A Cross-case Analysis of the Effects of EMR Deployment on Antenatal Care Services in Rural Health Centres in Malawi

Marlen Stacey Chawani

University of Oslo, Oslo, Norway

marlensg@ifi.uio.no

Background and Purpose: The use of Electronic Medical Records in developing countries is considered important for monitoring and facilitating the achievement of health-related Millennium Development Goals. Many studies have analysed the effects of EMRs in supporting care provision in hospitals, mostly with a focus on HIV/AIDS services. However, there are limited studies on EMR use for maternal health services in small primary care facilities in rural settings. This paper aims to address this gap by presenting findings from evaluation of two EMR systems implemented to support Antenatal care in two rural health centres in Malawi.

Methods: This study was undertaken as part of an Action Research project exploring the use of EMRs in Malawi. The paper presents a qualitative analysis of the effects of EMRs on Antenatal care services in two rural health centres. Data was collected through interviewing end-users and pregnant women, participant observation of health services, and analysis of Antenatal care data.

Results: The study reveals that EMRs have the effects of redistributing work and increasing collaboration among different types of health workers; increasing attention and knowledge on the health domain, and redistributing risks in care and data quality.

Conclusions: The findings highlight the need for EMR system designs that support coordination of work and provide for easy correction of errors. The study also shows that introducing EMRs can facilitate learning about the healthcare domain in addition to gaining computer skills.

Keywords: Antenatal care, EMR systems, evaluation, effects, rural health centres, developing countries, Malawi, qualitative research.

1   Introduction

The fifth goal of the Millennium Development Goals is to improve maternal health with specific targets to reduce Maternal Mortality, and to achieve universal access to reproductive health. Antenatal care is one of the maternal health services important for preventing maternal deaths as it provides a platform for delivering several maternal and new-born interventions. However, developing countries in Sub-Saharan Africa are struggling to provide quality maternal health services including Antenatal care (ANC). Studies reveal there is a substantial quality gap in the provision of ANC with fewer women receiving the full range of interventions during pregnancy (Kinney et al., 2010; Lungu et al., 2011). Furthermore, the quality of maternal health data itself is considered unreliable which makes it challenging to monitor progress of various interventions (Sharan et al., 2009; Summers, 2009).

Electronic Medical Record (EMR) systems are being implemented as one way of improving the quality of health services through efficient information management (WHO, 2012). EMR systems are expected to primarily improve the quality of data recorded in health records, accessibility of patients' data by healthcare providers for continuity of care, support clinical decision making, and simplify generation of mandatory reports to higher authorities (Car et al., 2008; Chetley, 2006; WHO, 2006; WHO, 2012). Within the context of developing countries, several studies have reported implementation and use EMRs to support healthcare services. These implementations have mostly been at a small scale focusing on specific health programmes or hospital departments, with the majority of studies reporting EMR use to support

HIV/AIDs and TB programmes (Fraser et al., 2005; Oluoch et al., 2012; Castelnuovo et al., 2012; Douglas et al., 2010). These studies have shown that EMR systems are a valuable aid in supporting clinical management of an increasing number of patients and for reporting. Other studies have also reported the use of EMRs to support primary care services including Maternal and Child health, and outpatient clinical care, for instance, in Kenya (Rotich et al., 2003), Cameroon (Kamadjeu et al., 2005), India (Singh et al., 1997), Malawi (Waters et al., 2010), Tanzania (Ngoma et al., 2012), Zambia (Chi et al., 2011), and Nigeria (Thompson et al., 2010). These studies are considered to attest the feasibility of implementing EMR systems in primary care settings of developing countries.

Reviews of EMR literature reveal that most studies within health informatics have focused on objective quantitative evaluations of the impact of the systems on healthcare processes and outcomes on patient care (Car et al., 2008; Greenhalgh et al., 2009; Fitzpatrick & Ellingsen, 2012). In addition, literature reviews of EMR systems in developing countries indicate that there are limited rigorous evaluation studies and call for more scientifically rigorous studies that have clearly defined measures, for instance, randomised controlled trials, cost-benefit studies and cost-effectiveness studies (Blaya et al., 2010; Oluoch et al., 2012). However, other researchers have argued that the impact of EMR systems cannot simply be measured by standardised factors such as efficiency and cost because such views neglect to reflect on the ambiguous nature of such technology and the changes in work practices (Berg, 1999; Vikkelsø, 2005; Boulus, 2009). As a result, pre-set measurement instruments often miss unpredictable relevant changes that take place (Berg, 1999). Thus, researchers argue for employing qualitative research methods that allow in-depth analysis of the nature of changes in the healthcare work associated with the introduction of EMRs (Berg, 1999; Boulus, 2009). Therefore, the aim of this paper is to present a qualitative analysis of the effects of implementing EMRs on Antenatal care services in rural primary care settings in Malawi, a developing country in Africa. The paper contributes to the growing body of evidence on the impact of EMRs in developing countries, with a specific focus on addressing the question: what are the effects of implementing EMR systems on Antenatal care services in rural primary care settings of Malawi?

With the specific focus on rural settings, the qualitative approach allows for an in-depth analysis of the social and technical aspects that resulted in the observed use and the perceived effects of the EMR systems. Such an analysis provides deep insights into the changes of Antenatal care work in these settings and thus, highlights important considerations that need to be made when developing EMR systems for such contexts.

The paper is structured as follows. The next section presents a review of literature on EMR systems in developing countries, and on EMR systems evaluation approaches. This is followed by details of the research context, case descriptions and the research methodology in section 3. In section 4, the findings from the evaluation studies for each case are presented. The findings are analysed and discussed in section 5 in relation to the presented literature. The paper concludes by presenting a summary of the key insights.

2   Literature Review

2.1   EMR Systems in Developing Countries

Different EMR systems have been implemented to support various healthcare services in developing countries. Existing literature reports of their use to support HIV/AIDS programmes, Tuberculosis (TB) programmes, Immunisation, Maternal and Child Health, cardiac disease, and general primary care (Fraser et al., 2005; Fraser & Blaya, 2010; Kamadjeu et al., 2005; Rotich et al., 2003; Chi et al., 2011; Singh et al., 1997; Douglas, 2009; Thompson et al., 2010; Waters et al., 2010; Were et al., 2010; Castelnuovo et al., 2012; Ngoma et al., 2012; Anantraman et al., 2002). The range of functionality in the EMR systems included patient registration, visit data collection, tracking/monitoring patients and their treatments in health programs, medication order entry, drug/supplies inventory management, appointment scheduling, decision support, statistics and generating reports. Decision support systems have received attention as a possible solution to the lack of trained clinical personnel, especially in rural areas of developing countries (Blaya et al., 2010).

There are mainly two modes of implementation that are employed for EMR systems. The first and most common mode is whereby paper-based forms/tools are used by the health providers to record the

patient/client's information during consultations. The form is then used by other staff (e.g. a data clerk) to enter the data into the EMR and this is referred to as retrospective data entry (Douglas et al., 2010; Oluoch et al., 2012). The other approach is whereby the health providers use the EMR directly during consultations with patients. These systems are referred to as Point of Care (POC) or Provider-based EMR systems (Douglas et al., 2010; Chi et al., 2011; Castelnuovo et al., 2012). Researchers have argued that when data entry is retrospective, there is a tendency to transfer the deficiencies of a manual registry to the computerised registry leading to missing and inaccurate data; and that it hinders the realisation of the positive impact that protocol guidance and decision support features can add to patient-level clinical care (Tomasi et al., 2004; Mamlin et al., 2006; Douglas et al., 2010; Castelnuovo et al., 2012). However, others have argued that clinical summaries from EMR systems can still assist in patient care even when providers have almost no direct interaction with the computer (Were et al., 2010).

There are various challenges identified with regards to the implementation and use of EMR systems in developing countries. The first challenge is associated with low computer literacy of health workers (Sood et al., 2008; Oluoch et al., 2012). To address this, in some of the cases, health providers undergo computer training prior to deploying the EMR system in order to familiarize them with using computers, e.g. (Rotich et al., 2003; Ngoma et al., 2012). Others, however, have opted for simplifying the interface design and tools, for instance, opting for touchscreen devices instead of the conventional desktop or laptop computers (Douglas, 2009).

Shortage of qualified staff is another problem that challenges the use of EMR systems (Sood et al., 2008). The shortage leads to high workload for the available staff, and this is often the reason why retrospective data entry, done by data clerks, is opted for. Another challenge in developing countries is the lack of systems for accurately obtaining unique identification for patients (Rotich et al., 2003; Piette et al., 2012; Douglas, 2009). In addition, low literacy contributes to inconsistent spelling of patients' names and addresses (ibid.). Implementers have therefore addressed this by implementing patient registration systems that produce patient ID cards e.g. (Rotich et al., 2003; Douglas, 2009).

Other identified challenges to implementing EMR systems are: poor electricity and ICT infrastructures which results in a lack of reliable electricity and internet access; and lack of local technical expertise to support the systems (Sood et al., 2008; Douglas, 2009; Lewis et al., 2012).

Effects of EMR systems .
EMRs are expected to improve the quality of care, the efficiency of the care process, and reduce healthcare costs (Chaudhry et al., 2006). Most evaluation studies have focused on process indicators, and attitudes of users or patients, rather than costs and patient outcomes (Blaya et al., 2010). Evaluation studies of EMR systems in developing countries have reported several benefits to health services. Improvement in the accuracy and completeness of data is one of the identified benefits (McKay & Douglas, 2008; Castelnuovo et al., 2012). This has been attributed to incorporation of checks/validations in the EMRs at the time of data entry, as well as having real-time data entry which eliminates transcription errors and allows immediate verification of the data while the patient/client is still present (ibid.). Castelnuovo et al. (2012) also indicate that EMR systems can make the clinic staff to gain knowledge and experience, and awareness on data quality, thereby contributing to improvements in the data quality.

Studies have also reported the effects on efficiency in terms of: time saved in locating patient information and in producing monthly reports; reduced waiting time for patients, reduced provider time per patient and shorter visits in general (Rotich et al., 2003; Fraser et al., 2005). Blaya et al. (2010) reveal that the use of fingerprint scanners and barcode scanners decrease time for locating records. Automation of some functions such as calculation of pills and appointment dates and assessment of adherence were also considered to increase efficiency of healthcare provision (Msukwa, 2011). However, some cases also reported an increase in workload and duration of consultation time due to introduction of EMRs, e.g. Kamadjeu et al. (2005).

Another positive effect of EMR systems identified in existing literature is reduced medication order errors and increased adherence to healthcare protocols (Fraser et al., 2005; Kamadjeu et al., 2005; Douglas et al., 2010; Oluoch et al., 2012). This is associated with decision support functions within EMRs such as: computer alerts or reminders to prescribe drugs, administer vaccines, and to request for lab orders; warnings on drug dosage, drug incompatibilities, abnormal lab results and other risk factors (ibid.).

Furthermore, the ability to track patients to detect risk factors, complications and absentees, and to monitor and remind patients of healthcare needs or treatment are other EMR functions considered to have a positive effect in improving the quality of care (Tomasi et al., 2004; Blaya et al., 2010).

Looking specifically at maternal health services, there are limited evaluation studies that have been reported from developing countries, the notable cases being from Nigeria (Thompson et al., 2010), and India (Singh et al., 1997). The perceived effects of the EMR systems included increased client attendance because computers were associated with an advanced clinic (Thompson et al., 2010); and reduction in immunisation drop-out rates as EMR reports on immunisation drop-outs were used by health workers to communicate health information to the community (Singh et al., 1997).

In general, the existing studies have focused mainly on evaluating pre-specified effects and as such do not fully examine unplanned effects and consequences of EMRs which may entail new risks (Kaplan, 2001; Ash et al., 2004; Stoop & Berg, 2003). In addition, there is a potential bias of reporting 'successful' projects with positive effects as unsuccessful cases are hardly published (Berg et al., 2003; Greenhalgh et al., 2009). Therefore researchers argue for undertaking qualitative evaluations that are grounded in a sociotechnical perspective, which allow in-depth investigation of why and how the systems are being used (or not), and the planned and unplanned effects (Ash et al., 2004; Berg, 1999; Stoop & Berg, 2003; Kaplan, 2001). I present more about sociotechnical evaluation approaches in the next section.

2.2   Sociotechnical Evaluation Approaches

Sociotechnical approaches recognize the interrelation between technology and its social environment, and aims to increase understanding of how information systems are developed, introduced and become part of social practices (Berg et al., 2003). Sociotechnical evaluations involve researching the way technical and social dimensions change and shape each other over time (Cresswell & Sheikh, 2014). The dimensions that may be studied include implementation strategies, attitudes and experiences of individuals, organizational consequences, and impact on quality of care (ibid.). There are various theoretical frameworks used in sociotechnical evaluations, such as: the theory of Diffusion of Innovations; Human, Organization and Technology-fit factors; and Social Shaping of Technology (Cresswell & Sheikh, 2014; Clausen & Yoshinaka, 2004; May et al., 2003; Yusof et al., 2008). In this paper, I adopt theoretical perspectives within Social Shaping of Technology.

From a Social Shaping of Technology perspective, evaluation of EMR systems is focused on how the technology affects the distribution and content of work tasks, information flows, and the visibility of the work (Berg, 2001). Along the same lines, Vikkelsø (2005) argues that there are three dimensions of medical practice that are affected by the introduction of EMRs, and these are work tasks, organisational attention, and risks.

With regards to work tasks and responsibilities, Vikkelsø (2005) indicates that some work tasks may disappear while others emerge. Some of these new tasks are officially recognised whereas others are left as invisible work. Furthermore, the workload is not equally distributed among staff. In relation to organisational attention, she argues that attention may weaken on some aspects of care and increase the focus on other areas. In terms of risks, Vikkelsø (2005) argues that while EMRs are assumed to reduce notorious risks of errors in patient treatment, they may also introduce other risks for patients, for instance, inconsistent medical information across documents. As such, it may not be obvious that the introduction of EMRs has resulted in work procedures becoming better or more efficient all in all. Rather, it results in a different kind of medical practice with a new distribution of work, responsibilities, capabilities, attention and risks (ibid.). Hence, the effects of introducing EMRs should be measured in terms of altered work practices, refocused organisational attention and new kinds of risks.

3   Study Context and Research Methodology

3.1   Antenatal Care Services in Malawi

Antenatal care relates to the healthcare of the pregnant woman and her foetus from conception to the onset of labour (MOH, 2009). In this regard, standardisation and continuity of care throughout the pregnancy is of central concern. Within the Malawi healthcare system, the Focused Antenatal Care (FANC) ap-

proach is the operational protocol, which encourages women to have a minimum of four visits (ibid.). The visits are targeted in that they are supposed to take place during specific periods within the pregnancy. The activities conducted during each visit consist of measuring vitals (weight, height and Blood Pressure), providing TTV immunization, conducting lab tests (for HIV, Syphilis, Haemoglobin, and urine protein), taking the woman's history and current pregnancy details, planning for delivery, conducting a physical examination, scheduling the next visit, prescribing and administering drugs, giving bed nets and registering the visit in an ANC register for the facility. Some of these activities are only conducted on the first visit (e.g. history taking), and therefore there are fewer tasks done on subsequent visits. A detailed description of the activities has been presented elsewhere (Chawani et al., 2014).

Each woman has a booklet, called a health passport, which is used by health providers to record the client's information during care provision. The booklet consists of specifically-designed antenatal care pages for recording the care activities for each pregnancy. At the end of the visit, the information from the health passport is transcribed to the antenatal care register and the health passport is kept by the woman. During the registration, the client is given a sequential number from the register and the number is copied to the client's health passport. This number is used to retrieve their record in the register during the subsequent visits. In this way, all the visits for a particular woman (in that pregnancy) are recorded on the same page in the register, with each visit recorded as a row in the register. The data from the registers is compiled on monthly basis in form of a cohort report and is sent to the district level. The aim of the cohort report is to assess the quality of care given to the clients throughout their pregnancies. For example, one of the data elements on the report assesses the number of women who had a total number of 4 visits, which is the recommended number of ANC visits. For the report, the clients are grouped together according to the month they start attending ANC services, thereby forming a cohort.

3.2   Research Setting and Case descriptions

This study was undertaken as part of an Action Research project exploring the use of EMRs to support maternal health in Malawi. As part of this project, two EMR systems, Baobab ANC EMR system and DHIS2 Tracker system, were deployed in two different rural health centres to support provision of Antenatal care services. Table 1 provides basic details about the two health centres.

Table 1. Summary of Implementation sites

Attributes	Health Centre A	Health Centre B
Location	Lilongwe district, 30kms from Lilongwe city through dirt road.	Dowa district, 50kms from Lilongwe city through tarmac road. Close to a trading centre and bus stop.
Maternity staff	1 nurse, 2 Hospital Attendants	3 nurses, 3 female hospital attendants
Organisation of maternal health services	ANC services provided on Mondays (for new clients) and Thursdays (for subsequent visits). Family planning and postnatal services provided on Tuesdays, Wednesdays and Fridays.	ANC services provided throughout the week, but new clients attend on Fridays. Family planning and postnatal services provided throughout the week.
EMR System Implemented	Baobab ANC system	DHIS2 Tracker

Systems design and implementation.

The two health centres had no electricity; therefore the type of hardware infrastructure was of concern. The implemented systems used Baobab hardware technologies which had proved to work in other rural health centres using renewable sources of energy. This infrastructure consisted of a power system based on solar energy and low-power consumption hardware, similar to what is described in Douglas et al. (2010). The technical design adopted a server-client setup with several workstations at different points of care. Each health centre had a Local Area Network and a server on site which hosted the EMR application. The main component of the workstation was a touchscreen computer. In Health Center A, the work-

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station included a thermal printer and a barcode scanner as shown in Figure 1; whilst in Health Center B,
the workstation had a keyboard and mouse as shown in Figure 2.

Fig. 1. Touchscreen workstation with printer and barcode scanner at Health Centre A


Fig. 2. Workstation with keyboard and mouse at Health centre B

Overall, the functional requirements for the ANC EMR systems were: registering ANC clients; capturing and validating client's antenatal care data; providing alerts and reminders for patient care based on the patient data entered; reviewing client's ANC data captured; scheduling ANC appointments; ending ANC service for the pregnancy; producing statistical reports; and reviewing a client's ANC history for previous pregnancies (i.e. if the previous pregnancy was captured in the system). The specific functionality and designs of the two software applications are presented below.

Baobab ANC EMR System.
The overall goal of the ANC EMR system was to support the Antenatal care services, by capturing all the details that were recorded in the client's health passport and the Antenatal register in order to produce required reports including the monthly cohort report. The software development process and overall design principles have been described elsewhere (see Chawani et al. (2014)). In brief, the design of Baobab EMR systems adopts a Point of Care (POC) approach whereby health workers use the workstations to record client's information during clinical encounters. To increase usability for a POC system, the touchscreen interface has been chosen as a solution that is easy to learn and use. In addition, a wizard-like approach to capturing information is used whereby each screen is dedicated to collecting a single piece of data, as shown in Figures 3 and 4. Thus, large forms are represented as a series of steps/questions with branching of data elements, as such, data elements that do not apply for that client are never shown. Furthermore, the workstation is designed as an appliance model computer in that the device is used for the sole purpose of running the EMR application rather than a general computer.
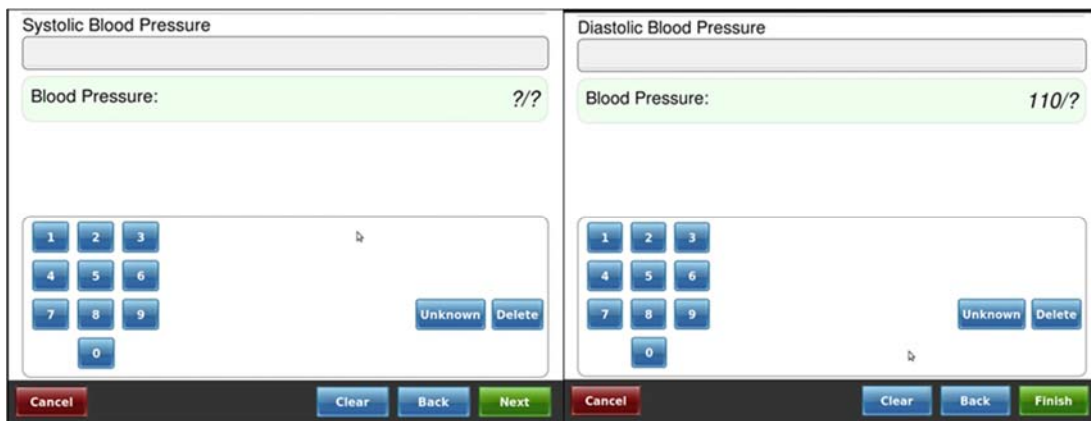
Fig. 3. Blood Pressure screen 1

Fig. 4. Blood Pressure screen 2

At patient care level, the Baobab ANC EMR software functionality consisted of: client registration; capturing ANC information, and reviewing the ANC service history. As part of the registration process,

the system automatically printed out a sticker that had the patient demographics, a unique identifier number and a barcode representation of the ID number. The sticker could be affixed on the client's health passport, as shown in figure 5. The barcode was used to search/retrieve a client's record in the system using the barcode scanner.

Fig. 5. Health passport with a Barcode sticker

Once the client was registered, the system displayed a patient dashboard which provided links for entering Antenatal care data and for viewing the data that had been captured for the client. The patient history for the client was collected during the first visit only. The history data was organized into four categories - obstetric history, medical history, social history and surgical history, with each of these categories having a set of data elements (i.e. questions) that had to be entered. All the questions in a selected category had to be answered/entered before the data could be saved in the system. The patient history could be printed on the label stickers and affixed in the health passport (see Figure 6).

Fig. 6. Obstetric history sticker (left side) and lab results sticker (right side) placed in a health passport

To capture current visit details, the current visit option on the patient dashboard provided links to several categories as shown in figure 7. The captured visit data could also be printed on the label sticker and affixed to the health passport.
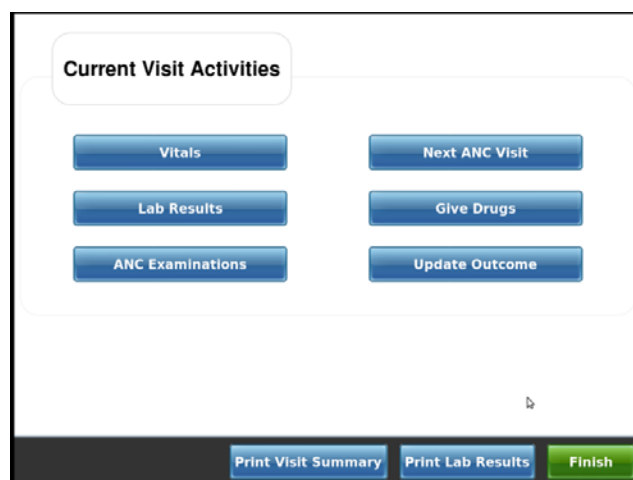
Fig. 7. Current visit dashboard in Baobab ANC EMR system

The data entered in the system could be viewed from various tabs on the patient dashboard. The tabs were colour coded to show the status of the data. A yellow colour indicated the data had not been entered, red colour indicated there was a danger sign or high-risk factor within that group of data, and black indicated the data had been entered and there was no high-risk factor.

To correct the Antenatal care data entered, firstly the wrong data had to be deleted which was done from the patient dashboard. After this, the data could be re-entered. This implied deleting and re-entering all the data in that category, e.g. the obstetric history.

The system also provided statistical information on the services provided in two ways. Firstly, the system dashboard displayed a summary of clients registered and number of clients who had received a particular type of care, such as the number of clients registered and the number of clients whose obstetric history had been entered in a day. Secondly, the system could be queried for ANC monthly cohort reports for the facility.

The Baobab ANC EMR system was deployed at Health Centre A in March 2012. Fourteen health workers were trained prior to deployment and these were one nurse, three hospital attendants, one medical assistant, one statistical clerk, eight Health Surveillance Assistants (HSAs), and one assistant environmental health officer. Initially, two touchscreen clinical workstations were installed at the health centre, one in the nurse's ANC examination room, another at the maternity registration desk. However, after two months of use, another workstation was installed in another room for purposes of history-taking.

DHIS2 Tracker System.

DHIS2 Tracker is a free and open source generic software for collecting, managing and analysing transactional, case-based data records. The DHIS2 Tracker is a module of the DHIS2 platform, a web-based solution for collecting, managing and analysing aggregated health data. The DHIS2 Tracker system provided functionality for maintaining data about individuals enrolled under longitudinal health programmes, which could be aggregated and fed into the main aggregated data warehouse in the same DHIS2 System. The generic DHIS2 was customised to support Antenatal care service provision according to work practices at Health centre B. Details of the customisation process have been described elsewhere (Chawani, Forthcoming).

The customised software that was deployed was DHIS2 version 9 and it had the following patient-level functionality: client registration, enrolment to ANC programme, visit data entry and scheduling of visits, tracking/monitoring services provided to a client. The DHIS2 Tracker also had the possibility to configure aggregation of the patient data for monthly reports; however, the required cohort report was not configured in the deployed software due to challenges in the customisation process.

The registration of the client involved capturing the demographic details on a form as shown in figure 8. A system unique identifier was generated automatically for the client after registration. However, this unique ID could only be viewed when viewing the client's profile in another window. The ANC registra-

tion number from the registers could be entered as an identifier for the programme, only after enrolment to the ANC programme.

Fig. 8. Client Registration form in DHIS2 Tracker system

In order to retrieve a client's record, search functionality was provided for as shown in figure 9. Different criteria could be used to search such as the name or identifier, ANC registration number or residential village. The client record could also be retrieved by looking through a list of all the clients registered at the facility.

Fig. 9. Client search functionality

Once the client was registered, she could be enrolled into the ANC program. The enrolment required specifying the date of the first ANC visit and the LMP date. The system then automatically calculated the visit dates for all the subsequent visits based on the FANC protocol (see figure 10). The visits were displayed as color-coded boxes to show the status of the visit. Green was used to indicate the visit had been completed, purple indicated the visit was incomplete (but had some data), red indicated the visit was overdue, and yellow meant the visit was scheduled in the future. The visit dates could be modified in a separate tab.

Fig. 10. Part of a visit data entry form in DHIS2 Tracker system

The client data for the visit could be entered by firstly selecting the visit and then specifying the actual visit date. The data entry form for the visit was then displayed (see figure 10). The data captured on the form could be validated based on validation rules configured during customisation. It was also possible to mark the form as 'completed' which indicated that data entry for that visit had been completed.

The DHIS2 Tracker also had functionality for generating an ANC program summary report for a particular period. This provided a summary of the clients registered during the period and the status of their visits.

The DHIS2 Tracker system was deployed at Health Centre B in November 2012. Prior to the deployment, thirteen health workers were trained on how to use the system. These were a medical assistant, a statistical clerk, three nurses, five hospital attendants, and three HSAs. Two workstations were installed at the health centre, located at two registration points.

3.3   Research Method

A qualitative study was conducted at each health centre to evaluate the system in use, six months after deployment. The data was collected through interviews, participant observations, and analysis of the health data. Semi-structured interviews were conducted with the end-users of the systems and some ANC clients in order to get a sense of the clients' perspectives of the services. Participant observations of the services were done over a period of six days at each health centre, focusing on analysing the workflow and the interaction with the system. The observation hours per day ranged from two to five hours, depending on the client attendance. The patient records in the EMR systems and registers were also analysed to assess accuracy and completeness of the health data. After the data collection exercise at each health centre, a meeting with the health workers was conducted to discuss the evaluation findings. Table 2 provides details of the data collection methods employed at each health centre.

Table 2. Data collection methods during evaluation

Data Collection	Baobab ANC EMR system at Health Centre A	DHIS2 Tracker system at Health Centre B
Time period	September to November 2012	July to August 2013
Semi- structured interviews	1 nurse, 2 hospital attendants, 1 statistical clerk, 1 Health Surveillance Assistant, 6 ANC clients	3 nurses, 4 hospital attendants, 2 Health Surveillance Assistants, 1 medical assistant, 9 ANC clients
Participant Ob-	ANC service observations for 6 days, 2	ANC service observations for 6 days, 2

servations	to 5 observation hours per day	to 6 observation hours per day
Health data Analysis	Comparison of patient records in EMR and in ANC register for April 2012 cohort	Analysis of patient records in EMR for July 2013[7]

Several ethical considerations were made during the study. Ethical clearance for the overall research project was obtained from the National Health Sciences Research Committee in Malawi. In addition, prior to interviews, written consent and verbal consent were obtained from the health workers and ANC clients, respectively.

Data Analysis.

The interviews were audio recorded, and therefore, the analysis involved transcribing the interviews. Notes were also taken during the observation of services. The findings were organised into themes based on the interview guide. These themes were on the workflow, use of the system, advantages and disadvantages of the EMR, most/less useful features, reliability of the data, influence on ANC knowledge, challenges/problems faced, and recommended improvements.

Based on the content of the findings and review of existing literature, the findings on the effects have been organised into the following themes: workload, time taken in service delivery, knowledge of ANC work, data storage, data accuracy, data completeness. The discussion of these effects has been guided by the three dimensions of medical practice proposed by Vikkelsø (2005), which are work tasks, organisational attention, and risks.

4   Findings from the Evaluations

4.1   Baobab ANC EMR System Implementation

Antenatal Care process flow .

A sequential flow of activities for service delivery had been defined together with the health workers during training & deployment. However, during the evaluation, it was observed that several of the activities occurred concurrently. The activities of weighing, client registration (in the EMR) and TTV immunization often occurred concurrently at the waiting area/registration desk when several health providers were available. In addition, sometimes the nurse also did Blood Pressure examinations in the nurse's room while these other activities were taking place. Simultaneously, an HIV testing counsellor did the HIV testing. After the registration, the clients went into the history taking room where the weight and TTV were entered in the EMR and the patient history was taken, and then they went for HIV testing (if it wasn't done already). The client was expected to go to the nurse's room for physical examination when all these activities had been done. It was indicated that the health workers coordinated among themselves on the work flow. One health worker explained the observed situation as follows:

> "First visit, it depends on how many people are there, everyone wants their work to be done quickly on their side, so what happens is some women are taken to be registered in here(history room), some are being tested for HIV, when they are tested there the nurse takes their BP." [Interview, Sept. 27, 2012]

However, sometimes disorder was evident due to the concurrent activities. For instance, there were cases where some clients went into the nurse's room for physical examination before getting their HIV results or before going for history-taking.

For subsequent visits, the workflow was more straightforward since it required fewer activities. The work flow was such that the clients would be weighed and TTV checked at the waiting area. The weight and TTV would then be entered in the system and then the client would go into the nurse's room. If there were clients who had not previously been registered in the system, after taking their weight, the client would go to the history-taking room where they would be registered, their weight and TTV entered into the EMR, and their patient history would be taken.

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[7] No comparison with register data was done due to known gaps in data entry in the system

For every visit, after physical examination and getting drugs in the nurse's room, the client was expected to go back to the registration desk for registration in the ANC register book and to receive Iron tablets (if prescribed). However, it was noted that not all clients went back to the registration desk after the nurse's room; instead they left the facility without being registered in the ANC book. Two reasons were indicated for this. Firstly, sometimes the nurse could not find the client to be pregnant hence it was considered an unconfirmed pregnancy, and such cases were not supposed to be entered in the register book. Secondly, it was indicated as a mistake made by the clients i.e. they just left without going to the registration desk. During one visit, it was noted that some clients had left without being registered in the book and one health worker attributed it to the fact that the clients had already received the iron tablets before going for consultation with the nurse, and therefore the clients probably didn't think there was a reason to go back to the registration desk.

Roles and Scope of System Use.

Prior to the system deployment at the facility, the nurse was the primary service provider for ANC, conducting the tasks of: history-taking; taking BP and other physical examinations; prescribing and administering drugs; and scheduling visits. The hospital attendants mainly performed the tasks of registering the clients in the ANC book, dispensing iron tablets and sometimes weighing the clients and taking their BP. The HSAs were the ones who weighed the clients most times and also provided TTV immunisation. The statistical clerk was mainly involved in administering ART drugs to the ANC clients who were found HIV positive (at the ART clinic) and in obtaining monthly statistics from the nurse for reporting.

Due to the deployment of the system, the roles of the health providers changed in several ways. The HSAs, hospital attendants and the statistical clerk were given the responsibility to register the clients into the EMR system. The statistical clerk was also responsible for creating new users in the system and generally functioned as the local support provider. The HSAs, hospital attendants and clerk also shared the responsibility of measuring the weight and height of clients and entering these vitals into the system. Although the idea behind the point of care approach was that these details should be captured during the measuring activity, and thus replace writing in the health passports, the providers often recorded the weight and height in the health passport first and captured those details in the system later on. The HSAs, attendants and clerk were also responsible for entering TTV provided to the client on that visit, whilst the nurse was responsible for entering previous TTV received prior to the current pregnancy. Another change was shifting of the history-taking task from the nurse to the other staff (i.e. HSAs, attendants and the clerk).

Nevertheless, there was also 'overlapping' or shared use of some functionality in the system depending on the circumstances, for instance, capturing the Blood Pressure (BP). At times, the BP would be taken by the nurse and entered immediately in the system. In other cases, the nurse would record in the health passport or on a piece of paper and it would be entered by the other staff later on. One health worker explained the situation as follows:

> "*Sometimes the women are called for BP testing whilst we're doing registration (or other things) so you find that the first clients their BP was not measured so for those, she'll measure them and enter into the computer immediately. But if we see that their BP has been measured, we enter it in here* [patient history room] *so she doesn't have to, she just enters the lab results and does the physical examination.*" [Interview, Sept. 27, 2012]

In addition to the other activities described above, the Hospital attendants also registered the clients in the ANC book and dispensed Iron tablets to the clients.

Effects on ANC work.

Nurse's Workload.

Due to the changes in the distribution of ANC work among the health workers, a perceived advantage of introducing the system was reduced workload of ANC work on the nurse. One health worker explained as follows:

> *The system has helped because before that it was just pressure for one* person [the nurse] *but this has provided the opportunity for many people to know how ANC is done, it's really helped.*

That the woman should come with the husband, and when they come, they'll start with this and then that, like that. [Interview, Sept., 2012]

Other health workers also expressed a similar point as follows:

"It has improved because at first work was tough. It was tough for the nurse to start writing everything so the workload was a lot. Now the workload is less. With the system everyone is interested to take part so we are simplifying work." [Interview, Sept., 2012]

"The work is improving because like the nurse, in the past, she would start working in the morning but finish very late in the day, because everything was for her, but now the work load for her is less, because some parts like history we help her so she does a smaller part there. While at first everything was hers…[ ] In the past we were only helping her with weight, height and TTV that's all. But now its more things we are helping her with so that the work should be lesser for her." [Interview, Oct., 2012]

Thus, it was a common perception among the health workers that the workload for the nurse was reduced due to the fact that more health workers were involved in ANC work.

Time taken in service delivery.

The health workers perceived the delivery of ANC services to be faster with the EMR system in place. This was attributed to several factors. The first reason was indicated in relation to the fact that there were more health workers doing the work, as previously mentioned. For instance, one health worker explained it as follows:

"With the system things are faster, especially since we have three computers now so one is doing registration, one is doing history like am doing so the nurse's work is less." [Interview, Oct., 2012]

The health workers also perceived that capturing information in the system was faster and easier than writing as shown in the quotes below:

"It's like a shortcut cause at first you had to write everything but now you just ask questions and enter in here" [Interview, Sept., 2012]

"ANC work is improving with this system because everything is shortened. Writing was difficult and was making the head boil...Of course, we started writing since Standard 1 up to now, but still, at our age, writing [laughs], *for me, this is good, it makes it shorter."* [Interview, Oct., 2012]

"With the printing, there is no need for us to be writing anymore, most of the things were already installed, like the obstetric [history], *there are so many things there so for a person to be writing, to be asking and writing, asking and writing, whilst in here* [the system] *its already installed so its not difficult, just take it* [printout] *and stick in there* [health passport]. *So things like that reduced the work"* [Interview, Oct. , 2012]

Some clients also perceived service delivery to be faster. One client explained that previously they were writing so it was slow. However, other clients were of the opinion that service delivery was slower because there were many questions being asked as shown in the quote below:

"Now it's slow because there are many things being done... like the questions, so when they're asking they are pressing the computer, so that also takes time... Before there weren't many questions like now" [Client Interview, Nov.,2012]

A comparison of the consultation times before and after deploying the EMR system revealed mixed results with regards to whether service delivery was faster or slower. This was due to the fact that consultation time was dependent on the specifics of the client, for instance, the higher the number of previous pregnancies the client had, the more time it took to collect the obstetric history.

Knowledge of ANC work .

The involvement of other cadres in ANC work was perceived to have led to increased knowledge on ANC work activities. This is reflected in the first quote presented in the section *"Nurse's Workload"*. Another health worker expressed the effect on his knowledge as follows:

> "*It has helped me because I am a data clerk so I have to know what is happening everywhere, so with the introduction of the computer, it has made me to advance in terms of my understanding of terms for ANC. *" [Interview, Sept. , 2012]

Another health worker also indicated that he was able to use this knowledge during community activities as explained below:

> "*It has increased, because we couldn't ask the nurse many things because of time at first, but now we can do it so it's added new things that we didn't know before. Even when we go out, what we see here, when someone asks us, we are able to answer them clearly cause we are used, it's what we are doing.*" [Interview, Oct., 2012]

The hospital attendants had been more involved in ANC work prior to system deployment, as compared to the HSAs and clerk. Nevertheless, they also indicated that their understanding of some terms had improved, for instance, the difference between gestation and fundal height.

Data Storage .

The health workers perceived that the system improved the storage of client's information at the health centre since the clients kept the health passports after service delivery. It was indicated that this was an advantage because sometimes the clients lost their health passports. This can be seen in the quotes below:

> "*Another thing is that all the information is being entered in the system, while in the past, if a woman loses the* [health passport] *book, we couldn't follow up properly*" [Interview, Sept. 20, 2012]

> "*When the woman is registered, we don't have to ask the details again, everything is there, even if they bring a new book, maybe the old book is filled up, we can find them again and simply transfer that obstetric history from the old book to the new book, so information is kept, and that's very important and useful. Because they can change their name but their information can't be changed, cause they can remarry* [and change the name] *but that information is unchanged*" [Interview, Sept., 2012]

The second quote also shows that the system was perceived to make it easier to transfer the client's information if the client obtained a new health passport. This was possible because of the printouts from the system.

Data Accuracy .

The health workers had different views with regards to the accuracy and reliability of the data in the system. Some of the health workers indicated that, sometimes, there were inaccuracies in the data captured. For instance, clients were indicated as having had a caesarean section or vacuum extraction when it was just an episiotomy. One health worker explained as follows:

> "*For new visits, the main problem that is there when entering obstetric history, sometimes it is entered as the client had an operation when it was not an operation, it is indicated vacuum* [extraction] *when it is not vacuum, symphysiotomy, there are still problems.*" [Interview, Sept., 2012]

Some of the health workers indicated they had challenges in understanding some of medical terms on the obstetric history. One health worker said:

> "*When entering, there is symphysiotomy I don't really understand it still, I try to ask but the answers that I get don't really satisfy me. There's PPH, Eclampsia. I ask them but without the real knowledge, like since I heard like this, let me ask like this. But if the client would tell me those signs are happening, I wouldn't know where to go.*" [Interview, Oct., 2012]

It was also noted that some of the health workers did not understand the terms related to abortion cases particularly, Manual Vacuum Aspiration (MVA) and Evacuation and some terms related to the medical history (i.e. Renal disease and Fistula repair).

In addition, it was indicated that, at times, there were inaccuracies when registering clients whereby a client could be registered twice. This was because some of the health workers did not know how to correct mistakes made e.g. to change a client's name, so they would just register the client again.

It was also indicated that the calculations for some of the drug prescriptions were incorrect. Furthermore, it was discovered that errors were made when entering TTV doses at the registration desk in that instead of only entering the TTV dosage given on that visit, some health workers were including the previous TTV doses. This was because the health workers were not aware that the nurse entered the previous TTV doses as a different data element. It was also noted that at times, incorrect visit dates for the next appointment were entered. For instance, a previous date or the present date was sometimes entered as the next visit date.

However, other health workers were of the view that the data in the system was accurate and therefore reliable. It was indicated that they had tried to sort out some of the previous problems. They further indicated that they try to correct mistakes made:

> "*It's reliable because we are interested; when we make a mistake we call each other. Even at the end of the day we ask how many have we entered today so if it balances then we are happy, if it's different, we are dejected.*" [Interview, Oct., 2012]

A comparative analysis of the client data in the ANC register and in the EMR also revealed errors in capturing visit numbers. For instance, for one client, the visit number in the EMR was entered as 6 whilst the register showed the client only had 1 visit. In another case, two visits with the same visit number were also found, which made the total number of visits for the client (in the report) to be less than the actual visits a client made. It was also noted that some health workers were uncertain whether to include visits attended in other facilities. For instance, there was one client who had been referred to the referral hospital for scanning services and her referral visit had been recorded in the health passport as an ANC visit. The health worker was therefore unsure whether to include that referral visit when entering the visit number for the current visit.

Furthermore, miscalculations of some data elements of the cohort report were also identified which in turn affected the accuracy of the cohort report. This required correcting the formulas for the calculation of those data elements.

Data Completeness .

The comparison of the data in the register and EMR also gave an indication on the completeness of the data with regards to missing data. It was discovered that some clients had fewer number of visits recorded in the ANC register when compared to the EMR i.e. some visits were not recorded in the register. This was explained to be due to clients not going back to the registration desk.

It was also discovered that there were some clients who were registered in the system but were not registered at all in the register book. The health workers explained that this was because some of the clients had unconfirmed pregnancies and were therefore not supposed to be registered in the book. On the other hand, the clients were registered in the EMR because registration was done prior to physical examination by the nurse.

In addition, it was discovered that there were missing values in the EMR and on clients' printouts (stuck in the health passports) for some of data elements such as the weight, Lab tests results, TTV doses, next visit date, and drugs.

Challenges in using the EMR system.

There were several challenges faced in using the system, some of these have already been presented in describing the effects on ANC work. Here I present additional challenges that were identified.

Capturing Obstetric History.

It was generally challenging for the health workers to collect the obstetric history and this was due to multiple factors. First, as previously presented, some of the health workers had challenges in understanding the medical terms. This was due to the fact that they had not received any medical training in maternal health care.

In addition, it was challenging to collect the history due to contextual factors coupled with the system design, i.e. the logic/sequencing of the data elements. More specifically, the logic and sequence was such that the first data element was the Gravida, which is the total number of pregnancies ever had, including the current pregnancy. The next data element was on whether the client previously had a multiple preg-

nancy (i.e. twins, triplets etc.), which had options for either a 'yes' or 'no 'answer. After this, the number of deliveries was specified. Based on the number specified, details of each delivery were collected (i.e. the year, place of delivery, gestation age, labour duration, delivery method, condition at birth, estimated birth weight, whether the child was still alive, and if not, the age at death). After this, the number of abortions was indicated and the details for each abortion case were also collected. A validation rule was included to ensure that the number of deliveries plus the abortions should be equal to the total number of pregnancies (Gravida). This was only applicable for cases where a woman never had a multiple pregnancy. Otherwise for multiple pregnancy cases, each baby was supposed to be captured as a separate delivery, thus the number of deliveries could be equal to or even more than the Gravida.

It was challenging to capture the Gravida because when the health workers asked in the local language saying "Uchembere wachingati?", women often indicated the number of deliveries they had and excluded abortions or miscarriages (still births) because locally/culturally uchembere is often associated with childbirth and children born. As a result, it was only discovered later on when asking the abortions that the Gravida was not inclusive of abortions. This then required recapturing all the previous information in order for the Gravida, deliveries and abortions to balance up according to the validation rule.

In addition, a validation was included which indicated that abortions have gestation of 6 months or less. Thus if the woman lost the baby at 7 months, it was supposed to be entered as a delivery and not an abortion. The local term for abortion is 'kutaya mimba' but locally/culturally this is often associated with induced abortions which are illegal. Therefore, to ask about the abortions, the health workers used the term "kupita pambali" which locally/culturally is used to refer to miscarriages including still births or neonatal deaths. Thus, the health worker would start capturing the abortion details only to discover that the pregnancy was 7 months or more and therefore it had to be captured as a delivery with a still birth or neonatal death. This therefore required going back and recapturing all the information.

Furthermore, it was indicated that the health workers faced challenges in capturing cases where the client previously had twins as they were not sure whether to enter it as one delivery or two. One health worker indicated that sometimes they didn't capture the other baby's details.

Correcting captured data.

As previously explained, some health workers had challenges in correcting captured data on obstetric history as well as registration of clients. One health worker indicated as follows:

> "*Right now, maybe when you make a mistake, to find it for example to delete something, I don't know how to do it*". [Interview, Oct., 2012]

Another aspect that made it challenging was that it was not possible to correct one specific item, rather it required deleting all the relevant/associated data elements within that grouping and re-enter them all. For instance, it was noted that during nurse's consultation with clients, some of the clients would indicate a complaint towards the end of the consultation, after the nurse had already captured the examination findings. This implied having to delete and re-enter all the examination findings (i.e. fundal height, position, presentation etc.) just in order to capture the complaint. As a result, some of the health workers simply corrected the information on the printout and not in the EMR leading to inconsistencies.

Another aspect that made it challenging to correct the data was that the privileges were set in a way that only the one who had entered the data could delete it. One health worker presented the following example of when they wanted to change the data but could not:

> "*Through my experience, when you register someone and then you go to the social history, let's say you indicated that the person smokes, but on the next visit you realise this was a mistake, how can you change it because it seems the star for deleting does not appear.*" [Interview, Sept., 2012]

Thus, even if a mistake was recognised, if the health worker who entered it wasn't there, or if they didn't know who entered that data, it could not be corrected.

4.2   DHIS2 Tracker system Implementation

Antenatal Care process flow.

During the evaluation, it was indicated that the workflow was such that the clients were registered at the end of the visit rather than registering the clients first before going into the nurse's room (which was

the initial arrangement during deployment). Thus both registration and capturing visit details were done at the same time. In this regard, there was minimal change to the workflow prior to deployment since the system was simply used at the end of the visit. It was explained that this was opted for because they were having problems with the initial arrangement in that clients would leave the facility before their visit details were entered as they would say that they had already been registered in the system. As a result, the health workers decided to be doing both, registration and entering visit details, at the end of the visit.

Roles and Scope of System Use .

The registration of clients and capturing of visit details in the EMR system was done by the Hospital Attendants and HSAs. It was indicated that most of the times, there were two people available, and therefore one would enter the data in the register while the other entered in the system.

The nurses rarely used the system and they indicated this was due to high workload as they were also required to provide other services i.e. postnatal check-ups, family planning and maternity deliveries. In addition, there had been a change in that a new drug, Misoprostral, had been introduced, which required the nurses to fill another form when administering the drugs to clients. The nurses were also required to administer/dispense all the other drugs (SP, Iron tablets) themselves. This was previously being done by the hospital attendants.

It was indicated that two of the staff who had been trained, one hospital attendant and one statistical clerk, were no longer working at the facility. Furthermore, others who had been trained from the OPD section did not use the system. One health worker was of the view that some of the trained staff did not use the system due to lack of a time table as explained below:

> "Because some people since they learnt, they fail up to now, why? Because they're not serious, they just leave that those ones are the ones trying hard, let them do it. Whilst if there was a timetable people would say, today is my day. We said X should make a timetable so she just said she'll do it. Because sometimes this thing is ok, but we have a syndrome that there were many of us trained, so why should we only be the ones doing it. So you leave it for your friends and go do other things. So for us who use timetables, we see that it would be very good that our timetable we should also incorporate this" [Interview, July 2013]

There were also two hospital attendants at the maternity section who had not been trained on using the EMR. This was because one of them was working at the OPD and had not been incorporated when the training was done, whilst the other attendant was new at the health facility. It was indicated that when these two were on duty, it was the HSAs who entered the data in the EMR system or sometimes one of the other Hospital attendants (who were not on duty) would come to enter the data.

Effects on ANC work .

Time taken in service delivery.

The health workers indicated that there was a delay in ANC service delivery with the use of the system which resulted in the ANC clients going home late. The delay was considered to be due to several reasons. Some health workers perceived the delay to be due to the fact that they had not mastered using the system and so they were slow. One of the reasons indicated for this was lack of practicing using the system during their free time, i.e. when clients were not around. The other reason was that the system had not been functioning for almost 2 months because there was a problem with the power system.

Other health workers perceived the delay was because other health workers who had been trained did not help with entering the data in the system, and hence the work was just left to a few people. Another reason given for the delay was that at times, there was only one functioning workstation because the mouse and keyboard for the other workstation had problems and had been taken for fixing. Prior to that, one of the touchscreens was displaying very small text that was not readable and therefore it couldn't be used. One health worker explained as follows:

> "It's not the same, things have changed but somewhere, maybe because we haven't mastered it yet, or sometimes its just one person doing it others aren't there, then for the women to go home, they go very late, delaying is there. So maybe if we all put our heart to it and things are going well, maybe the delaying will be reduced. Because they are entering on one system the

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*other one isn't working so things can't go well…. If both were working things can go well but the
problem is that those who were trained it's not everyone who puts in effort"* [Interview, July
2013]

Another health worker perceived the delay to be due to services starting late in the day. The delay in
service delivery was also expressed by the ANC clients. One client explained as follows:

"*In my opinion, the system makes it slow because last month when we came, we left in the
evening, it was even getting dark"* [Interview, July 2013]

Some of the health workers also perceived the EMR to have increased the workload at the facility,
thereby making it time consuming. One health worker explained as follows:

"*We see that there is more work because they have to be entered in the register and then in
the system after that so it's like it takes time. But maybe if we stopped using the registers and just
used the system it may be a bit faster"* [Interview, July 2013]

The delays were also observed to be due to the fact that on subsequent visits, the health workers were
also entering data for the previous visits, particularly for clients who had started ANC when the system
was down.

Despite the indicated delays, some health workers were of the view that entering in the system was
faster than writing in the registers.

Knowledge of ANC work.

The hospital attendants and HSAs indicated that they had learnt some things about ANC from using
the system. One health worker explained as follows:

"*For example, when we were not writing in the register, we didn't know what happens, but when
we learnt on the computer and then when we see in the register we know that it's the same thing
we were doing on the computer. For example when a woman comes at 5 months, knowing that
the baby has this particular position or how things are, we learnt it there."* [Interview, July
2013]

The HSAs also indicated they knew more information about Antenatal care which was used to give
advice to the women in the field, for instance, when facilitating safe motherhood groups in the communi-
ty.

"*For all the trimesters we know how the child is supposed to be based on how the nurses write
like heart beat etc., that the woman is supposed to have 4 visits, the 5th one is optional, all of this
we knew here, and what they are supposed to get when they come."* [Interview, July 2013]

However, another hospital attendant explained that the knowledge was somehow the same but what was
different was that they made sure they collected some information that they were not asking before, such
as religion and education. This information was being collected because it was being entered in the sys-
tem.

Data storage.

The health workers perceived that the EMR had improved the storage of data because with the regis-
ters, the pages go torn, but with the system, the data would always be there as long as it was not deleted.
One health worker gave the following example

"*the registers get torn, for example the register that we've just stopped using, some pages fell
out and we can't find them, which means that we lost that information. While if it's in the system,
everything will be intact"* [Interview, July 2013]

Another health worker perceived the EMR to improve storage in that it was not bulky to keep data, it
could store data for many clients while for the same amount of clients, there would be 'heaps of regis-
ters'. Some health workers also indicated that the data could be easily retrieved from the EMR if someone
was looking for the information.

Data accuracy.

The hospital attendants and HSAs were of the view that the data in the system was accurate because of the checks and validations in the system. One of them explained it as follows

> "*Because those in the registers, sometimes when you mess up the numbers, you didn't know that you've messed up the numbers, you would just continue but in the system, when you mess up, the system tells you that you have made a mistake so you go back immediately. Whilst when you are writing with a pencil you just continue.*" [Interview, July 2013]

Another health worker explained that the data was reliable because data entry was

> "*on the spot, the owner is right there so you don't have to think what if I write this. If there is an error somewhere, you are able to go back to the nurse and find out.*" [Interview, July 2013]

One of the nurses also perceived that the data in the EMR was accurate because she perceived that the health workers were more serious when entering in the EMR rather than in the register book.

However, it was discovered that some errors were made in recording some data elements such as the HIV status. For instance, the health workers were capturing the HIV test results on subsequent visits as 'previous negative' instead of indicating that it was 'not done' on that visit. Errors were also made in capturing number of abortions because the nurses wrote it as a code that the other health workers did not understand, e.g. G2+1 meant Gravida 2, 1 abortion.

Data completeness.

Some of the health workers perceived the data in the EMR to be incomplete because of the gap in using the system when the system was down. Furthermore, the nurses also perceived the data in the registers to be incomplete because they noted that when women came to deliver at their facility, their health passports indicated they've had 4 visits or more, but in the registers, they would only find that two visits were recorded.

However, other health workers were of the view that an advantage of the system was that it provided alerts when there were missing data elements and therefore, all the required information was collected as shown in the quote below.

> "*it helps us because every information related to the woman, when we are entering, if we miss somewhere that is important, the system shows us that you've missed this, you're not supposed to omit this... so every important information from the client is collected unlike in the paper.*" [Interview, July 2013]

Challenges in using the EMR system.

There were several challenges in using the DHIS2 Tracker system that were identified. Some of the challenges have been presented in the previous sections. One of the challenges faced was that the system had been down for almost 2 months due to problems with the power system. This resulted in a back log of data that needed to be entered for that period.

Another challenge in using the EMR was on searching for clients in the system. It was observed that some of the users often forgot to indicate or change the search criteria i.e. whether they were searching by the name or ANC registration number. As a result, when searching, the client could not be found because it was searching on the wrong information. Another challenge with the search functionality was that sometimes the spelling of the names entered in the EMR was different from what was recorded on the health passport, for instance Idess vs Idesi. Thus, the client would not be found if the name spellings did not match. These challenges resulted in duplicate accounts being created for the same client.

In addition, it was noted that some of the users were not familiar with how to change the client attributes that were captured during registration. For instance, the users would discover that they captured the age of the client to be under 9 years old and as a result the client could not be enrolled into the ANC programme. Therefore instead of changing the age of the client, they would register the client as a new client, resulting in duplicate records as well.

Some of the health workers also faced challenges in connecting the devices (i.e. touchscreen, keyboard, mouse, network cable and power adapter). Some health workers indicated that sometimes, when certain health workers were not available, they often struggled to connect the devices or could not identify the source of a problem and therefore at times, they would end up not using the computer that day. This

was attributed to low education levels among some of the health workers. One of them explained as follows:

> "*the problem is that sometimes we are not able to know the problem properly, maybe the cable of the network has moved, we don't know that it has moved. Maybe this thing, you press with the buttons*[keyboard], *when you put it, sometimes it doesn't show the light, so we just say it's not working without really knowing what the problem is, because its like English -we don't know it very well. Because at first we didn't know what things mean, so now we are learning little by little.*" [Interview, July 2013]

Another challenge in using the system was navigating the computer. For instance, at times, the user would accidentally right-click the mouse and selected some option which led to a new window or tab being opened. The users were then unsure of what happened and how to proceed to get back to the system. One heath worker explained as follows.

> "*when we are entering the data in the system, sometimes you just find that we have opened another page, because we don't know it very well, so to go back to the right place properly it takes us time because we haven't mastered it properly. So sometimes we might say the computer has broken down when it's not, but it's just because we don't know where we should press. So that might lead to not using the computer that day and we just write the clients details on a paper.*" [Interview, July 2013]

Another challenge indicated was the confusion between the password for logging on to the computer, and that for logging in to the DHIS2 Tracker system. The health workers indicated they had forgotten how to deal with the computer log on screen and if it appeared, they ended up not using the computer that day.

5   Analysis and Discussion

The previous section presented the actual use of the EMR systems in the two rural health centres, the perceived effects of the systems on Antenatal care work, and challenges encountered in using the systems. There are several differences that exist between these two use cases that should be noted. The software used was different in terms of the interface design whereby the Baobab ANC system had each screen dedicated to capturing one data element, while the DHIS2 Tracker had forms with multiple data elements. The data entry was through the touchscreen for the Baobab ANC system, whilst the DHIS2 Tracker system implementation had a mouse and keyboard. The Baobab ANC system allowed for printing of the entered data on label stickers while the DHIS2 Tracker system implementation did not provide for printing. In addition, in Health Center A, a point of care approach was adopted for system use, similar to the cases of Douglas et al. (2010) and Castelnuovo et al. (2012); while in Health Center B, it was more of retrospective data entry, which is more common (Oluoch et al., 2012).

Furthermore, the organisation of the services was different in that specific days were assigned for ANC at Health Center A, while in Health Center B, ANC was provided throughout the week together with other services. The staffing levels were also different, for instance, two hospital attendants were usually on duty during the day shifts in Health Center B, while in Health Center A, only one was available per week for both day and night shifts. Health Center B also had three nurses available who took weekly shifts while in Health Center A, only one nurse was available at the health centre and therefore she was never off-duty. Considering these differences, it is challenging to discuss which EMR system is better solely based on the perceived effects, as these effects are the result of the combination or interrelation of the social and technical aspects within that setting.

However, this is not to imply that there are no similarities in the effects between the two cases. For instance, introducing the EMRs was perceived to have increased the knowledge of other cadres of health workers (i.e. HSAs, hospital attendants, clerks) on Antenatal care work in both implementation cases. Furthermore, some of the perceived effects relate to issues that have been identified in previous literature as the areas which EMRs can have a positive effect (Rotich et al., 2003; Fraser et al., 2005; McKay & Douglas, 2008; Blaya et al., 2010; Castelnuovo et al., 2012). In particular, these are issues of efficiency of the care process (i.e. time taken); the data quality in terms of accuracy and completeness; and the management of data i.e. data storage. The health workers perceived the EMR systems to improve data storage

in both implementation cases. However, there were mixed views on whether the systems had a positive or negative effect on efficiency and data quality. In the Baobab ANC EMR system implementation, the health workers perceived service delivery to be faster with the system in place and some clients had the same view. However other clients were of the view that things were slower with the system in place. Whilst, in the DHIS2 Tracker implementation, health workers and clients perceived that there was a delay in ANC service delivery with the use of the system. In terms of the data quality, there were different views on whether the electronic data was accurate and complete. In the Baobab ANC implementation, a general view among the health workers was that the client data captured was accurate and complete, even though they acknowledged existence of some errors in some cases, such as the obstetric history, visit numbers, double registration of clients, and drug miscalculations; as well as some missing data. In the DHIS2 Tracker case, some of the health workers perceived the captured data to be accurate but incomplete because data had not been entered when the system was down for almost two months.

It is, therefore, important to examine the underlying reasons for the perceived effects which provide more insight to the types of changes that occur when EMR systems are introduced or are in use. Therefore, below, I discuss the changes in Antenatal care services from the two EMR system implementations along the dimensions of work, attention and risks, as proposed by Vikkelsø (2005).

5.1   Work redistribution

According to Vikkelsø (2005), introducing EMR systems can lead to redistribution of work with some work tasks disappearing while others may emerge. As already indicated in the findings, in the Baobab ANC EMR case, the introduction of the EMR system in Health Centre A led to radical changes in the distribution of Antenatal care work among different types of health workers at the facility. Before the EMR, the nurse performed most of the tasks but following the introduction of the EMR, the HSAs, hospital attendants, statistical clerk were assigned the tasks of history-taking. In this way, the health workers perceived that the workload was reduced for the nurse, but on the other hand, the workload was also increased for the other health workers. In addition, new tasks were introduced as a result of the system such as the registration of clients into the system, which was given to the HSAs, hospital attendants and the clerk. The clerk also assumed a new role as a super user responsible for creating new users into the system and generally functioned as the local support provider.

In the case of the DHIS2 Tracker system, the tasks of registering clients and entering their visit data were added to the ANC process. The responsibility for these tasks was shared among the nurses, hospital attendants and HSAs; however, the evaluation revealed that it was only the attendants and HSAs who performed these tasks. Thus it could be said that the workload was mainly increased for the attendants and HSAs but not the nurses.

In this regard, the introduction of EMRs, in both cases, came with additional tasks such as the client registration. However, the Baobab ANC EMR was designed to replace writing in the health passports and had a printout produced instead. In this regard, data entry was not to be an additional task that increased the workload, but rather it was to replace writing, hence the overall workload (in terms of data capturing) was expected to be the same. On the other hand, the DHIS2 Tracker system implementation was not aimed to replace writing but rather data entry was an additional task to writing in the health passports, therefore it can be considered to have increased the overall workload (on data capturing).

Nevertheless, an emergent consequence of introducing the EMR systems in both cases was that collaboration between different types of health workers increased at the health centres, for instance, the HSAs became more involved in ANC service delivery. Hence the nature of Antenatal care work became more collaborative with the activities occurring more concurrently rather than in a linear workflow. Intrinsically, this also meant a need for more coordination between the health workers in performing the ANC work.

5.2   Organisational attention

The introduction of EMRs can weaken or strengthen the attention on certain aspects of care (Vikkelsø, 2005). In the Baobab ANC case, introducing the EMRs increased the attention of some of the health workers in ANC since most health workers had never used computers before and this was considered a chance to learn how to use one. For instance, some health workers indicated that other health workers mainly assisted in the EMR-related tasks but not recording in the register book. Similarly in the DHIS2

Tracker case, some health workers indicated that they used the system because they really wanted to master the computer.

In the Baobab ANC case, the attention was also increased on specific ANC tasks, such as the history-taking, which was new to the other health workers and was often viewed as challenging to capture, as compared to the other details (e.g. weight, height). In addition, the increased attention on the history was noted by the clients who indicated that more questions were being asked as compared to previous pregnancies.

Another area that had increased attention, in both cases, was the LMP date. Prior to the EMR systems, the LMP could be left blank. However, following the EMR implementations, the health workers made more effort to obtain an LMP date as it was a mandatory data element in both EMR applications. Other areas where attention was also increased was the collection of demographic details such as the place of residence, education, occupation, marital status. The attention was also increased on the accuracy of some data elements due to validation rules that were incorporated in the EMR systems. As a result, the health workers were perceived to be more serious with data collection on the EMR than when entering in the registers as they would seek clarification on the data. This is similar to the observation by Castelnuovo et al. (2012) that EMRs can improve knowledge and awareness on data quality. However, this could also have reduced the attention on other data elements that did not have validation rules or that were not indicated as mandatory.

Furthermore, as already indicated, introducing the EMRs was perceived to have increased the knowledge of other cadres of health workers on Antenatal care work in general. The gained knowledge was not only used during ANC service provision at the facility but also in other areas of their work, for instance, in community level activities. Thus EMRs do not only change the level of attention on certain aspects, it can also improve the level of knowledge on the health domain. This is particularly true for rural primary care settings with limited qualified staff as deployment of the EMR requires the involvement of other cadres of health workers in addition to the main service providers (i.e. nurse/midwives in this case).

5.3   Redistribution of risks

EMRs are expected to reduce risks in healthcare work such as medication errors and data entry errors (Tomasi et al., 2004; Fraser & Blaya, 2010; Castelnuovo et al., 2012; Oluoch et al., 2012). However, Vikkelso (2005) indicates that EMRs may also introduce other risks. As previously indicated, in both implementation cases, the EMRs were perceived by some health workers to reduce the risk of making errors during data entry due to the validation rules. This has also been indicated in previous studies (McKay & Douglas, 2008; Castelnuovo et al., 2012). The EMRs were also perceived to reduce the risk of losing data due to lost health passports or torn register pages. Furthermore, in the DHIS2 Tracker EMR case, the risk of missing data for some data elements was also perceived to be reduced due to completeness checks on mandatory data elements. However, there were still risks of gaps and errors in some of the data elements that were not indicated as mandatory or those that did not have validation rules in the DHIS2 Tracker system. Similarly, the Baobab ANC EMR did not have completeness checks and therefore there were still risks of missing data for some data elements e.g. test results.

In the Baobab ANC case, shifting the history-task to other cadres introduced the risk of errors in the history captured, for instance, misdiagnosing cases as symphysiotomy or vacuum extraction cases; which was due to a lack of in-depth understanding of the medical conditions by the health workers. This, in turn, resulted in clients having false-positives on some of high-risk factors. On the other hand, this also introduced the risk of clients with actual risk factors not being identified during ANC. Introducing more details (e.g. symptoms) to be asked for some of the conditions is one possible way to assist the health workers in the diagnosing process. Other areas that also had errors were: in the prescription of drugs where it was noted that there were miscalculation on some drugs; and miscalculation of some data elements on the reporting form.

Another risk that was introduced in both cases was the risk of inconsistent data between EMR data and the paper records. In the Baobab ANC case, inconsistency between the EMR data and data in the health passports and registers occurred due to several reasons including challenges in correcting the data which led to data corrections being made on printouts only and not in the EMR or vice versa; and printing visit summaries before all the data was entered. In the DHIS2 Tracker case, a prolonged system down-time led to differences in the EMR data and data in the register book. Furthermore, in both cases, having all clients

registered in the EMRs at the beginning of the ANC process led to registration of clients who, for instance, had unconfirmed pregnancies or were visiting clients, whilst in the registers such clients were excluded.

In both cases, another risk that emerged was the double registration of clients in the EMRs. However, the risk of such errors seemed higher in the DHIS2 Tracker case due to the challenges health workers faced in searching for existing clients in the EMR as well as in challenges in editing or correcting the existing data. In the Baobab ANC case, availability of the unique IDs from the system and the barcode scanner reduced the difficulty in searching of clients.

6   Conclusion

The aim of this paper was to investigate the effects of EMRs on Antenatal care services in rural primary care facilities in Malawi. The paper therefore contributes to the body of knowledge on effects of implementing EMR systems in rural primary care settings of developing countries. I have presented a qualitative cross-case analysis of the effects of two Antenatal Care EMR systems implemented in two rural health centres in Malawi.

The findings show that some of the perceived effects relate to issues of efficiency, data quality and data storage which have been identified in previous studies from Developing countries. However, it is challenging to conclude in general whether the services were more efficient, or if the data quality improved due to the redistribution of attention and risks that occurred. For instance, while the attention and accuracy may have improved on some data elements, there were errors that occurred on other data elements. Hence, the analysis shows how the deployment of EMRs introduces different types of risks in healthcare work and in data quality, rather than completely eliminating errors, due to challenges encountered. A common challenge faced by health workers in both cases was the ability to edit or correct erroneous data. This, therefore, highlights the need for designing EMRs that provide for easy correction of errors in the systems, bearing in mind the level of computer competency among the health workers and their high workloads.

The analysis also shows that the EMRs changed the work distribution among the health workers with some tasks being shifted to other cadres and new tasks being created as well. An unforeseen consequence was therefore increased collaboration among different types of health workers, as other cadres became more involved in the ANC work. This may be the case particularly in rural primary settings as the staffing levels of qualified health workers are low. Therefore, the Antenatal care work became more collaborative in nature simultaneously requiring the need for more coordination among the health workers. This implies that EMR system designs should support the coordination of work by ensuring that the health workers have the required access to the EMR (in terms of hardware); and the software design should facilitate awareness of the work done by other health workers. Furthermore, there is need for mechanisms at an organisational level for coordinating the work such as timetables.

The analysis also reveals that introducing the EMRs led to increased knowledge among other cadres of health workers, on the Antenatal care work, due to the increased collaboration. In addition, the attention on specific areas of Antenatal care work increased. Thus, introducing EMRs had the effect of increasing the organisational attention on ANC work at the health facilities. This implies that introducing EMRs can facilitate learning about the healthcare domain in addition to gaining computer skills.

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