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Design and implementation of an affordable, public sector electronic medical record in rural Nepal

Anant Raut, MS[1,*], **Chase Yarbrough, MD**[1,2,3,*], **Vivek Singh**[4], **Bikash Gauchan, MBBS, MD-GP**[1], **David Citrin, MPH, PhD**[1,5,6,7], **Varun Verma, MD**[8,9], **Jessica Hawley, MD**[10,11], **Dan Schwarz, MD, MPH**[1,2,3], **Alex Harsha**[1,12], **Biplav Shrestha, MBBS**, **Ryan Schwarz, MD, MBA**[1,2,13,14], **Mukesh Adhikari**[15], and **Duncan Maru, MD, PhD**[1,2,3,13]

[1]Possible, Bayalpata Hospital, Sanfebagar-10, Achham, Nepal

[2]Brigham and Women's Hospital, Department of Medicine, Division of Global Health Equity, Boston, MA, USA

[3]Boston Children's Hospital, Department of Medicine, Division of General Pediatrics, Boston, MA, USA

[4]ThoughtWorks India, Bengaluru, Karnataka, India

[5]University of Washington, Department of Anthropology, Seattle, WA, USA

[6]University of Washington, Department of Global Health, Seattle, WA, USA

Correspondence: Duncan Maru, MD, PhD, Division of Global Health Equity, Brigham and Women's Hospital, 75 Francis Street, Boston, MA. 02115, duncan@possiblehealth.org.

*Indicates co-first authors.

AUTHOR CONTRIBUTIONS:

Designed the EMR system: AR, CY, VS, DC, DM
Implemented the EMR system: all authors
Conducted focus group discussions: AR, DC, CY
Analyzed data and evaluated the EMR system implementation: AR, CY, DC, DM
Contributed to writing the manuscript: AR, CY, DC, DM
Reviewed manuscript and critically revised content: all authors
ICMJE criteria for authorship read and met: all authors
Agree with manuscript results and conclusions: all authors

CONFLICT OF INTEREST STATEMENT:

AR, BG, BS, and DC are currently employed by a nonprofit healthcare company (Possible) that delivers free healthcare in rural Nepal using funds from the Government of Nepal and other public, philanthropic, and private foundation sources. CY, DS, RS, AH, and DM all work in partnership with Possible and VV and JH worked in partnership with Possible at the time of electronic health record implementation. CY, DS, and DM are employed at two academic medical centers (Brigham and Women's Hospital and Boston Children's Hospital) that receive public sector research funding, as well as revenue through private sector fee-for-service medical transactions and private foundation grants. DC is a faculty member and employed part time at a public university (University of Washington). VV is employed part time a non-profit medical center (Vassar Brothers Medical Center) that receives revenue from fee-for-service medical transactions and private foundation grants. VV also works in partnership with a venture-capital funded startup (Sutro Health), but receives no compensation for his work. JH is employed at an academic medical center (UCLA Medical Center) that receives public sector research funding, as well as revenue through private sector fee-for-service medical transactions and private foundation grants. JH is also faculty at a public university (UCLA). AH is a medical resident at a public hospital (Contra Costa Regional Medical Center), which receives revenue through fee-for-service medical transactions and other grants. BS was employed by Possible at the time of electronic health record implementation. RS is employed at two academic medical centers (Brigham and Women's Hospital and Massachusetts General Hospital) that receive public sector research funding, as well as revenue through private sector fee-for-service medical transactions and private foundation grants. MA is employed by the Government of Nepal. DM is a non-voting member on Possible's board of directors, but receives no compensation. DM is also a faculty member at a private university (Harvard Medical School). All authors have read and understood the Journal of Innovation in Health Informatics' Ethics and Publication Malpractice Statement, and declare that we have no competing financial interests. The authors do, however, believe strongly that healthcare is a public good, not a private commodity.

[7]University of Washington, Henry M. Jackson School of International Studies, Seattle, WA, USA

[8]Vassar Brothers Medical Center, Poughkeepsie, NY, USA

[9]Sutro Health, San Francisco, CA, USA

[10]UCLA Medical Center, Santa Monica, CA, USA

[11]David Geffen School of Medicine at UCLA, Department of Medicine, Division of Hospitalist Services, Los Angeles, CA, USA

[12]Contra Costa Medical Center, Martinez, CA

[13]Harvard Medical School, Department of Medicine, Boston, MA, USA

[14]Massachusetts General Hospital, Department of Medicine, Division of General Internal Medicine, Boston, MA, USA

[15]Ministry of Health, Department of Health Services, District Health Office, Mangalsen, Achham, Nepal

Abstract

Introduction—Globally, electronic medical records are central to the infrastructure of modern healthcare systems. Yet the vast majority of electronic medical records have been designed for resource-rich environments and are not feasible in settings of poverty. Here we describe the design and implementation of an electronic medical record at a public sector district hospital in rural Nepal, and its subsequent expansion to an additional public sector facility.

Development—The electronic medical record was designed to solve for the following elements of public sector healthcare delivery: 1) integration of the systems across inpatient, surgical, outpatient, emergency, laboratory, radiology, and pharmacy sites of care; 2) effective data extraction for impact evaluation and government regulation; 3) optimization for longitudinal care provision and patient tracking; and 4) effectiveness for quality improvement initiatives.

Application—For these purposes, we adapted Bahmni, a product built with open-source components for patient tracking, clinical protocols, pharmacy, laboratory, imaging, financial management, and supply logistics. In close partnership with government officials, we deployed the system in February of 2015, added on additional functionality, and iteratively improved the system over the following year. This experience enabled us then to deploy the system at an additional district-level hospital in a different part of the country in under four weeks. We discuss the implementation challenges and the strategies we pursued to build an electronic medical record for the public sector in rural Nepal.

Discussion—Over the course of 18 months, we were able to develop, deploy and iterate upon the electronic medical record, and then deploy the refined product at an additional facility within only four weeks. Our experience suggests the feasibility of an integrated electronic medical record for public sector care delivery even in settings of rural poverty.

Keywords

electronic medical records; implementation research; global health; Nepal; open source technologies; health systems strengthening

INTRODUCTION

The digitization of healthcare delivery systems is a pressing global need, including in settings of poverty (1, 2). The opportunity costs of continuing with paper systems are significant. The absence of electronic medical records (EMRs) can hamstring already challenging efforts to transform human resource management, financial accountability, healthcare systems performance evaluation, public health surveillance, and longitudinal care delivery systems (3, 4). Paper-based systems are human resource- and time-intensive, and are often plagued by inaccurate reporting processes leading to out-of-date and irrelevant data (3–5). An effective EMR is an essential component of a robust and efficient modern healthcare system (3, 6, 7).

Despite the strong evidence that adoption of health information technology leads to improved care (8, 9), only recently have wealthy countries started to see widespread adoption (10). Low- and middle-income countries face additional challenges such as a lack of engineering and other technical expertise, limited funding, poor information technology infrastructure, and unreliable power (2, 11). Indeed, many hospital information systems that have been successfully implemented in resource-poor countries tend to be focused on specific clinical diseases rather than care integration (12), and there are only limited descriptions of such integrated systems (13).

Even the most sophisticated and well-funded systems have achieved greater success in data recording, research, and program evaluation than in creating a tool that physicians can refer to during a clinical encounter (2, 14). Although there have been efforts to address these challenges (14–17), successful implementation of integrated EMR systems, particularly those that are actively used by healthcare providers during clinical encounters, has been an elusive goal.

DEVELOPMENT

Possible, a non-profit healthcare organization, started in June 2014 to customize and deploy an EMR system appropriate for the Nepali public sector healthcare system. *Possible* works on a public-private partnership model with the Ministry of Health in rural Achham District in the Far-Western Development Region. There, *Possible* independently manages the government-owned, district-level Bayalpata Hospital and implements community healthcare delivery programs. Bayalpata Hospital has 25 beds, and sees approximately 60,000 outpatients and 2,000 inpatients per year. Patients are seen by physicians and health assistants, a mid-level non-physician provider role common throughout Nepal.

We originally identified the following key needs as central to developing an EMR: to be simple for physicians and mid-level providers, to improve government reporting, to decrease wasteful expenditures on unnecessary medications, to use the EMR for healthcare services research, and to advance quality improvement initiatives. After some review and deliberations in the first months of 2014, *Possible* selected *ThoughtWorks*' (Chicago, USA) Bahmni system as its design characteristics were suited to the on-the-ground realities of Achham (Box 1).

Box 1

DESIGN CHARACTERISTICS

Longitudinal care	The product needs to be designed to enhance the goal of improved longitudinal care, including both patient tracking and performance quality monitoring. Simple disease management protocols and data tracking should be modularized and accessible within the system.
Cross-Site Integration	The product should be integrated from the hospital, where human resource, electricity, and internet capacity are all substantial, to the primary clinics which are severely resource-constrained, to patients and community health workers, who would interface with the product on mobile devices.
Scalability	In everthing we do, we have to design for scale. This is particularly true because there is a strong push for us to expand the idea of pubic-private partnerships where the government is a payer and regulator and Possible is the direct implementer. If the technology can't ultimately be scaled at a national level, then it is not worth the effort.
Simplicity	The tool should be elegant and simple for the user, designed for a healthcare provider with minimal computer literacy.
Reliability	Patients will suffer needless delays in care if the system is not exquisitely reliable in the setting in which the product is deployed.
Offline capability	The product needs to be online/offline capable, or at least intranet-capable, since, while Possible can get computers electricity 95% of the time, the internet (despite serious investments) is only 85% at best.

Bahmni (http://www.Bahmni.org) is an open source framework built as a javascript application on top of the OpenMRS (http://www.openmrs.org) data model and application program interface. Bahmni uses OpenERP (https://www.odoo.com/) for billing and inventory management and OpenELIS (http://www.openelis.org/) for laboratory management. *ThoughtWorks* has been developing Bahmni over the last four years for deployments in India, Uganda, Haiti, and other countries. We provide a diagram of the system architecture as supplemental material (See Supplemental Figure 1).

A primary innovation of the Bahmni system is that it provides a stripped-down user-friendly interface for the robust and widely-used OpenMRS architecture. In a resource-limited setting such as rural Nepal, most providers have had limited prior exposure to computers or EMR systems. A well-tuned user-experience without non-essential features is thus of critical importance for providers to be able to use the EMR at the point of care without feeling overwhelmed. Workflow efficiency in the outpatient department is paramount, since Bayalpata Hospital can care for over 600 outpatients per day during peak seasons (Figure 1). *Possible* uses the EMR in the inpatient department for bed management, drug administration, laboratory orders and results review, progress notes documentation, and discharge planning and documentation. In the operating theaters, *Possible* uses the EMR to document operative notes.

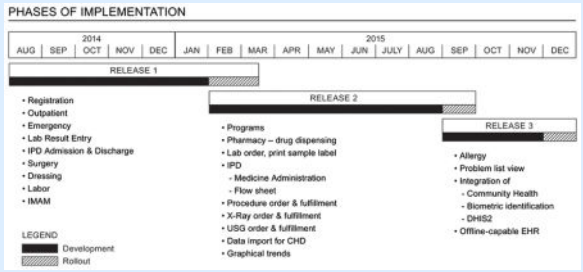
APPLICATION

Bayalpata Hospital EMR Implementation

Electronic medical record implementation necessarily took place in a phased manner (Box 2). In preparation for the initial rollout of Bahmni at Bayalpata Hospital, a team from *ThoughtWorks* came to the hospital and together with a staff trainer, trained the doctors,

mid-level providers, nurses, and registration staff over a period of two weeks in July of 2014. Over the subsequent six months, we undertook several off-site and on-site design iterations and planning sessions. On February 10, 2015, Bahmni went live at the hospital with the patient registration module. The EMR was deployed to the laboratory and outpatient departments over the following week. This phased rollout allowed the deployment team to adequately support each department during the initial stage. Initially, providers were only required to enter diagnoses for patients, but over the course of time, these providers became able to review medical history and lab results, enter vitals, fill out notes, order lab tests, and prescribe medications from within the EMR.

Box 2



Providers access the EMR on touchscreen Chromebooks made available at all points of care. Chromebooks were chosen because they are low-maintenance, inexpensive (below USD $300) and ideal for browser-based applications like Bahmni. Clinical notes have been designed to take advantage of the touchscreen functionality through use of buttons where possible for quick data entry. Unlike with electronic tablets, a physical keyboard is available when typing is required (see Supplemental Figures 2, 3a and 3b).

EMR Response and Challenges

We conducted individual focus group discussions with three different participant groups—doctors, mid-level providers, and nurses—three months after the deployment of the first phase. Five doctors, thirteen mid-level providers, and twelve nurses participated in the focus groups. We held a discussion with each group that began with directed questions and ended with open discussion. Participants also completed an anonymous survey with questions scored on a scale from one to ten, as well an area for free-text comments (Supplemental Table 1).

Overall, the respondents described the EMR as a useful tool that improved the hospital, and had the potential for making their work easier in the future. The focus group discussions and free-text responses, however, elicited several challenges. The doctors expressed concerns that introducing a computer into the room distracted from building the patient-provider relationship. The mid-level providers and doctors raised the issue that the EMR led to extra documentation time; when the power went out, they were forced to document encounters on paper and again later in the EMR. The nursing focus group revealed that there was some confusion about documentation responsibilities, and what the nurses were responsible for

documenting. Many participants expressed challenges that parallel those of others working with EMRs in wealthier countries (18, 19).

An anticipated challenge, and one that was persistently difficult to mitigate, was regulating the server room's temperature. The servers require maintenance of temperatures below 23 degrees centigrade, yet during the summer months, ambient temperatures frequently reach 35 degrees. This required installation of air conditioner – heater systems that have significant power needs. Like many district hospital systems, at the time of pre-deployment the hospital was already operating beyond its electric power capacity. This issue caused occasional EMR down-times, which challenged clinicians' faith and patience with the system. Bayalpata Hospital addressed these issues with ongoing investments in grid improvements, solar power, generators, battery backups, and more effective load balancing. It was difficult, however, to keep up with the demands on reliable electricity throughout the roll-out period.

Human resource management and training have also been core challenges. Most of the end-users had only minimal exposure to computers, and no prior experience with EMRs. Initially, users voiced some discontent about an increased time investment per patient. Becoming adept at the EMR system, and to the computers themselves, took focus and time away from the patient. *Possible* designated a staff physician as the lead clinical point-person to help coordinate trainings, make announcements on system changes, and gather feedback and suggestions from the care delivery team on how to improve the functionality and interface. The use of a champion from within the clinical staff helped with encouraging, processing, and utilizing feedback from frontline providers. Over several months, the clinicians developed significant improvement in their ability to efficiently navigate Bahmni.

Following this model, *Possible* selected focal personnel from different departments within the hospital (e.g., nursing, surgery, mental health, and pharmacy) to form an EMR-focused clinical informatics team at Bayalpata Hospital. This team meets quarterly to discuss ways to further optimize the EMR. Additionally, Bahmni and the OpenMRS development community have created a system and culture responsive to user feedback, and as a result, *ThoughtWorks* continues to enhance the user interface to make Bahmni as intuitive and efficient as possible. In order to take full advantage of the EMR system, work still remains to educate providers, habituated in paper-based systems, to write good notes and use the data for better clinical decision-making.

EMR Refinement

Constant iteration is necessary in these early implementation phases to optimize the system for usability and utility, ensuring that the EMR is providing increasing value to patient care, and meaningful data for program management, evaluation, and quality improvement. Our focus thus far has been on setting up a simple yet robust EMR system, and building end-user capacity to take advantage of the system. Our efforts at monitoring and evaluation have centered on increasing EMR use and improving data quality. To this effect, we measure indicators such as "percent of patients who were discharged without a discharge note in the EMR" and "percent of outpatients without a treatment plan documented" (see Supplemental Figure 4). We also review manually-entered, non-coded diagnoses and perform daily data

quality sweeps. These efforts continue in earnest as we are increasingly using the system to monitor indicators directly related to patient care, and patient experience; e.g., we are currently refining our approach to measuring outpatient cycle time and care-to-wait-time ratios using time-stamped data pulled from the EMR in a quality improvement dashboard (see Supplemental Figure 5). Using data generated from the EMR, we have rolled out indicators that monitor chronic disease-specific quality metrics, for example, blood pressure, glycosylated hemoglobin (HbA1c), and CD4 targets.

Improvement in stock management at both the supply chain- and facility-levels are significant advantages of the EMR. The digital platform allows us to monitor the requisition and movement of medicines and other consumables, and flexible reporting systems enable quality improvement efforts (see Supplemental Figure 6). For example, we measure stock out and maintenance rates, as well as the percentage of essential medicines received from the government. At Bayalpata Hospital, drug orders by providers are sent directly to the pharmacy for dispensing, saving patients time, and orders are then automatically deducted from hospital inventory.

Replication and Scale

A major rationale for the OpenMRS-based Bahmni system was that it is affordable (see Supplemental Table 2) and designed for the types of providers found among public healthcare institutions in South Asia. From the beginning, *Possible* engaged government partners at the local and national levels. Indeed, using an OpenMRS-based system like Bahmni was itself predicated on the Ministry of Health's commitment to OpenMRS as the back-end program for its healthcare system. This engagement requires constant dialogue, as there are frequent shifts at the leadership levels within the Ministry. Policy priorities themselves have been dynamic, particularly after the devastating April 25 and May 12, 2015 earthquakes.

The national dialogue surrounding EMR standards and possibilities has been influenced by successful implementation of a full-service EMR in a rural district hospital, leading our government partners to wonder whether a similar system might be employed more broadly across government facilities. Subsequently, when *Possible* initiated a new public-private partnership at a district hospital in Dolakha, a district heavily affected by the earthquakes, *Possible* quickly and successfully deployed the EMR within four weeks.

The IT infrastructure required to host an open source EMR system like Bahmni requires initial investment in materials and expertise. In our experience, however, ongoing costs are much lower due to availability of remote support, the lack of licensing fees since we have used open-source software, a substantial OpenMRS design and implementation community on the web, and regional experts for maintenance of the system. These resources are available within Nepal, even in rural areas. Indeed, partly as a result of deployments in Achham and Dolakha, the government has made commitments to expand an OpenMRS-based EMR throughout the country, using private sector technology companies to deploy and maintain the systems.

DISCUSSION

We have successfully implemented an affordable, integrated EMR system at two public sector rural district hospitals in Nepal. Our initial deployments have proven acceptable to clinicians, technologically feasible, and compatible with the national healthcare information system. We are now refining and expanding the EMR and making preparations for scale.

Major implementation research questions remain, and future deployments of both Bahmni and other EMRs should incorporate more rigorous evaluation designs than were feasible in our case. In particular, a set of process measures should be incorporated, for example, measures of relative time per patient, provider and patient satisfaction, adherence to clinical protocols, delays in care delivery of particular aspects of the care process, and detection of errors in ordering or pharmacy. These metrics should aim to ask the iterative question of "how to continuously improve digitization of healthcare?" rather than posing static questions like "is this EMR better than paper, or better than another EMR?". This is because the development and selection of particular EMRs are contingent upon local markets, contexts, political, and social systems. Research is unlikely to shape the selection of one EMR over another. Rather, implementation research should help to develop a set of standards and best practices around the measurement of EMR performance. These evaluations will further the broad goal that EMRs can become affordable, acceptable ways of generating and presenting patient-level and population-level outcomes for quality improvement, health systems research, and public health surveillance systems. It is unquestionable, after all, that EMRs are part of the 21st century healthcare system; yet many open questions remain as to what that actually looks like.

Acknowledgments

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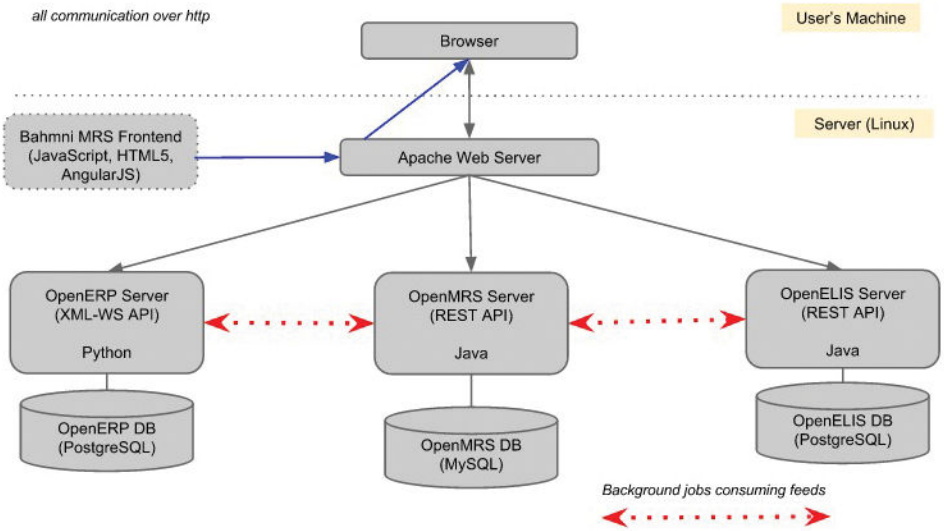
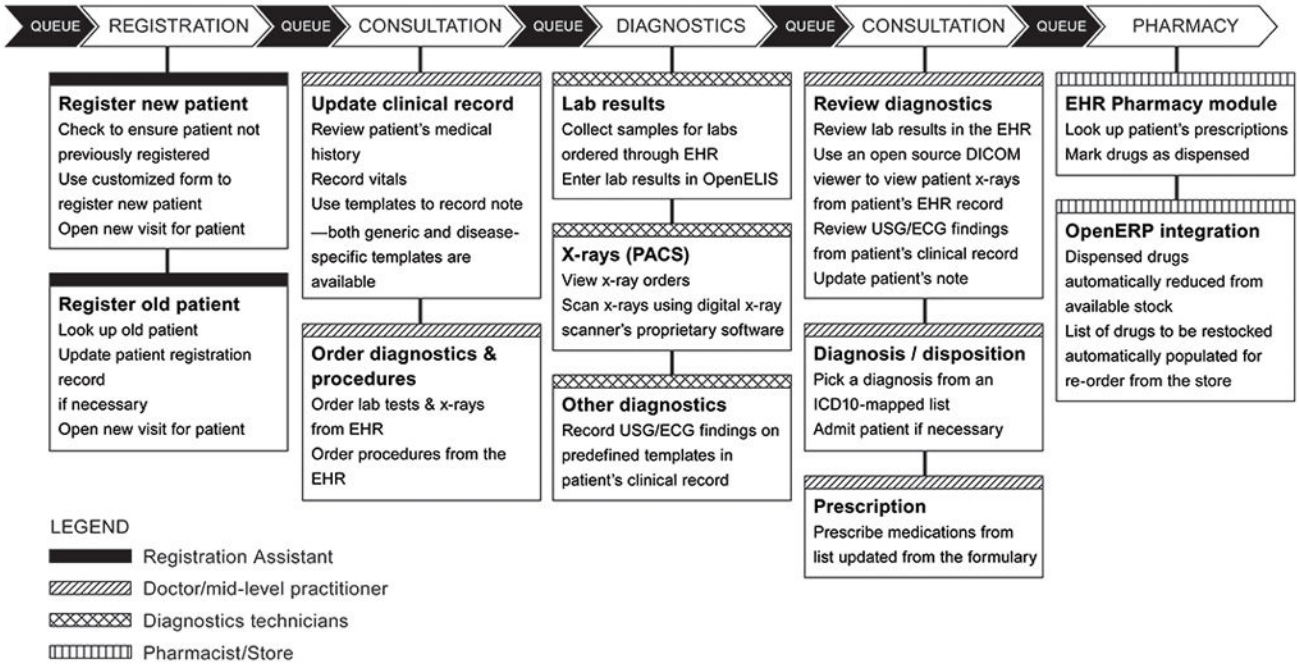
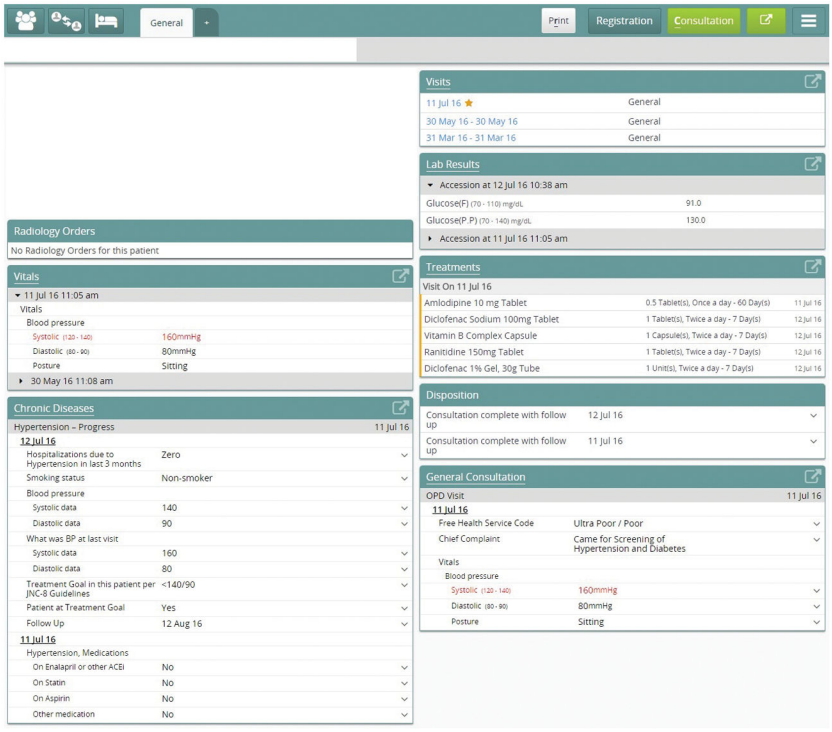
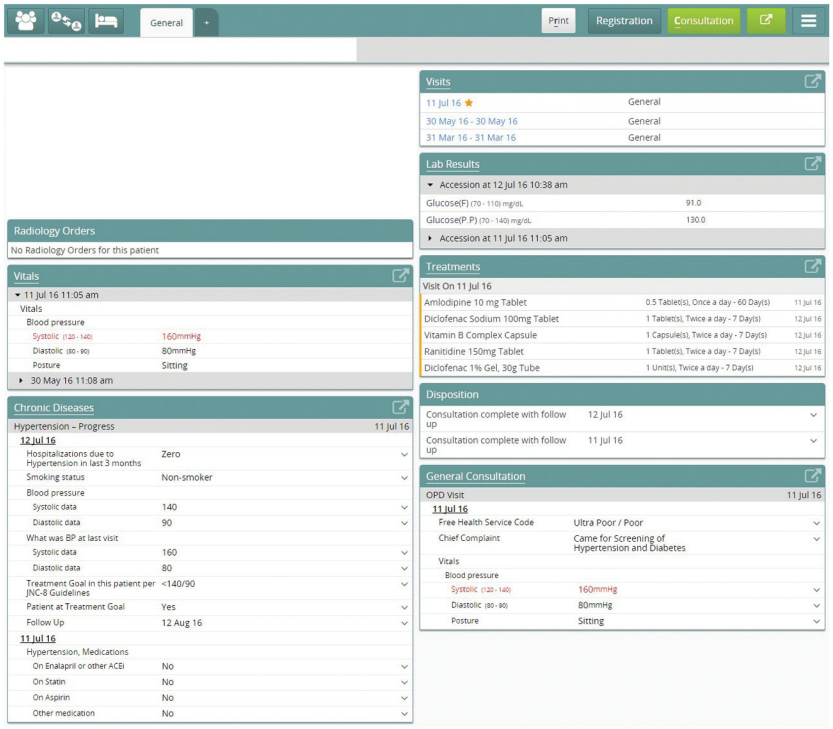


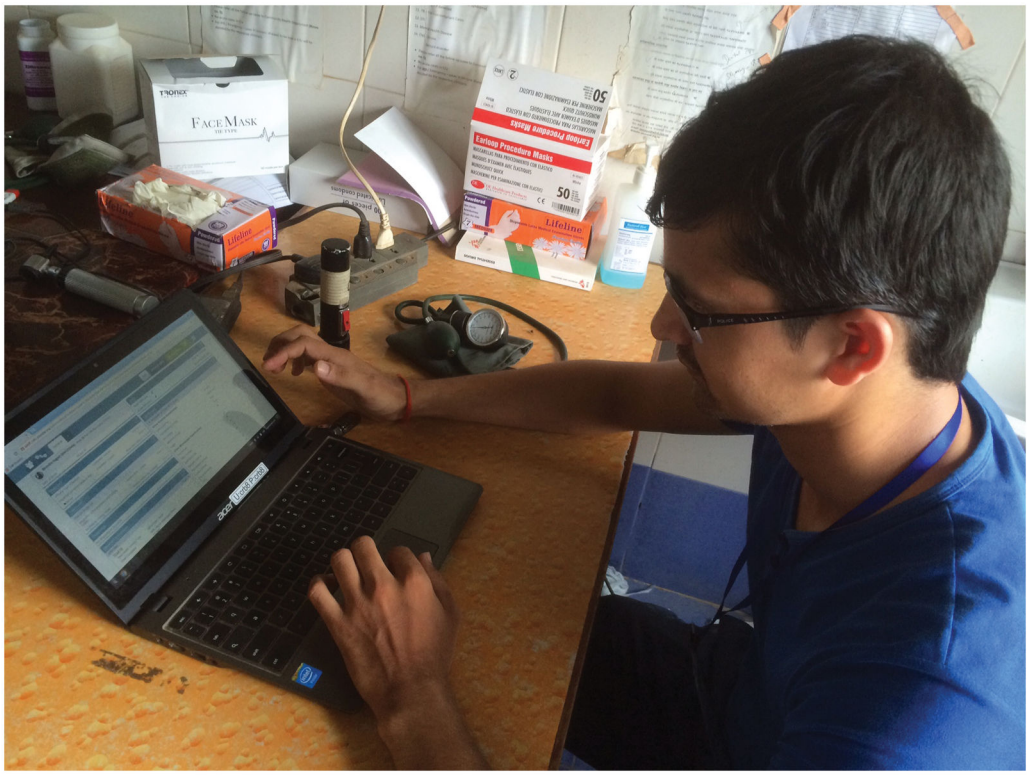
Supplementary Figure 1.



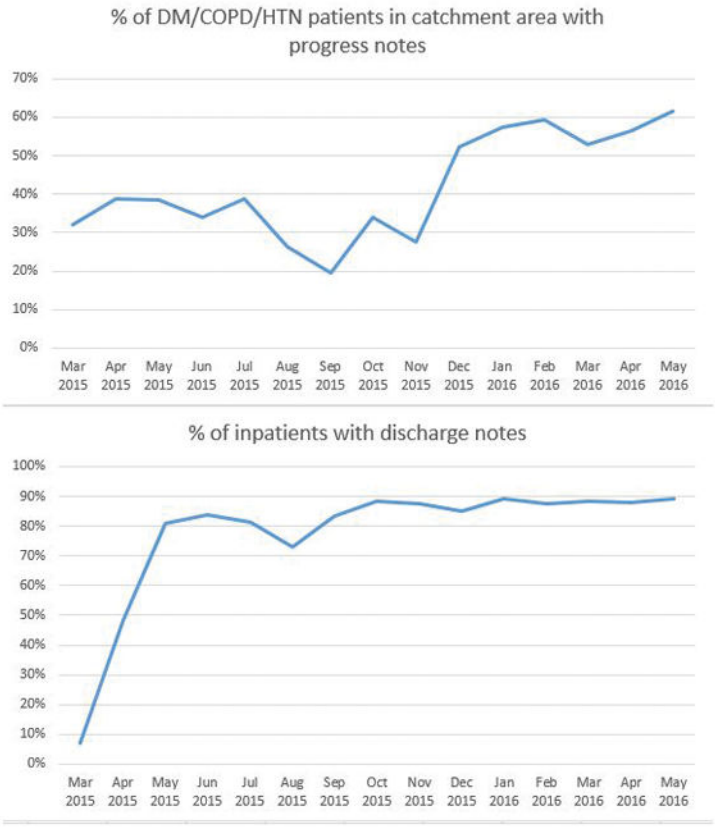




Supplementary Figure 2.



Supplementary Figure 3.



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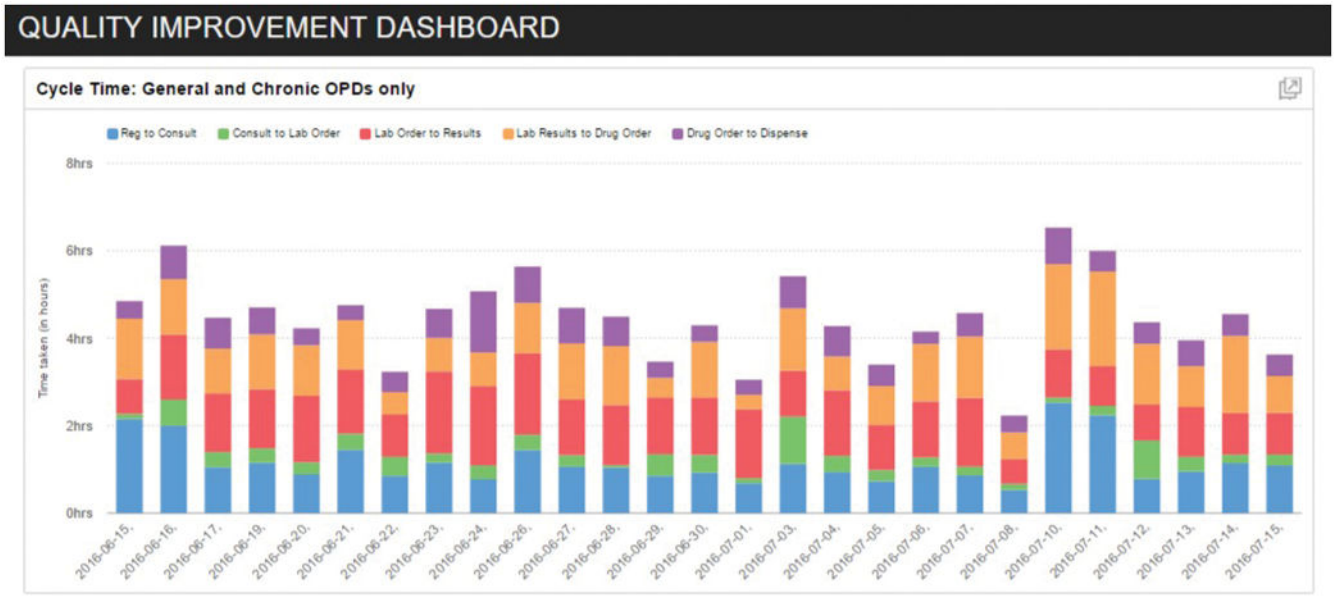
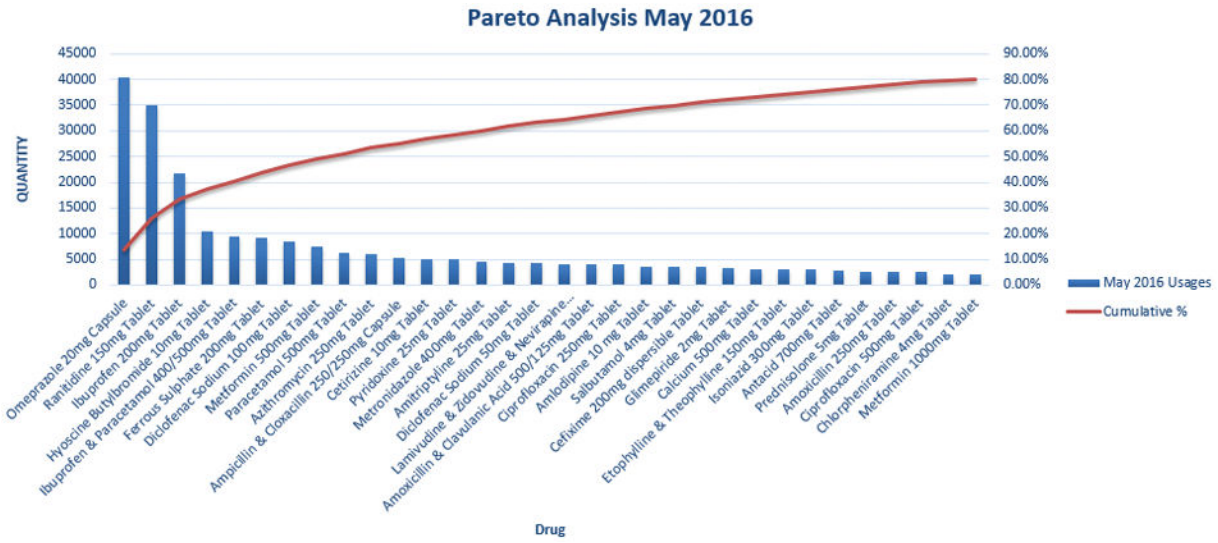


Supplementary Figure 5.



Supplementary Figure 6.

Supplementary Table 1

EHR Focus Group Survey Responses

Doctors, health assistants, and nurses were surveyed on their opinion of the EMR. There were eight questions scored on a scale of 1 to 10.

Question	Score (avg)
On a scale of 1 to 10, how useful is the EHR for you right now?	7.9
On a scale of 1 to 10, how useful could the EHR be for you in the future?	9.0
I feel competent using the EHR	7.9
I like using the EHR	8.9
The EHR makes my work more difficult	3.2
The EHR makes my work easier	8.4
The EHR will provide useful data that will improve patient care	9.1
The EHR is good for Bayalpata Hospital	9.4

Supplementary Table 2

#	ACTIVITY	DURATION	ESTIMATED COST
1	Development, customization, rollout	11 Months	$160,000
2	Travel (analysis and rollout)		$8,200
3	Post Production Support	1 Year	$10,000
4	Servers and networking		$32,000
5	Chromebooks (29@300)		$8,700
	TOTAL (Estimated.)		**$178,200**