.

Rather than providing support in the form of patient-level recommendations to healthcare providers [21], many of these EMRs focus on reporting aggregate statistics to institutional stakeholders. This is unfortunate because healthcare in low-income countries is primarily delivered by lightly-trained providers (often nurses) who might benefit from this assistance.

Attempts at providing more clinical support have focused on generating paper-based summaries which are added to the patient record. Of course, the very properties that make paper-based summaries popular (cheap, available, robust, etc) are tradeoffs for potential increases in functionality. Ideally, when a patient appears for a clinical visit, the provider should be able to immediately locate the patient's data instead of searching through a large stack of paper records. Rather than look through all previous encounters, the provider should see summaries of clinically relevant information (like a graph of weight over the last three

Figure 1: When a patient comes into a clinic, the provider fills out a paper form about the visit. The paper form goes into the patient's folder and when the patient returns a month later, the provider reviews previous encounters before continuing care.

months) and reminders about deficiencies in care (like a late CD4 test) or patient-specific recommendations. Because acting on the summary or reminder might require more information (like reviewing weight over the last few years), exploring latest underlying data is also critical. Paper-based summaries and reminders simply cannot enable such functionality.

While a mix of servers, computers and printers could provide summarization and reminder assistance to providers, such infrastructure is hard to maintain in low-income regions [22, 23]. Much of this is due to environments with intermittent power and connectivity and users who are unfamiliar with the technology [24]. With the growth of mobile phone usage in low-income regions [25], there have come opportunities to transition to more mobile clinical summaries and reminders systems.

While mobiles are potentially more robust and user friendly, but there are still obstacles to overcome. Designers must manage the cultural challenges [26, 27, 28], developers must navigate the variety of technical and infrastructure obstacles [29, 30], and organizations must fight to ensure sustainability and scale [31].

In this work, we build on our recent Open Data Kit project building information services in low-income regions [32] and apply those lessons learned to clinical summaries and reminders systems. The rest of this paper is organized as follows. Section 2 outlines the contributions of the proposed research. Section 3 details related work in electronic medical records in low-income regions, computerized reminders for healthcare, and mobile information systems. Section 4 outlines the development and evaluation of a summaries and reminders system designed to increase the quality of care. We finish by summarizing our goals.

2 Contributions

We seek to build a software framework that reliably delivers clinical summaries and reminders and the relevant data in resource-constrained settings. For this work, we will focus on HIV care in Sub-Saharan Africa.

Our goals are to first understand how providers in low-income countries currently make decisions about HIV care and how computing technology could speed that process. Second, we seek to implement a framework that will allow providers to receive clinical summaries and reminders. We will enable the exploration of clinical data despite environmental and user challenges. We will show using instrumentation and user studies that such a system is more available and can lead to more compliance with CD4 count and other important testing guidelines.

3 Related Work

3.1 Medical Record Systems

In this section, we discuss electronic medical record systems (EMRs) that have been deployed in low-income regions. Because EMRs provide the patient-centered data needed to reliably generate summaries and reminders, we focus on implementations that have met the high bar of sustained operation. We explore themes of integration with paper, considerations for sustainability and designing for usability. We also detail design and implementation choices which influenced the success or failure of previous work.

3.1.1 Integration with Paper

The impact of EMRs on clinical care in low-regions cannot be understated [33]. Rotich et al. [34] in Kenya found patient visits were 22% shorter, with clinician time per patient reduced by 58%, and patients spending 38% less time waiting in the clinic. Similar studies show improvements in legibility of clinical notes, prescriptions and lab tests [35], readily available patient charts [36], support for program monitoring [37], management of chronic diseases [38, 39] and, reminders and alerts about lab results and drug prescriptions [40].

Most long-lasting medical record systems in the literature are server-based, designed for the low-income regions[1] and run in parallel with existing paper-based systems. One well-known example is the Academic

[1]Careware, a popular system for HIV care in America and has been deployed for a few hundred patients in Uganda [41].

Model for Providing Access to Healthcare (AMPATH) Medical Record System (AMRS) [42, 43] which grew from Mosoriot medical record system [44]. AMRS contains information on 100,000 patients and the system includes paper-based encounter forms, technicians entering and managing data, and exporting of patient summaries and care reminders.

Similar functionality exists with work from Partners in Health (PIH) in Peru [38], Haiti [45], and Rwanda [46]. In the latter case, Anokwa et al. [47, 48] create patient search and patient summary functionality that can display relevant clinical information (shown in Figure 2) to providers. This builds on work by Wilcox et. al [49] who show increased clinical compliance using printed summaries and Nygren et. al [50] who describe how improvements in record design, even on paper, help clinicians find data. Current implementations of these EMRs from AMPATH and PIH are now built on OpenMRS [51], a common framework that can serves as a foundation for EMRs in low-income regions.

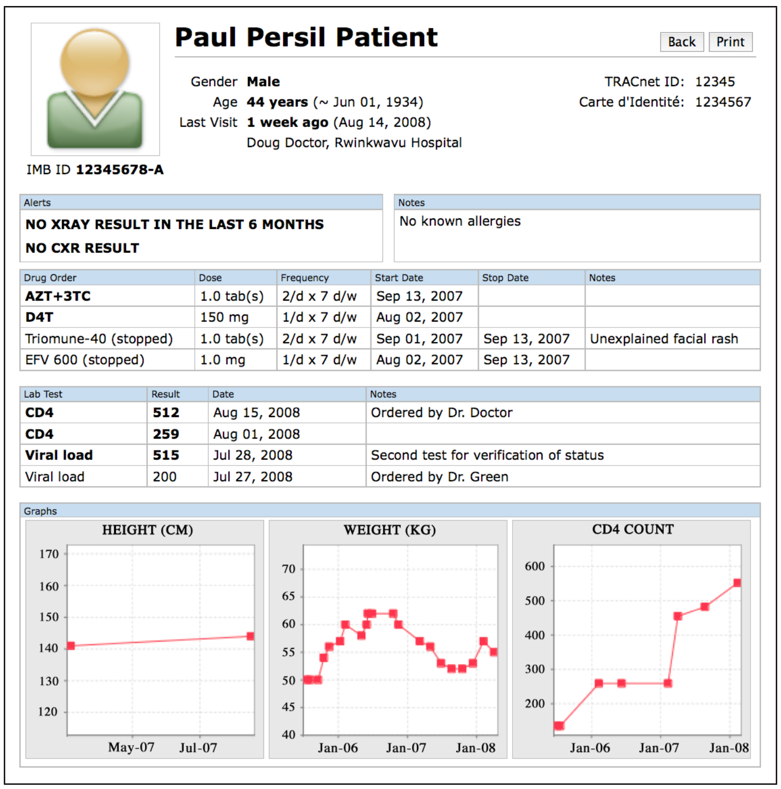

Figure 2: The Patient Summary module summarizes relevant patient data into a printable format.

Other successful systems in this domain include ARV medication tracking in Brazil [52], tuberculosis management by Vranken et al. [37] in Botswana and Blaya et al. [53] in Peru and HIV patient tracking and outcomes monitoring in Zambia [54]. More relevant to our work is iSanté in Haiti. Lober et al. [55]

note the tradeoffs that must be made. Early on, a decision was made to "reject preprinting forms with identification or historical information due to unreliable printing capacity at the clinic sites, though that would have afforded considerable workflow benefit". As more sites using iSanté have entered data directly into the system, they now occasionally generate complete clinical histories as backups but not for clinical care. This is a common theme in existing EMRs. Using paper for input is relatively easy to implement but suffers from delays in digitization. Paper for output is unreliable due to infrastructure, organizational and user challenges.

Our work will differ from many of these previous systems by focusing on providing more automated, real-time and dynamic information to providers at point of care. Our goals are to augment an existing EMR system with an alternate (and possibly better) path for accessing clinical information.

3.1.2 Considerations for Sustainability

Implementing and sustaining medical record systems is difficult. The literature features many systems that have not survived the test of time. MEDCAB [56] in Cameroon was evaluated with fourteen providers who were selected primarily on their personal interest in the research and computers. No rigorous testing of the core goals were reported and after 14 months of usage, only eight of the providers remained. Reasons for terminating usage included "changes in personnel (with trained personnel leaving the practice or the facility), management giving lower attention to the project, loss of computer (continual hardware breakdown) and departure of the main investigators."

Work from Littlejohns et al. [57] in South Africa note the challenges these systems face. "Problems arose because of inadequate infrastructure as well as with the functioning and implementation of the system [and] not ensuring users understood the reasons for implementation from the outset and underestimating the complexity of healthcare tasks." Even large (and presumably well-resourced) projects like the Follow-Up and Care of HIV Infection and AIDS (FUCHIA) [58] software It the experienced Médecins Sans Frontières have suffered a similar fate. All available information suggests that FUCHIA is no longer actively in use or development.

Clifford et al. [59] suggest that critical to success is the "creation of long-term relationships to build infrastructure and solving systemic problems to provide health care". Magnus et al. [60] note success also goes beyond lack of resources – "With proper preparation, even resource-poor HIV care delivery programs can successfully adopt IT." Similar challenges exist in the broader Information and Communication Technologies and Development (ICTD) community. Anokwa et. al [26] note that "planning for adoption, ownership, and long-term use of the proposed solution plays a critical role in ensuring that the technology addresses the development goals for which it is designed."

3.1.3 Designing for Usability

Critical to success seems to be learning how to better support users. Work by Sequist et al. [61] describe an electronic health record for rural and underserved Native Americans. In their survey of providers, the authors conclude that their research "supports prior evidence of the importance of enlisting clinician support in the implementation of electronic health record." A review of the ART programs in lower-income countries by Forester et al. [62] discover that the quality of the data collected and the retention of patients are unsatisfactory because of insufficient staff training. This view is echoed by Fusco et al's [63] successful ART program in Zambia – "overwhelmed clinical staff need support managing longitudinal clinical information, complex reporting requirements, and pharmaceutical stock inventories".

Given the existing burdens providers face, understanding the workflow of each clinic and involving providers at each stage of the design process helps ensure a usable and relevant system. In Malawi, Baobab Health's EMR [35], unique for its novel use of a simple touchscreen user interface supports over 160,000 patients. Douglas et al. [64, 65] report that the system is intuitive and easy to use, with providers eager to use the system and reaching proficiency with 30 minutes of training. The authors attribute their success to "an appropriately designed system [that] can simplify patient management for the clinician."

There are no specific guidelines that guarantee successful EMRs. What we can learn from previous work is to gather feedback from stakeholders, start with small solutions, focus on usability, and build incrementally. While these lessons apply to most human-computer interaction concerns, we must modify them with context. For that, we will build on the user-centered design methods in Human-Computer Interaction for Development (HCI4D) highlighted by Ho et al. [66].

3.2 Clinical Reminder Systems

In medicine, there are a wide range of interventions that could lead to improvements in practice and outcomes [67]. One such intervention is reminding clinicians about best-practice guidelines or deficiencies in the patient's record. For HIV clinics in low-income regions where there is a shortage of health providers and historical patient data are often unavailable, reminding is particularly important.

In this section, we explore the history of clinical reminders as decision support and focus on their impact on the efficiency of HIV care. We also touch on the barriers and facilitators to implementation.

3.2.1 Reminders as Decision Support

Broadly speaking, clinical decision support (CDS) gives providers with person-specific information at appropriate times to enhance care [68, 69]. CDS includes clinical guidelines, patient summaries, diagnostic support, clinical workflow tools and computerized alerts and reminders [70, 71]. In the latter case, alerts and reminders serve to automate clinical practice guidelines.

Alerts and reminders were conceived in the late 1970s to bypass man's imperfect memory and thus ensure the highest quality of care [72]. This notion of the "non-perfectability of man" has not changed much in decades with current systems still providing these suggestions about guidelines at the point of care [73]. Today, alerts and reminders are often delivered to computers in consult rooms where providers are seeing patients but computer-generated paper reminders included in a patient's chart are a common alternative [49, 74].

As noted earlier, simply transporting existing systems to low-income regions has not been shown to work. Many of these CDS systems assume desktop computers with high availability and build around legacy user interfaces (shown in Figure 3). An extensive review by Garg et al. [75] in 2005 notes that only 15% of examined systems had graphical user interfaces. Existing systems are also often tied to expensive, legacy and proprietary medical record systems that clinics in low-income regions can not afford to install or maintain [23].

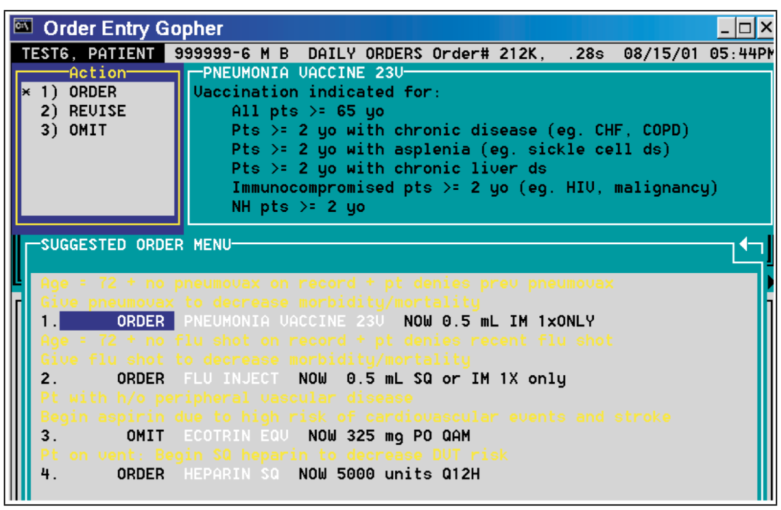

Figure 3: An example of a computerized reminder from Wishard Memorial Hospital [76]

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3.2.2 HIV Care and Effectiveness

Reminders and alerts are particularly critical for HIV care where providers must frequently monitor patient status and intervene with various treatments [77]. As the care is highly algorithmic, it is amenable to decision support [78]. One study found that HIV clinical reminders delivered at the time of care was associated with more timely initiation of recommended practices [79]. Another concluded that when alerts and reminders were linked to patient's record, adherence to HIV practice guidelines increased [80].

The literature exhibits discrepancies in regards to the proven effectiveness of clinical reminders on patient outcomes and physician behavior. While there have been systems that show improvements [75, 76, 81, 82, 83, 84, 85], others show little to no effect [86, 87, 88, 89]. Moreover, adherence to an individual system has been shown to vary across clinics, providers and reminders [90]. Much of this research focuses on if a system worked (increased adherence to guidelines, changed patient outcomes, etc.) rather than what properties (format of reminder, delivered at point of care, etc.) contributed to success or failure. Essentially, we cannot extract important decisions the implementers made.

A systematic review of the effectiveness of reminders on provider behavior by Shojania et al. [91] reaches a similar conclusion. While stating that no specific features were associated with improvements, the authors admit a major limitation – "the heterogeneity of the interventions and the variable degree with which they were reported, including limited descriptions of key intervention features of the reminders and the systems with which they were delivered". That is, much of the work evaluating reminders report success or failure without describing how the properties of the reminders affected improvements in care. The authors go on to say that "there are no 'magic bullets'...future research will need to identify key factors that reliably predict larger improvements in care".

Narrowing the scope of the research to low-income regions, we learn that summaries and reminders provably benefit HIV care. Were et el. in Uganda [92] note "efficiency and quality of care can be improved through clinical summaries, even in settings with limited resources". The authors replicate and build on this success in Kenya [93] concluding that "summaries with computer-generated reminders significantly improved clinician compliance with CD4 testing guidelines in the resource-limited setting of Sub-Saharan Africa". So while key factors to success are likely context-sensitive, in Sub-Saharan Africa summaries and reminders show promise.

3.2.3 Barriers and Facilitators to Success

To guide successful implementation, research that identifies facilitators and barriers to adoption of reminders must be considered. That work, primarily by Patterson et al. [94, 95, 96], notes that limiting the overall number of reminders, improving integration of reminders into workflow, and adding the ability to document problems and receive feedback are critical to adoption. This mirrors recent work by Zheng et al. [97] who leverage usage data analysis of an existing clinical reminder system to create a more efficient user interface. For our research where paper-based records are the baseline, we look to work by Sittig et al. [98]. The authors note that improving the effectiveness of CDS interventions remains a grand challenge. They recommend summarizing patient-level information and filtering recommendations to the user.

This adds to the underlying theme of the importance of understanding context of the clinic, the provider, and the patient. While broad in scope, we use these recommendations and the broader work on clinical reminder systems to guide the design of our research.

3.3 Mobile Information Systems

As shown earlier, summaries and reminders must be delivered at the point of care to be effective. To ensure reliability, the ideal delivery device should be sensitive to power and connectivity challenges in Sub-Saharan Africa. To ensure providers feel comfortable with the system, the device should be easy to use and master.

The mobile phone holds much promise as this appropriate delivery device. Current phones have long lasting batteries and work well asynchronously. Moreover, with mobile phone subscriptions in Sub-Saharan Africa growing at near-exponential rate [99], providers are likely familiar with mobile user interfaces. Building on these ideas, we use this section to explore mobile information systems that work in low-income regions. We focus on systems that have been used in healthcare.

3.3.1 Personal Digital Assistants

Historically, mobile information systems for low-income regions have been PDA-based. Early examples include a malaria morbidity survey tool in the Gambia [100], a Newton MessagePad-based device for nurse midwives in India [101], a tool to monitor tuberculosis lab results in Peru [102], decision support for paramedics in India [103] and Epihandy [104, 105], a generic data collection system. As the technology matured, Pendragon Forms [106], a commercial solution came to dominate the space. Pendragon-based systems have been used for tuberculosis result collection in Peru [107], surveying in Tanzania [108] and assessing health outcomes in Kenya [109].

In work with PDAs and HIV, there has been a focus on how appropriate the technology is. Kurth et al. [110] suggest that PDAs may be a culturally appropriate way to support ART adherence and safer sex for patients living with HIV/AIDS in Peru. This is in contrast with work from Cheng et al. [111] whose results suggest that using PDAs for data collection in Angola may have led to biased reports of HIV/AIDS-related risk behaviors. As each study was context-specific, it is hard to generalize the results.

For broader understanding of the role PDAs can play in this domain, we note Lu et al. [112] who state that "most care providers found PDAs to be functional and useful in areas of documentation, medical reference, and access to patient data. Major barriers to adoption were identified as usability, security concerns, and lack of technical and organizational support." As PDAs are no longer widely available, we must apply these lessons to newer mobile technology.

3.3.2 Basic Phones

While touchtone and speech-based systems used on basic phones have shown promise for delivering information in Pakistan [113], providing health surveillance in Peru [114], and data collection in India [115] and Uganda [116], they have not been shown to enable the rich data presentation and interaction we wish to enable with reminders.

Similar constraints exist of Short Message Service (SMS)-based systems. Examples of these include FrontlineSMS [117] and RapidSMS [118, 119]. The strength of these platforms is the wide availability of SMS service and the low cost of basic phones. For our research, SMS is unreliable and expensive as a transport mechanism and is impractical for transferring large amounts of data needed [120] deliver clinical summaries and reminders.

3.3.3 Feature Phones

Feature phones add more programmability to basic phones and are typically built on Java Platform, Micro Edition (J2ME). Data collection clients like FrontlineForms [121], EpiSurveyor [122], OpenXData [123], and JavaRosa [124] have become powerful tools as improvements in mobile technology have trickled down to lower cost phones [125]. In the healthcare domain, there have been tools for viewing patient information [126], providing neonatal [127] or community health worker [128, 129] support. Despite this, there are challenges with feature phones.

Commonly equipped with small screens, slow processors and inadequate memory, feature phone hardware can be quite limiting for the large amounts of data needed to enable this research. Feature phone applications must often be certified by the vendor, carrier, or manufacturer before interactions with storage, networking, or hardware accessories are usable. Without the appropriate certificates, users are prompted with confusing dialogs before every such action. Even after signing authority is obtained, using images, audio, video, and location remains difficult because each device implements the interface to its underlying hardware differently. J2ME programmers are forced to test every software release on each physical device they wish to support – a requirement that nullifies the benefit of a wide phone base.

These tradeoffs must be deeply considered. For example, Parikh et al.'s CAM [130] and Froehlich et al.'s MyExperience [131] demonstrated exciting possibilities of mobile information systems, but were hampered by the limitations of their chosen platforms.

3.3.4 Smart Phones

Hartung et al.'s [32] work on Open Data Kit [132] presents a convincing case that modern smart phones and cloud infrastructure enables better mobile information systems in low-income regions. Smart phones, although more expensive than feature phones, provide more functionality.

(a) Patient search in ODK Clinic. (b) Patient weight in ODK Clinic.

Figure 4: Open Data Kit has been modified to connect to OpenMRS. With these modifications, providers view patient data.

In the high-income regions, there are systems like Epocrates [133] and WebMD [134] for clinical reference, AirStrip [135] for critical patient information, and Haiku [136], SmartPHR [137], Mobile Health Viewer [138] to connect to medical record systems. These systems primarily run on the iOS [139] and Android [140] platforms which leverage advanced programming interfaces, fast processors, large amounts of RAM, high speed wireless connectivity, and a wide variety of form factors. As with much of the previous work, these smart phone systems are generally tied to expensive and proprietary servers and have not been designed or deployed in low-income regions.

More appropriate examples include Sana's telemedicine platform [141] and Android OpenMRS, a distributed phone-based medical record system [142]. Applicable to clinical summaries and reminders is work we have done with form filling and patient record syncing in ODK Clinic [143]. In this application, providers download a customizable patient list and view each patient's entire record. There is also support for patient search (shown in Figure 4(a)) and viewing data like lab results (shown in Figure 4(b)). While ODK Clinic is conceptually sound, it does not deliver clinical reminders nor has it been deployed in a clinical setting. Our goals are to build on this existing work and rigorously evaluate its efficacy.

4 Proposal

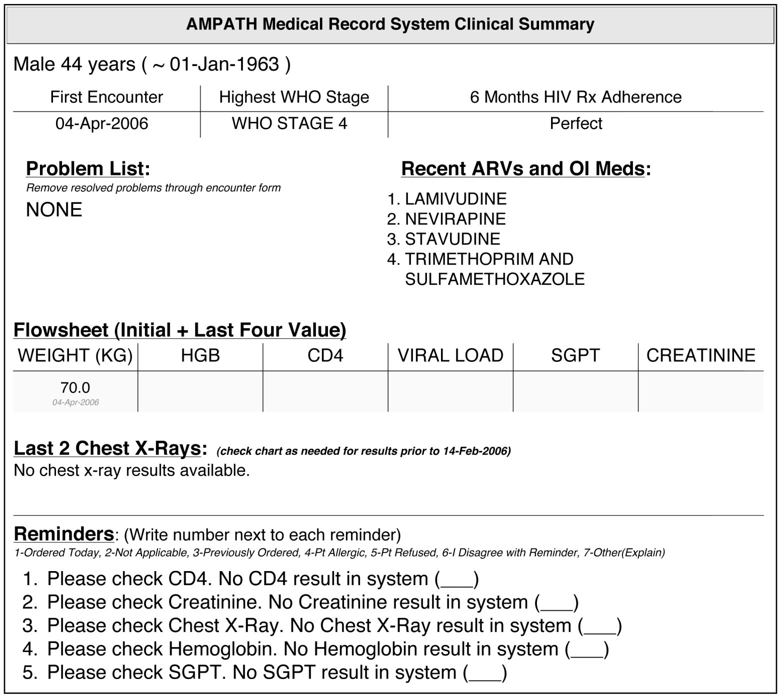
Effectively designing, implementing, deploying and evaluating a clinical summaries and reminders system is a challenging research problem. As context is key to success, the studies described below will be performed only after thorough mapping and analysis of workflows at each clinic. Additionally, our work will build on experiences generating clinical summaries in OpenMRS for PIH and collecting and delivering data on mobile devices using Open Data Kit.

The proposed studies will be conducted at AMPATH in Kenya with the help of their providers, researchers and programmers. The results will be used by AMPATH to determine how they deploy clinical summaries and reminders.

4.1 Reliably Deliver Summaries and Reminders to Phones

AMPATH clinics generate a patient summary with important information from the patient record. This example shown in Figure 5, has the patient's recent data and includes reminders for providers. The summary is generated when the patient arrives at the clinic and is placed in the patient's chart before being seen by the provider.

The problem with this approach is the availability of the data at the point of care. Work by Were et al. [93] at AMPATH showed that "39% of the patient visits, the summaries with reminders were inadvertently not printed...mostly because the computer or printer in the clinic was not working." Work by Noormohammad



AMPATH Medical Record System Clinical Summary

Male 44 years (~ 01-Jan-1963)

First Encounter	Highest WHO Stage	6 Months HIV Rx Adherence
04-Apr-2006	WHO STAGE 4	Perfect

Problem List:
Remove resolved problems through encounter form
NONE

Recent ARVs and OI Meds:
1. LAMIVUDINE
2. NEVIRAPINE
3. STAVUDINE
4. TRIMETHOPRIM AND SULFAMETHOXAZOLE

Flowsheet (Initial + Last Four Value)

WEIGHT (KG)	HGB	CD4	VIRAL LOAD	SGPT	CREATININE
70.0 04-Apr-2006					

Last 2 Chest X-Rays: *(check chart as needed for results prior to 14-Feb-2006)*
No chest x-ray results available.

Reminders: (Write number next to each reminder)
1-Ordered Today, 2-Not Applicable, 3-Previously Ordered, 4-Pt Allergic, 5-Pt Refused, 6-I Disagree with Reminder, 7-Other(Explain)

1. Please check CD4. No CD4 result in system (___)
2. Please check Creatinine. No Creatinine result in system (___)
3. Please check Chest X-Ray. No Chest X-Ray result in system (___)
4. Please check Hemoglobin. No Hemoglobin result in system (___)
5. Please check SGPT. No SGPT result in system (___)

Figure 5: An example medical record system clinical summary with problem lists, flowsheet and reminders.

et al. [144] at AMPATH suggest that reminders displayed on a computer terminal or delivered to a mobile device should be considered. It is on Were et al.'s experiences and Noormohammad et al.'s recommendations that leads us to the following hypothesis.

> **Hypothesis** – *A mobile device with clinical summaries and reminders will be more consistently available at the point of care than a printed page with the same information. Providers using the mobile device will be more likely to comply with testing guidelines of important indicators.*

To test the hypothesis, we will hold a controlled trial at three randomly-selected adult clinics from AMPATH. First, we will measure baseline order rates for CD4 cell count and other important indicators one month prior to the intervention. At the end of that month, each clinic will be assigned to either a Paper, Paper+Phone or Phone group. For the next month, when an adult HIV-positive patient presents for a return visit at a clinic, a patient summary report with reminders will be generated. The report will be printed and placed at the front of the patient's paper chart along with an encounter form. These will be made available to Paper and Paper+Phone clinics. We expect 4500 patients will present for a visit at the clinics.

Providers at the Paper+Phone and Phone clinics will be given a mobile phone which will connect to the clinic's EMR. The phone will attempt to fetch all summaries and reminders for patients who have had encounters at the clinic. Both the phone and EMR will be instrumented to determine which patient records are accessed. When the patient encounters a provider in the Paper+Phone clinic, the provider will have the choice to use the phone and/or paper to review the downloaded summaries and reminders. Providers in the Phone clinic, will use only the phone.

At the end of each encounter, providers must complete an encounter form. The forms will be modified to ask the provider which method, if any, was used to access summaries and reminders. At the end of the month, we will stop the intervention and measure lab order rates for another month.

We will use the data in the encounter forms and the instrumented phones and EMR to test our hypothesis. While our goal is to demonstrate that the mobile device is more available, we will also measure provider compliance with CD4 cell count and other indicator testing guidelines. We will measure the difference between ordering rates before, during and after the intervention. In the case of the Paper+Phone group, we believe that having both modalities available will result in the greatest compliance. That is, the phone will be more available, but the paper will be more familiar and thus more preferable to the providers.

4.2 Create Phone-Based Flowsheet for Patient Data

In addition to reliably delivering summaries and reminders, we wish to enable the exploration of the underlying data. Access to this data is important because for providers to act, they often need historical or circumstantial data. Such data is often complex and extensive, it must be organized before it is useful.

Traditionally, providers use paper-based flowsheets to organize this data. As explained by Brown et al. [145] document contains "data elements arranged on a grid – with time along the Y-axis and data elements such as laboratory values...vital signs, etc. along the X-axis." Brown et al. argue that by bundling the data, the flowsheet (as shown in Figure 6) helps clinicians quickly assimilate patient information.

We have argued for the potential benefits of a mobile device, but it is not clear that mobile devices can match the familiarity and information density of paper. We believe many of these tradeoffs can be captured in how quickly providers can reach clinical decisions. For that reason, we propose testing the following hypothesis.

> **Hypothesis** – *Providers will reach a decision about a patient's 'next steps' more quickly using an phone-based flowsheet than with a paper-based flowsheet. Decisions made with an phone-based flowsheet will result in indicator testing rates which are no worse than the paper-based alternative.*

Vitals	14-Apr 07.15	14-Apr 03.32	13-Apr 23.43	13-Apr 21.20	13-Apr 14.58	13-Apr 11.56	Units
Temp	98.5	98.4	98.3	**99.9**	**100.1**	**100.2**	degrees F
Heart Rate	95	94	**102**	**102**	**104**	**109**	beats/ min
Resting Rate	20	20	20	20	20	20	beats/ min
BP Systolic	119	107	108	104	116	114	mm_Hg
BP Diastolic	88	58	62	67	51	59	mm_Hg

Figure 6: An example medical record system flowsheet with vital signs from a patient.

4.2.1 Feasibility Study

To test the hypothesis, we will hold a lab-based study at AMPATH. The study will be based on a small but representative sample of HIV scenarios found in AMPATH's network. Each scenario will build on a set of anonymized encounters from an actual patient.

We will provide the encounters as a set of paper forms to representative providers chosen by AMPATH. Providers will be randomly assigned to two groups, A and B. Group A will receive the paper forms and a paper-based flowsheet. Group B will receive the paper forms and a phone-based flowsheet. Providers will have a chance to practice a few encounters with their assigned flowsheet.

Based on only the information on the flowsheet and paper forms, the providers will decide and document what the patient's next steps are. Providers will be asked to return three weeks after the initial trial to perform a second trial. In this trial, Group B will use the phone-based flowsheet while Group A will uses the paper-based version.

At the end of the study, we will use timing data to test our hypothesis. We will measure correctness as determined by World Health Organization (WHO) guidelines.

4.2.2 Field Study

To further test the hypothesis, we will hold a controlled trial at three randomly-selected adult clinics from AMPATH's network. We expect 4500 patients will present for a visit at the clinics.

First, we will measure baseline order rates for CD4 cell count and other important indicators one month prior to the intervention. At the end of that month, each clinic will be assigned to either a No Paper, Paper or Phone group. The paper flowsheet will be what AMPATH traditionally gives providers. The phone-based flowsheet will enable providers to view all historical data in the patient's record. For the next month when an adult HIV-positive patient presents for a return visit at a clinic, providers will use the appropriate flowsheet. In the case of the No Paper clinic, providers will have no flowsheet.

At the end of each encounter, providers must complete an encounter form. The forms will be modified to ask the provider which method, if any, was used to access the flowsheet. At the end of the month, we will stop the intervention and measure CD4 cell count and other indicator testing guidelines for another month.

We will use the data in the encounter forms and the instrumented phones and EMR to test our hypothesis. While our goal is to demonstrate that the mobile device is more available, we will also measure provider performance and acceptance. We believe the presence of a mobile device will increase compliance with CD4 cell count and other indicator testing guidelines. To determine this, we will measure the difference between ordering rates before, during and after the intervention. Acceptance will be determined through surveys of the providers.

4.3 Timeline

Below is a timeline which describes the different phases of this dissertation. Graduation will be scheduled for Spring 2012, approximately seven quarters from the date of the General Exam. Results from studies will the targeted for CHI, AMIA, ICTD and DEV and co-authored with collaborators at AMPATH.

- **Autumn 2010**: Finish analysis of existing HIV summaries and reminders system at AMPATH clinics. Begin testing of high-fidelity summaries and reminders prototype with experts at AMPATH. Implement system for reminders study outlined in Section 4.1.
- **Winter 2011**: Setup and conduct reminder study from Section 4.1 at AMPATH. Design and field-test high-fidelity prototype for phone-based flowsheet system.
- **Spring 2011**: Implement system for flowsheet study outlined in Section 4.2. Begin testing of system with AMPATH. Integrate reminder system with flowsheet system.
- **Summer 2011**: Conduct flowsheet study proposed in Section 4.2 at AMPATH. Integrate flowsheet system with encounter form system.
- **Autumn 2011**: Conduct any follow up studies.

- **Winter 2012**: Finish remaining analysis and research.

- **Spring 2012**: Prepare dissertation and defend.

5 Conclusion

Despite the effective use of computerized clinical summaries and reminders in high-income countries to increase the quality of care, the difficulties of implementing and deploying such systems in low-income countries have hindered their adoption. To become viable in these settings, clinical summaries and reminders systems must reliably deliver information while enabling healthcare providers to explore relevant data.

In this paper, we have explained the need for summaries and reminders and how they might increase the efficiency of care. We have discussed the challenges similar systems have overcome and how those lessons learned apply to the context of providers in Sub-Saharan Africa. Finally, we described the development and evaluation of a phone-based clinical summaries and reminder system designed to increase the quality of HIV care in Sub-Saharan Africa. We hope the results of this proposed work provides insight to the many organizations caring for the HIV patients the world over.

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