MCH EMR Pilot Report

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SUMMARY

The Uamuzi Bora electronic medical record (EMR) has made health information available at different levels of the health service to inform clinical and public health decision-making for maternal and child health (MCH).

Given the short time period of the pilot it has only been possible to undertake a descriptive analysis of patients registered and to evaluate the impact of the EMR on data quality:

- 946 women, 206 deliveries and 302 children enrolled
- Average age of pregnant women 23.6 years
- Average of 1.9 clinic visits attended per pregnant woman during pilot period
- 0.2%, 4.7% and 14.0% of women confirmed TB, Malaria and HIV positive
- 50.4% HIV positive women receiving ART during pregnancy
- EMR verification of data reduced missing data by 66.3%

Further evaluation of the impact of the EMR on provision of care and retention in care will be undertaken at the end of the year. With knowledge of the above data, the EMR can now be used, for example, to follow up pregnant women who do not return to clinic and increase the average number of antenatal clinic visits attended. The EMR can also be used to flag those HIV positive women who are not receiving ART and increase coverage of ART prophylaxis during pregnancy. The EMR will be used to monitor the impact of this follow-up.

Uamuzi Bora is a medical project that supports the Ministry of Health and partners in Kenya to implement an electronic medical record to improve clinical and public health decision-making. The EMR is built using free, open source software and is based on the Open Medical Record System (OpenMRS) platform, increasingly being adopted in developing countries around the world.

The MCH EMR pilot, implemented in partnership with the Japanese International Cooperation Agency (JICA) and Ministry of Public Health and Sanitation (MOPHS), took place in five clinics in Kisumu West District, Nyanza Province between April and June 2013.

The pilot has demonstrated the feasibility of implementation of an electronic medical record (EMR) for maternal and child health in resource-constrained settings and the ability to make health information available at different levels of the health service to inform clinical and public health decision-making. A total of 946 women, 206 deliveries and 302 children were registered in the EMR between 2 April and 24 June 2013.

A significant number of pregnant women were confirmed HIV positive during the pilot period (14.0%), however only 50.4% of women positive for HIV were started on ART prophylaxis during this time. An average of 1.9 clinic visits were attended per pregnant woman during pilot period. Given the short time period of the pilot it has only been possible to undertake a descriptive analysis of patients registered and evaluate the impact of the EMR on data quality.

Further evaluation of the impact of the EMR on provision of care and retention in care will be undertaken at the end of the year. With the knowledge of these data, the EMR can now be used, for example, to follow up pregnant women who do not return to clinic and increase the average number of antenatal clinic visits attended. The EMR can be used to flag those HIV positive women who are not receiving ART and increase coverage of ART prophylaxis during pregnancy. The EMR will also be used to monitor the impact of this follow-up.

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Thanks to Dr Tomohiko Sugishita and Kaori Saito at the Japanese International Cooperation Agency (JICA) without whom the MCH EMR pilot would not have taken place. Dr Sugi and Kaori led implementation of the pilot and its conception both at Ministry of Health headquarters in Nairobi and with the District Health Management Team in Kisumu West. Thanks to Dr Shanaaz Sharif, Dr Annah Wamae and their teams at Ministry of Public Health and Sanitation for their vision and leadership in taking the EMR concept forwards for MCH and thanks to George Odhiambo, Elizabeth Onyango and the Kisumu West District Health Management Team for leading the pilot in their district.

Finally, sincere thanks to all clinic staff who participated so eagerly in implementing the EMR and the pregnant women and mothers who have accepted to be a part of this pioneering pilot. We hope this project can inform future work to improve the delivery of maternal and child health care in Kenya.

SECTION 2

Uamuzi Bora Electronic Medical Record

2.1 Uamuzi Bora EMR and OpenMRS

The Uamuzi Bora electronic medical record is built on the open-source OpenMRS platform, adhering to national and international standards.

The Uamuzi Bora electronic medical record (EMR) is built using free, open source software and builds on common platforms and previous work, notably that of Open Medical Record System (OpenMRS). (1) We does not wish to develop "another EMR". While many features of this system are new and specific to the health needs in Kenya, we are interested to share intellectual resources and to build on what has been done before.

OpenMRS was created as a collaboration between Partners in Health (PIH) and the Regenstrief Institute in the USA and has been approved for EMR use in Kenya. (2) The platform supports open standards for data exchange such as HL7, allowing exchange of patient records with other medical records systems, including a WHO-supported record standard. (1) OpenMRS supports a modular architecture that enables new modules to be designed without disturbing core functions. A Concept Dictionary allows users to enter new concepts, develop data collection forms and store data.

2.2 Our Model

The Uamuzi Bora model removes the need for local clinic infrastructure and enhances access and sharing of health information at all levels of health care.

Traditional models of EMR implementation have installed a local infrastructure, such as a server and network in each clinic (see Figure 1). Such locally installed infrastructure can be costly to implement and maintain and can be a barrier to EMR

implementation in some areas. (3-5) A local clinic model also limits the ability of the system to readily share information between different levels of the health service.

This underscores the need for innovative solutions that are appropriate for resource-constrained settings. (6) Uamuzi Bora uses a cloud-based model of deployment to clinics that only requires a single server to be maintained centrally, with no infrastructure required by the individual clinic (Figure 2). We have established a secure, encrypted virtual private network (VPN) with Safaricom, a mobile phone provider in Kenya, to which the server and clinic computers can connect securely (see Section 2.4). The VPN is air gapped from the internet and only computers that have been registered by the project can access this secure private network.

Each clinic only requires a single computer to run the EMR. We have selected the Google Chromebook as the clinic computer of choice. Chromebooks function as a laptop and are capable of hosting a SIM card and connecting directly to a mobile data network. In this manner, each clinic can connect securely to the EMR server via the VPN on the mobile data network. The server is currently hosted for the Ministry of Health by Uamuzi Bora and is located in Kakamega (see Section 2.4).

We have extended this cloud-based model one step further, to allow health information to be shared in real-time between different levels of care to improve clinical and public health decision-making. Every 24 hours, the database of individual patients (which remains encrypted and secure and only accessible to clinics) is copied and all patient-identifiable information is removed. This anonymous version of the database is then used to provide health information to different users at different levels of health care (see Section 2.5 for more information about our data management procedures).

Figure 1. Features of a local clinic model of EMR implementation

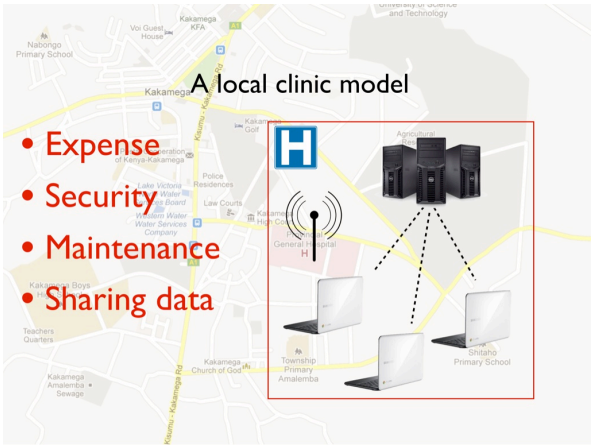


Figure 2. The Uamuzi Bora model of EMR implementation

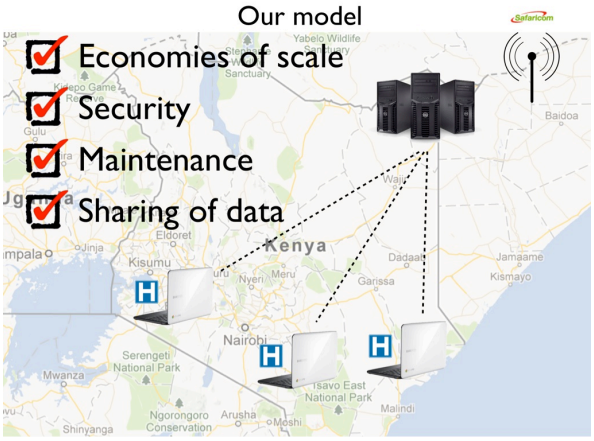
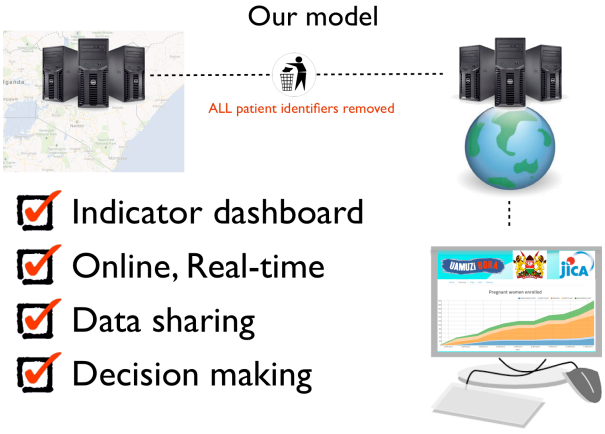


Figure 3. The Uamuzi Bora model of EMR implementation



2.3 Features of the EMR

2.3.1 Data Entry

Data is entered from the paper record to the electronic medical record either by the clinician or a data entry clerk.

During the first phase of Uamuzi Bora EMR implementation in a new clinic, the existing paper-record is entered into the electronic database. Clinic data clerks are trained in data entry and Uamuzi Bora data entry assistants support data entry and supervision in high volume sites.

Once the "backlog" of historical patient data is entered, prospective new patients and clinic visit data continues to be entered. Depending on the site, this data entry can proceed in two ways:

1. Data is entered during the patient consultation by the clinician
2. Data is entered after the patient consultation has finished by a data entry clerk

We support that clinicians should enter data directly into the EMR but accept that this adds to the clinician workload and may not be feasible in particularly high volume sites with a heavy workload. Indeed a recent systematic review of EMR implementation found direct data entry into the EMR by clinicians during consultations occurred in only one study. (3)

2.3.2 Data Verification

Data checks are run automatically on all data collected in the electronic medical record to ensure data is valid, accurate and complete.

Once data is entered into the Uamuzi Bora EMR, the system automatically reviews all data every 24 hours and produces a data verification report to indicate if pertinent data is missing from the record. Individual patient records are also flagged

to highlight which data is missing. Clinic data clerks can then review these reports and flags to correct missing data from the patient record.

The impact of data verification on the completeness and quality of the MCH patient record is reviewed in Sections 5.

2.3.3 Clinical Decision Support in Care

Clinical reminders and decision support is designed to ensure standardised care is provided that will improve the quality of care delivered.

Adherence to clinical guidelines is essential for ensuring a high standard of health care provision. Despite efforts and resources invested in developing and disseminating clinical guidelines, practitioners still ignore them [29]. EMR-based clinical decision support has been shown to improve adherence to guidelines related to ordering tests and results reaching the clinician, reduce data errors, and reduce missed appointments. (7,8)

The Uamuzi Bora EMR automatically reviews the database every 24 hours to generate a clinical verification report and flag patients who have not received care according to standardised guidelines and protocols. Clinicians then regularly review the clinical verification report and individual patient flags to review appropriate management plans.

The impact of this form of clinical decision support on maternal and child care is reviewed in Section 5.

2.3.4 Follow Up and Retention in Care

A successful outpatient program must ensure continuity and retention in care

Continuity of care and retention in care remain particular challenges for many health services in resource-constrained settings.

The Uamuzi Bora EMR can automatically flag and provide a list of pregnant mothers who have not attended clinic or have not attended the minimum number of antenatal clinic visits. The EMR can also automatically send out SMS text message reminders to these mothers or a phone call can be made from the clinic to ensure the pregnant mothers are retained in care and followed up appropriately.

2.3.5 Reporting

Standardised reports can be automatically generated to enhance the monitoring and evaluation functions of the clinic, as well as district and provincial health management.

The Uamuzi Bora EMR provides standardised reporting to the Ministry of Health and partners. Both external and internal reporting is essential to determine the success of programming and the Uamuzi Bora EMR provides the ability to generate such reports quickly and accurately.

Reports can be generated via the EMR itself. Online aggregated data tables are also available via the following web address:
`https://uamuzibora.org/reports/mch`

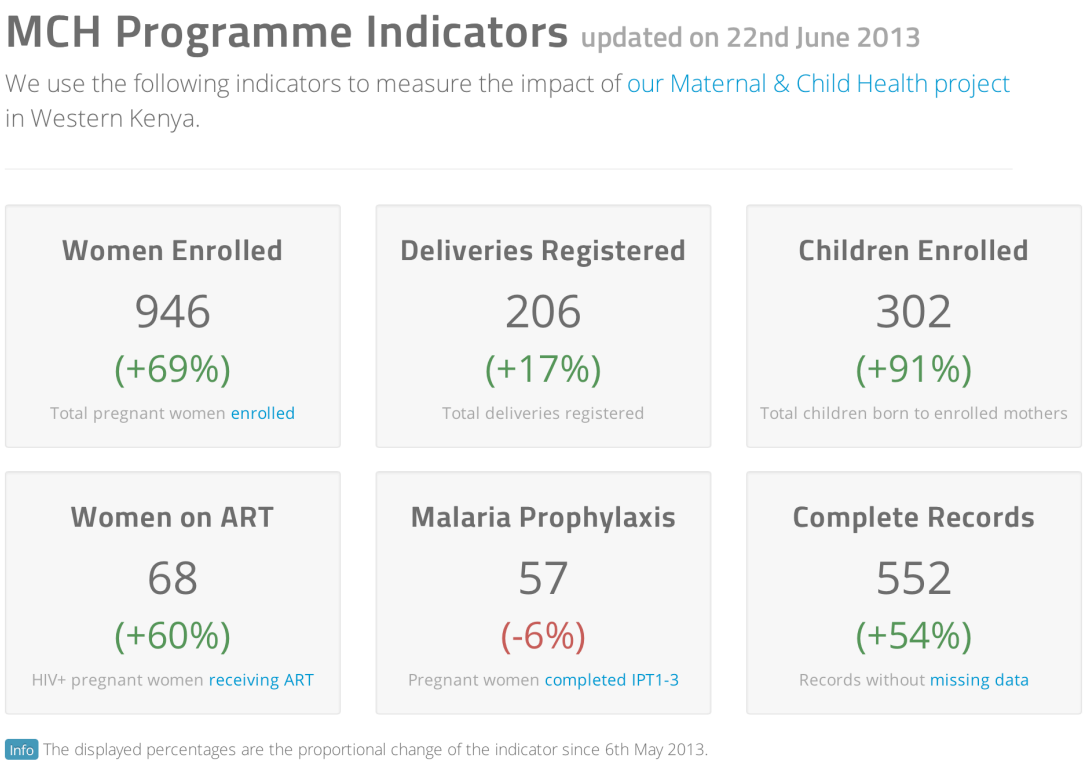
2.3.6 Indicator Dashboard

A real-time online indicator dashboard provides feedback and monitoring at all levels of health management and decision-making.

The Uamuzi Bora EMR improves access to and use of health information at all levels of public health and clinical decision making, from the clinic to national level, through the use of an online indicator dashboard.

An example view is shown in Figure 4. The indicator dashboard can be accessed at the following web address:
`https://uamuzibora.org/data/mch`

Figure 4. The Uamuzi Bora MCH EMR indicator dashboard



2.4 System Infrastructure

2.4.1 Network

Uamuzi Bora utilises a secure, encrypted virtual private network (VPN) with Safaricom, a mobile phone provider in Kenya, to which the server and clinic computers can connect securely. The VPN is air gapped from the internet and only Chromebooks and SIM cards that have been registered by the project can access the secure, private network.

2.4.2 Server

The physical server is hosted for Ministry of Health by Uamuzi Bora, and is currently located in Kakamega. It uses a WiMAX radio connection to connect to the VPN.

The Uamuzi Bora server runs a customised version of OpenMRS 1.9: a Java application running on top of Apache Tomcat 7, using MySQL 5.5 as a database server, and run behind Nginx as a reverse proxy server, on a server running Ubuntu 12.04 LTS Linux. Regular security updates are applied to the system from the main Ubuntu repositories.

The BIOS is password protected. The hard drives are encrypted using *dm-crypt* and a key file is used to decrypt the hard drives at boot time. The key file is stored on a separate USB memory stick that is required to be plugged into the server to boot. The USB stick is then removed after booting and stored in a locked cabinet elsewhere in the building.

The server runs a fully patched version of Ubuntu using only packages from official Ubuntu stable repositories. Only ports 80, 443, and 22 are open; the rest firewalled. SSH has a stringent configuration to resist brute force attacks and root login is disabled. MySQL has been secured from its default configuration, and only accepts connections from the localhost. Tomcat only serves pages over HTTPS: it redirects all port 80 traffic to port 443 and uses SSL/TLS with our own self-signed certificate.

All server processes are owned by non-privileged users and are sandboxed. OpenMRS user accounts have permissions relevant to their roles and may only access relevant data, as per principle of least privilege. A strong password policy is enforced.

2.4.3 Clinic computers

Clinic computers are Google Chromebooks, which use a 3G mobile internet connection to connect directly with the VPN. The 3G mobile internet connection does not permit access to the internet, and Wifi and Ethernet networking on the client machines is disabled.

Clinicians and data clerks use the Chromebooks to search, view, edit and create electronic patient records and access verification reports and clinical reminders within the OpenMRS web application.

2.5 Data Management

2.5.1 Data Protection

Uamuzi Bora stores patient data confidentially and, in accordance with best practices, data are protected through a variety of mechanisms.

The server is physically secured in a locked office in Kakamega, and physical access is limited to select Uamuzi Bora staff. An alarm is triggered if the server case is tampered with and the BIOS requires a password to continue booting. Patient identifiable information (such as the MySQL database) is stored on an encrypted file system that is decrypted at boot time using a USB key, which is then stored in a different secure physical location to the server.

Connections between the clinic computers and the server use exclusively HTTPS over an IPsec VPN. Core Uamuzi Bora staff can also connect to the server from the internet using public-key authenticated SSH over the IPsec VPN. All connections and connection attempts to the server are logged and audited.

2.5.2 Data transfer and backup

Encrypted backups are made of patient identifiable data. These backups are encrypted using GnuPG to a private key, which is split between four lead Uamuzi Bora staff using Shamir's Secret Sharing in a (2,4)-threshold scheme. This means that no-one person can decrypt the backup - it requires two people to combine their shares of the private key to decrypt it.

Encrypted backups are transferred to long-term storage on Amazon Glacier over the VPN and held for a period of 6 months for the purpose of disaster recovery after which time they are securely deleted. All backups are protected with strong encryption. Only the project's public keys are on the server; the corresponding private keys are held out of country by the research team. Temporary files are immediately securely deleted after encryption is completed.

2.5.3 Anonymisation

In addition to backups for the purposes of disaster recovery, regular anonymised versions of the database are created automatically by the server, which contain no patient identifiable data. This anonymous database is encrypted with a different key to the main backup and is held by all core project members.

The anonymisation process is automated by a backup script and does not involve any human intervention. It occurs on the same physical machine as OpenMRS, so data are anonymised at point of source.

Patient identification numbers, names, data of birth, relations, first line of address and free-text fields are considered represent patient identifiable data and these are deleted as part of the anonymisation process, apart from date of birth which is rounded to the nearest year. Our anonymisation process thus performs the following functions:

- Deletes the UPN (the unique patient identification number).
- Deletes the patient's forename(s) and replaces it with 'Unknown'.
- Deletes the patient's surname and replaces it with 'Unknown'.
- Deletes the patient's middle names (if applicable).
- Deletes the patient's maiden name or previous surnames (if applicable).
- Deletes any prefixes or suffixes of the patient's name (if applicable).
- Deletes the first line of the patient's address
- Deletes the patient's telephone number
- Rounds the patient's date of birth to the nearest month (e.g. 14/07/1970 would be come 01/07/1970)
- Deletes all details of the patient's treatment support (names, phone numbers and addresses)

The anonymous database is used to create aggregated data that is transferred over a VPN to a public webserver for use in the dashboard indicators and application programming interface (API), which allows partners to access aggregated data (se Section 2.3).

SECTION 5

Data Analysis and Impact

The Uamuzi Bora electronic medical record (EMR) has made health information available at different levels of the health service to inform clinical and public health decision-making for maternal and child health (MCH).

Given the short time period of the pilot it has only been possible to undertake a descriptive analysis of patients registered and to evaluate the impact of the EMR on data quality:

- 946 women, 206 deliveries and 302 children enrolled
- Average age of pregnant women 23.6 years
- Average of 1.9 clinic visits attended per pregnant woman during pilot period
- 0.2%, 4.7% and 14.0% of women confirmed TB, Malaria and HIV positive
- 50.4% HIV positive women receiving ART during pregnancy
- EMR verification of data reduced missing data by 66.3%

Further evaluation of the impact of the EMR on provision of care and retention in care will be undertaken at the end of the year. With knowledge of the above data, the EMR can now be used, for example, to follow up pregnant women who do not return to clinic and increase the average number of antenatal clinic visits attended. The EMR can also be used to flag those HIV positive women who are not receiving ART and increase coverage of ART prophylaxis during pregnancy. The EMR will be used to monitor the impact of this follow-up.

5.1 Descriptive Analysis

5.1.1 Women enrolled

946 pregnant women and mothers were registered in the MCH EMR, from the five clinics, between 2 April and 24 June 2013 (Table 2, Figure 5). The mean age of women attending clinic was 23.6 (Table 3, Figure 6). Each woman attended the ANC an average of 1.9 times during the pilot period (Table 4, Figure 7).

Figure 5. Women registered, by Location

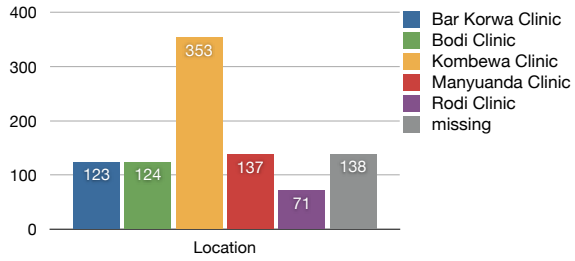


Figure 6. Age Group

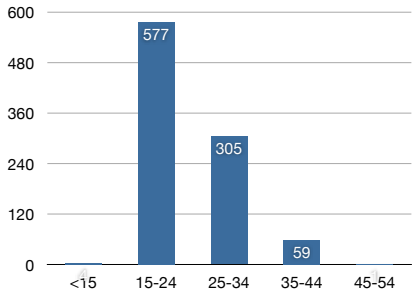
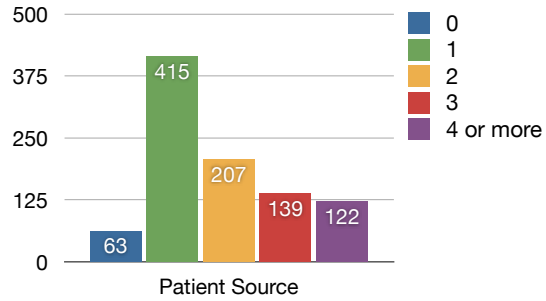


Figure 7. Number of clinic visits attended



5.1.2 Deliveries registered

206 deliveries were registered in the MCH EMR, from the five clinics, between 2 April and 24 June 2013 (Table 5). 107 (52.0%) deliveries were attended by a midwife (Figure 8, Table 6) and 136 (66.0%) deliveries took place in hospital (Table 7, Figure 9). 195 (94.7%) of deliveries were spontaneous vaginal delivery (Table 8, Figure 10).

Figure 8. Deliveries conducted by

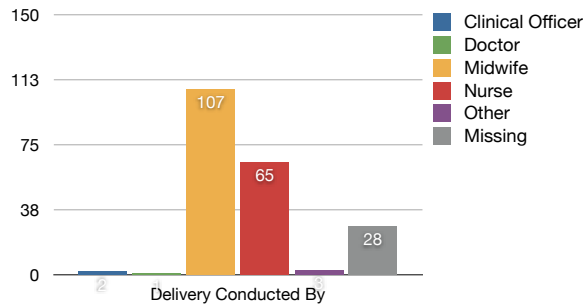


Figure 9. Place of Delivery

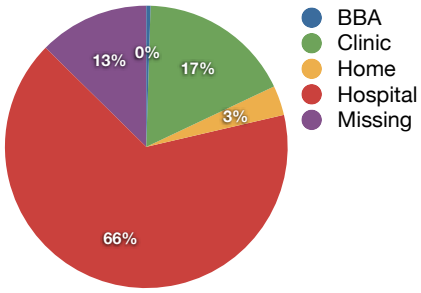
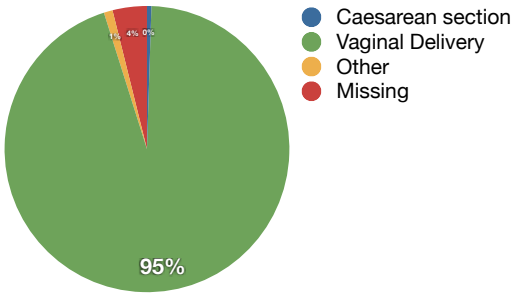


Figure 10. Method of Delivery



5.1.3 Children enrolled

302 babies were registered in the MCH EMR, from the five clinics, between 2 April and 24 June 2013 (Table 9, Figure 11). 160 (53.0%) were girls (Table 10, Figure 12).

Figure 11. Children registered

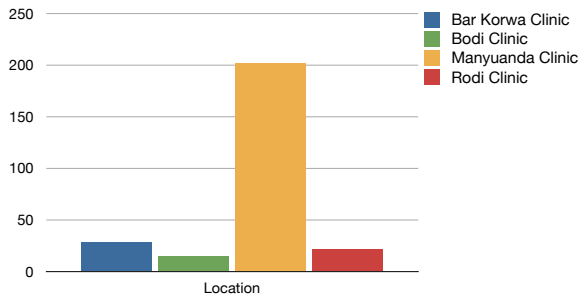
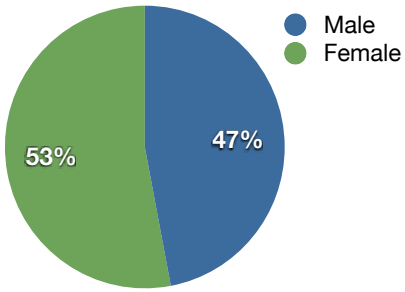


Figure 12. Child Gender



5.1.4 Record Keeping

Figure 13 and Table 11 shows the percentage of patient records missing data according to screening for hypertension, TB, Malaria and HIV. Table 12 and Figure 14 shows this missing data according to facility.

Figure 13. % of records missing data among registered women

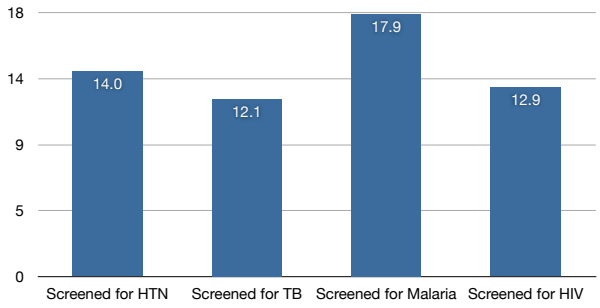
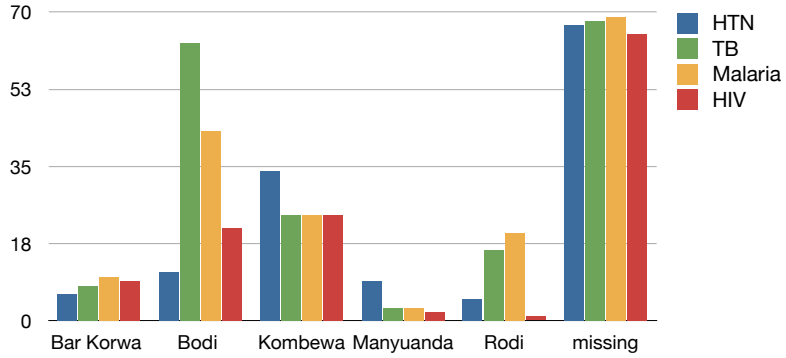


Figure 14. % of records missing data among registered women, by Location



5.1.5 Clinical Decision Support

Clinical reminders are designed to ensure standardised care is provided that will ultimately improve the quality of care delivered.

Only 5 (0.5%) of patients were screened for hypertension during the pilot period (Table 13). 2 women (0.2%) were receiving TB treatment (Table 14), 44 women (4.7%) registered had confirmed malaria (Table 15) and 132 women (14.0%) were HIV positive (Table 16). Only 68 (50.4%) of women confirm HIV positive were recorded as being on ART during the pilot period (Table 17).

5.2 Impact on Data Quality

We measured the impact of the MCH EMR in the five clinics, by comparing the amount and quality of data stored following data entry with the amount and quality of data stored following data verification and review using the EMR (before and after 6 May 2013 when data entry was completed and data verification began).

A significant reduction of 66.3% in missing data was recorded pre and post implementation of EMR verification in the database for important data regarding screening and status of hypertension, TB, Malaria and HIV (Table 1).

Table 1. Selected missing data recorded for patients registered

Missing Data	**N. (%)**	**N. (%)**	**% change**	**P ***
Screened for HTN	219 (39.0)	132 (14.0)	-64.1%	0.000
Screened for TB	271 (48.3)	182 (12.1)	-74.9%	0.000
Screened for Malaria	266 (47.4)	169 (17.9)	-62.2%	0.000
Screened for HIV	201 (35.8)	122 (12.9)	-64.0%	0.000

* Two-sample test of proportions

5.3 Impact on Clinical Care

Given the short time period of the pilot it has only been possible to undertake a descriptive analysis of patients registered and to evaluate the impact of the EMR on data quality.

Further evaluation of the impact of the EMR on provision of care and retention in care will be undertaken at the end of the year. With knowledge of the above data, the EMR can now be used, for example, to follow up pregnant women who do not return to clinic and increase the average number of antenatal clinic visits attended. The EMR can also be used to flag those HIV positive women who are not receiving ART and increase coverage of ART prophylaxis during pregnancy. The EMR will be used to monitor the impact of this follow-up.

SECTION

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List of Tables

Table 2. Women registered, by location

Location	**N.**	**%**
Bar Korwa Clinic	123	13.0
Bodi Clinic	124	13.1
Kombewa Clinic	353	37.3
Manyuanda Clinic	137	14.5
Rodi Clinic	71	7.5
missing	138	1467
Total	**946**	**100.0**

Table 3. Age groups of women registered

Age	**N.**	**%**
<15 years	4	0.4
15-24 years	577	61.0
25-34 years	305	32.2
35-44 years	59	6.2
>44 years	1	0.1
Total	**946**	**100.0**

Table 4. Number of clinic visits registered

Number of clinic visits	**N.**	**%**
0	63	6.7
1	415	43.9
2	207	21.9
3	139	14.7
4 or more	122	12.9
Total	**946**	**100.0**

Table 5. Number of deliveries registered

Deliveries registered	**N.**	**%**
No	740	78.2

Yes	206	21.8
Total	**946**	**100.0**

Table 6. Deliveries conducted by

Conducted By	**N.**	**%**
Clinical Officer	2	1.0
Doctor	1	0.5
Midwife	107	52.0
Nurse	65	31.6
Other	3	1.5
Missing	28	14.0
Total	**206**	**100.0**

Table 7. Place of Delivery

Place of Delivery	**N.**	**%**
BBA	1	0.7
Clinic	36	12.6
Home	7	22.8
Hospital	136	57.6
Missing	26	6.3
Total	**206**	**100.0**

Table 8. Method of Delivery

Method of Delivery	**N.**	**%**
Caesarean section	1	0.5
Vaginal Delivery	195	94.7
Other	2	1.0
Missing	8	3.9
Total	**206**	**100.0**

Table 9. Children registered, by location

Location	**N.**	**%**
Bar Korwa Clinic	28	9.3
Bodi Clinic	14	4.6

Manyuanda Clinic	201	66.6
Rodi Clinic	21	7.0
missing	38	12.6
Total	**302**	**100.0**

Table 10. Gender of children registered

Sex	**N.**	**%**
Male	142	47.0
Female	160	53.0
Total	**302**	**100.0**

Table 11. Missing data among pregnant women

Missing data	**N.**	**%**
Screened for HTN	132	14.0
Screened for TB	182	12.1
Screened for Malaria	169	17.9
Screened for HIV	122	12.9

Table 12. Missing data among pregnant women, by location

	Missing Screening Data			
Location	**HTN**	**TB**	**Malaria**	**HIV**
Bar Korwa	6	8	10	9
Bodi	11	63	43	21
Kombewa	34	24	24	24
Manyuanda	9	3	3	2
Rodi	5	16	20	1
missing	67	68	69	65
Total	**132**	**182**	**169**	**122**

Table 13. Pregnant women screened for hypertension

Screened for HTN	**N.**	**%**
No	809	85.5
Yes	5	0.5
missing	132	14.0

Total	**946**	**100.0**

Table 14. History of TB among pregnant women

Screened for TB	**N.**	**%**
No signs of TB	749	79.2
Receiving TB treatment	2	0.2
TB status not assessed	13	1.4
missing	182	19.2
Total	**946**	**100.0**

Table 15. History of malaria among pregnant women

Screened for Malaria	**N.**	**%**
Not performed	146	15.4
Test Indeterminate	6	0.6
Malaria Negative	581	61.4
Malaria Positive	44	4.7
missing	169	17.9
Total	**946**	**100.0**

Table 16. History of HIV among pregnant women

Screened for HIV	**N.**	**%**
Not performed	83	8.8
HIV negative	609	64.4
HIV positive	132	14.0
missing	122	12.9
Total	**946**	**100.0**

Table 17. HIV positive women on ART

HIV+ women on ART	**N.**	**%**
No	23	17.0
Yes	68	50.4
Missing	44	32.6
Total	**135**	**100.0**