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## Editorial of JHIA Vol. 2 (2014) Issue 1

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The *Journal of Health Informatics in Africa (JHIA)* was launched in 2013 as a major step forward for the health informatics community in Africa. Since the beginning of the HELINA (Health Informatics in Africa) series of conferences in 1993 and the later formal establishment of the HELINA association as the Africa Region of IMIA (International Medical Informatics Association), only one book of full-text edited conference proceedings had been published. Scientific papers on health informatics in Africa had been published only in general journals, mostly outside of the continent (Korpela, 2013).

The HELINA association decided to take a cautious approach on starting a scientific journal of its own, to ensure the sustainability of the effort despite it being completely based on voluntary resources. At least for the first couple of years, it was decided to publish two issues per year, one of which would be the edited proceedings of a HELINA conference and the other one an open-call issue. The association decided simultaneously to start to organize the conference annually, instead of the three year intervals initially decided on in 1993. This decision made HELINA conferences more in par with other IMIA conferences (AMIA, MIE, Medinfo) but also increased significantly the stress on restricted voluntary resources.

This issue starts the second volume (2014) of the JHIA. In accordance with the plan, it is an open-call issue containing of full scientific papers submitted to the journal and subjected to a double-blind peer reviewing process. Due to several unfortunate factors however, there was no public call for submissions and the editorial work on this issue started late. The editorial team thus wishes to express its gratitude to the authors – Marlen Chawani, Eustache Muteba, Aanuoluwapo Olajubu, Nima Shidende and their co-authors – for their activism for keeping JHIA on track. Well done, ladies, you have cleared the way for male researchers to follow your example in terms of both quality and initiative!

A major unfortunate factor, i.e. the Ebola epidemic, forced the HELINA 2014 conference to be postponed from October 2014 to March 2015. The second issue of volume 2 of JHIA, comprising the edited proceedings of HELINA 2014, will thus be published as a late issue. This also means that there will be no HELINA 2015 conference and consecutively both issues of JHIA volume 3, 2015, will be open-call issues.

### Reference

Korpela M. Two decades of HELINA conferences: A historical review of health informatics in Africa. *IMIA Yearbook of Medical Informatics* 2013: 197-205.

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## Coordination Challenges in Collaborative Practices in the Prevention of Mother to Child Transmission of HIV in Tanzania

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**Background and Purpose:** This paper describes some of the complexities that face health service provision in developing countries, with the motivation to inform design of appropriate information systems. In particular, we are interested in a better understanding of the challenges to coordination and collaboration between health staff that are located in different facilities and employed to work in different health programs.

**Methods:** The study reported and analyzed in this paper was conducted in two districts in Tanzania. Using ethnographic data collection methods, we studied health workers' practices of coordination and collaboration in Prevention of Mother to Child Transmission (PMTCT) services in Tanzania.

**Results:** In our study we describe the collaboration required when managing patient trajectories of PMTCT patients across facilities and programs, and how contingencies may change the course of a patient trajectory. We provide a rich empirical description of coordination work in a resource constrained setting and we propose improvements to the design of both computer and paper-based information systems.

**Conclusions:** The rich empirical description of coordination work in a resource constrained setting and our analysis of coordination challenges contribute to a better understanding that can strengthen collaboration and thus also improve health care provision.

**Keywords:** Patient-Care Information Systems, Collaborative Practices, Coordination Mechanisms, Coordination Artefacts

### 1 Introduction

While management information systems have received much attention in the health informatics literature of the developing countries, recently there is a focus on designing and implementing computerized patient information systems that are intended for tracking individual health problems and treatment over time (WHO, 2012). For instance clinical information systems for HIV care in outpatients, and inpatients clinics (Fraser et al., 2007; Kamadjeu, Tapang, & Moluh, 2005; Oluoch et al., 2012; Rotich et al., 2003). However, the design and implementation of computerized record systems is a complicated endeavour with many challenges (e.g. Berg, 1999b; Jones, 2003; Robertson et al., 2010; Safadi & Faraj, 2010; Vikkelsø, 2005). These studies for instance indicate that there is a main tension between existing work practices and new technologies. In this paper we contribute to understanding the challenge of designing patient information system by examining the existing work practices of tracking individual health problems and treatment over time. These practices require collaboration and coordination across facilities, health programs and in time along patient trajectories.

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Collaboration and coordination are key characteristics of health service provision (Berg, 1999a, 1999b; Reddy, Bardram, & Gorman, 2010; Schmidt, Wagner, & Tolar, 2007). Healthcare provision involves many professionals and often different specialties treat a single patient at the same time and location, or across time and locations (Reddy et al., 2010). Patient care develops as a trajectory in time that is partly shaped by the work of health professionals and partly emerges in a contingent way (Fagerhaugh & Strauss, 1997). Thus, the management of patient trajectory is a collective and cooperative effort of health providers where health practitioners not only have to inter-relate their work tasks, but also to know where the process of managing a patient's trajectory is (Berg, 1999b). When many health practitioners are involved in treating patients, patients' records are an important resource used to assess the overview of care provided (Berg, 1999b; Fitzpatrick, 2004). Patient records are repositories of patient information within an institution (Mønsted, Reddy, & Bansler, 2011). They perform a role of communicative artefacts between health providers and configure health care provision services, for instance by organizing consultations between providers and clients (Engestrom, Engestrom, & Saarelma, 1988; Heath & Luff, 1996). They also support administrative tasks (Garfinkel & Bittner, 1967). Moreover digitized medical records may have reminders which can prompt providers to perform due health care tasks (Mayo-Smith & Agrawal, 2007; Patterson et al., 2005). Further, Berg (1999b) asserts that both formal and informal aspects of patient records together with the work of clinicians are important for providing healthcare and supporting the collaborative work it entails.

Empirical studies conducted in a developing country context, have address the issue of collaboration in relation to the use of health information systems. For instance, telemedicine supports collaborative practices by facilitating communication between providers (sometimes with patients), the sharing of medical information, and also educational purposes (Bagayoko, Anne, Geissbuhler, & Fieschi, 2008; Bath, 2006; Geissbuhler, Ly, Lovis, & L'Haire, 2003; Mars, 2010; Martínez-Alcalá, Muñoz, & Monguet-Fierro, 2013). Geissbuhler et al. 2003 describe a telemedicine project in Western Africa that facilitated collaboration between Malian practitioners and practitioners at Geneva University (Geissbuhler et al., 2003). Other studies examine collaboration in the context of software development activities for health systems between different ICT specialists located in different settings (Korpela, Mursu, & Soriyan, 2002; Saugene, 2013; Saugene & Kaasbøll, 2013). However, despite the focus on collaboration, researchers in health informatics have given less attention to the understanding of collaborative practices during ordinary health service provision. Health practices in a developing country context often cut across multiple health programs provided in a dispersed and distributed setting and with limited resources, and require complex coordinative and collaborative work in order to be performed.

In this paper we aim to empirically describe and examine the complexities of collaborative work practices. Our study focuses on the work practices of healthcare providers in a cross-setting collaborative practice, and their use of patient-oriented artifacts. Specifically, our empirical material comes from research in the context of prevention of mother to child transmission of HIV (PMTCT) program in Tanzania. In this context we have empirically studied the collaborative practices of healthcare providers and the trajectories of HIV-positive pregnant women. These trajectories develop in time, across facilities and often across other health programs. In our analysis we pay particular attention both to information artefacts used in the facilities to track patients, and to those carried by patients themselves to bring information from one provider to another or to keep track of their visits. Our argument, based on CSCW research, is that the design of patient-care information systems should be based on understanding the collaborative practices of those actually working with patient information during ordinary health service provision and 'doing' the coordination work of patient trajectories. Our aim is to improve the understanding of coordination in collaborative practices and its associated challenges in healthcare provision in a resource constrained context, and to draw design implications for patient-oriented information systems. The following question is addressed in the study: What are the challenges to coordination in collaborative practices and what are the implications for the design of patient information systems as coordinative artefacts?

The rest of the paper is structured as follows. First, we review the relevant literature from CSCW and we present key concepts that are used in this study. Then, in section 3, we present the research context and research methodology. This is followed by the case description in section 4. Section 5 presents our findings and implications for design, and section 6 our conclusions.

## 2 Literature Review and Theory

Our theoretical approach is based on concepts from studies in Computer-Supported Collaborative Work (CSCW). The aim of the CSCW field is to understand the nature of cooperative work in its natural settings with the objective of designing computer based technologies to support work practices (Schmidt & Bannon, 1992). People engage in cooperative work when they are mutually dependent in their tasks and therefore are required to cooperate in order to get the work done (Schmidt, 1991). However, tasks interdependencies are tractable only if appropriate coordination mechanisms are in place (Schmidt & Simonee, 1996). A coordination mechanism is “a coordinative protocol with an accompanying artifact such as for instance a standard operating procedure supported by a certain form” (Simone & Schmidt, 1998, p. 295). Actors participating in cooperative work are assisted by coordination mechanisms in managing an otherwise overwhelming complexity (Simone & Schmidt, 1998).

In healthcare, collaborative practices are often mediated and supported by artefacts and coordinative protocols (Berg, 1999b). For example, coordinative artifacts support activities such as marking, checking, reading and writing and contribute to coordinate activities of practitioners in time (Berg, 1999a). Many studies in the CSCW tradition have investigated empirically the use of coordinative artefacts in order to draw implications for the design of digital artifact for supporting collaborative work (Berg, 1999a; Bjørn & Hertzum, 2011; Reddy et al., 2010). Bjørn and Hertzum (2011) for example, examined the use of whiteboards in collaborative work practices of health providers, and draw implications for improving the design of digital whiteboards. Likewise, Bardram (1998) reports a study in a large Danish hospital where he studied coordination and planning of patient care, and informed the design of a computer system for planning and scheduling surgical operations, and for requesting and booking diagnostic examination at other departments. These studies show the relevance of understanding the actual work practices of healthcare providers in their work settings in order to draw insights for designing improved collaborative artefacts.

Research in the field of CSCW recognizes that the design and implementation of coordination artefacts is challenging. For example, Cabitza et al. assert that artefacts could be not rich enough to facilitate communication between participants (Cabitza, Sarini, Simone, & Telaro, 2006). The deficit in coordinative artifacts may lead to the development of informal artifacts (Mellini, 2013), or the development of workarounds (Gasser, 1986) or unintended practices (Fitzpatrick, 2004). For instance, Fitzpatrick (2004) describes how clinicians tailored and augmented patient records in order to support their own role and practices. Safadi and Faraj (2010) show how workarounds emerged after the implementation of an EMR system in an ambulatory clinic in Canada. For instance since the software did not allow adding new disease to a list of favorite diseases, clinicians recorded diseases in the medical history of the patient. The study shows how workarounds carry rich knowledge about the needs of the users and the required customizations of artefacts.

While healthcare work has received considerable attention in CSCW studies less attention has been given to studying healthcare work in resource constrained settings. In a recent article reviewing 25 years of publications in CSCW in healthcare, Fitzpatrick and Ellingsen assert that “the developing world presents a very different context for CSCW research and design - reliable infrastructure cannot be depended on, markets are less vendor dominated, and there is significantly lower access to resources than in the developed world” (Fitzpatrick & Ellingsen, 2013, p. 33). However, in CSCW few studies reports from empirical cases conducted in such ‘different’ context. Specifically, in their review Fitzpatrick and Ellingsen have found only three publications reporting studies conducted in Africa (Fitzpatrick & Ellingsen, 2013). In the first study, Cheng and colleagues assess residents’ attitudes toward the use of handheld computers in the collection of HIV/AIDS survey data in Angola (Cheng, Ernesto, & Truong, 2008). They compare residents’ attitudes toward handheld computers with their attitudes toward the standard mode of data collection, paper surveys. The authors conclude that computerized data collection in Sub-Saharan Africa may lead to biased reports of HIV/AIDS-related risk behaviors, when compared to the traditional method of paper-and-pencil surveys due to social-economic factors. In the second study, DeRenzi and colleagues discusses how to facilitate management of child health through the design of software, specifically a Personal Digital Assistant (PDA) system which would help clinicians make decision and adhere to child treatment protocol (DeRenzi et al., 2008). During their study in Tanzania which focused on human-computer collaboration, some features from PDA software had to be redesigned in order to match the observed human-PDA collaborative practices. In the third study, Luk and colleagues

describe how providers collaborate with the use of telemedicine in Ghana and provide principles to inform the design of telemedicine systems in developing regions (Luk, Ho, & Aoki, 2008). The remote system enabled doctors to enter medical case information into a distributed repository and then requesting a consultation from a pool of medical specialists. As illustrated in these three studies, in health care service provision, coordination is important and can be improved by designing and implementing digital information systems. Hence challenges to collaboration and coordination in context with less resources and infrastructures need more attention, empirical research and understanding. In this study, we aim to contribute to understanding challenges to collaboration based on a study of maternal and child health care in Tanzania.

### 3 Research Setting and Methodology

This study is part of the Health Information System Program (HISP) which is run by the Department of Informatics, University of Oslo. The primary goal of HISP is to enhance the information use behavior of health managers, planners and workers, in the health sector of developing countries, by strengthening local professionals' capacity, for the development of a sustainable HIS (Braa, Monteiro, & Sahay, 2004). HISP has developed software known as DHIS (District Health Information Software), which is used to manage data in various levels of the health sector. Recently, HISP has focused on developing patient-oriented information systems (known as the DHIS Tracker module) which could be used for managing name-based patient data and also for providing reminders and alerts to practitioners and clients (Gizaw, Mukherjee, Lewis, & Sahay, 2012; Saugene, 2013). Our study contributes to HISP by providing an empirical understanding of the existing information practices in order to design patient-oriented information systems.

The study reported and analyzed in this paper was conducted in Tanzania, in Kitangili and Singidani districts<sup>1</sup> in Dodoma Region. The HIV prevalence among pregnant mothers in Kitangili and Singidani districts are 2% and 8% respectively. In Tanzania, primary health facilities (dispensaries and health centers) are responsible for health care provision such as curative, preventive, promotive, rehabilitative and palliative care to the population. Tanzania, is striving to reduce the impact of HIV pandemics by using various interventions, such as, prevention of mother to child transmission of HIV (PMTCT). Within the PMTCT program the aim is to prevent transmission of HIV/AIDS from the HIV positive pregnant women to the children. Based on guidelines from the World Health Organization (WHO), the program offers interventions during pregnancy, birth and breastfeeding period. One of the operational targets to be achieved by the year 2015 by the Tanzanian Government is to have PMTCT services provided to at least 80% of pregnant women, their babies and families. Comprehensive intervention for PMTCT services involves multiple clinics such as maternity care clinics, HIV/AIDS clinics (CTC), tuberculosis (TB) clinics (in case pregnant women develop TB infection), and clinics for children up to 5 years of age.

The data collection for the study was conducted during three periods: August 2011-January 2012, July – August 2012, and November 2013-April 2013<sup>2</sup>. Eleven primary health facilities offering maternal and child healthcare services were researched. The study design was inspired by multi-site ethnographic (see for example Madden, 2010; Marcus, 1995; Blomberg & Karasti, 2013; Nicolini, 2013). This approach was useful for gaining a deeper understanding of the work practices in different places, albeit being difficult to travel to geographically dispersed facilities in the two districts. The main data collection technique employed was participant observation by the first author with her role altering between observer as participant, and participant as observer (Bryman, 2012). In total, 101 sessions of observations were conducted in health facilities with each lasting between 3 to 7 hours. Observations were conducted in antenatal sections, maternity care clinics, children clinics, HIV clinics and one TB clinic. We performed in-situ interviews (Jordan and Henderson, 1995) in Kiswahili language to health providers in facility and Community Health Workers (CHW). In total we encountered 42 nurses, 13 doctors, 5 data clerks, 2 patient-tracing coordinators<sup>3</sup>, and 6 CHW who were involved in PMTCT services.

<sup>1</sup>The actual district names are not disclosed.

<sup>2</sup>The fieldwork was conducted as part of PhD work and it required spending at least one year in the field settings.

<sup>3</sup>Community health workers who coordinate defaulter tracing activities in certain facilities

We also studied and reviewed artifacts which were used to organize the collaborative work of service providers during health service provision. Artifacts reviewed included clients’ cards, clients’ folders, referral forms, laboratory forms and facility registers. We examined the artifacts to understand how they facilitated collaborative work by making visible work of others and coordinating one’s own work. We also conducted informal interviews with 5 (4 women and 1 man) clients<sup>4</sup> who gave oral consent first to health providers and then to us. The theme of the interviews was their experience of going to multiple settings carrying coordinative artifacts, as for instance patient cards and referral forms. The efforts to involve more clients did not bear fruits since in some cases nurses disapproved or we sensed that clients were not in good state or unwilling to cooperate. For instance, we arranged some appointments where clients who had agreed to be involved did not show up. Thus, most of our data are based on observation of meetings between nurses and clients in which we listened to their conversations, took notes, and observed information practices when clients’ information was registered or retrieved in different programs and settings. In addition, we reviewed several policy documents such as Tanzanian Health Policy, Reproductive and Child Health (RCH) Strategic Plan, PMTCT guidelines, Home Based Care (HBC) service guidelines, national guidelines for the management of HIV/AIDS and HIV Act and policy. These documents gave us background information about PMTCT healthcare provision protocols.

To get a better understanding of the observed coordination practices, we also interviewed coordinators for the health services supporting maternal and child health and HIV/AIDS services at district, regional and zonal<sup>5</sup> levels. A summary of the interviewees in relation to their program of affiliation and their work places is presented in Table 1.

**Table 1.** Summary of interviews at district, regional and zone levels

Location	Type of informant	Number of informants	Total number of interviews (with repetition)
Kitangili	RCH	3	9
	HIV/AIDS	2	4
Singidani	RCH	5	11
	HIV/AIDS	3	8
Regional	RCH	2	3
	HIV/AIDS	1	1
Zone	RCH	1	1
Total		17	37

The empirical study was approved by University of Dodoma<sup>6</sup>’s Research and Publication ethical committee. Ethical concerns were taken into consideration during fieldwork, for example, through gaining written permission prior to the fieldwork from both districts managers, and obtaining oral consent from health workers and clients prior to conducting interviews or observations. We have also changed the name of clients as well as districts and facilities in order to provide anonymity.

The study employed an interpretive approach for data analysis (Walsham, 1995). Notes were taken during fieldworks and later transcribed. Some interviews with nurses were recorded and transcribed. Field notes were read several times in order to obtain an understanding of the data, and concepts of cooperative work, patient trajectory, coordination mechanisms, and coordinative artefacts were used to make sense of the practices observed. Our interest was directed towards identifying and understanding the challenges faced by maternal and child health provision in coordinating their collaborative work. For instance, nurses during care encounters would interrogate or remind clients about attendance in other visits to check their compliance to health programs, but they would not have any formal way to check that attendance actually took place.

<sup>4</sup> The terms clients, pregnant women and patients have been used interchangeably

<sup>5</sup> Intermediary administrative level for several regions which is under the national level

<sup>6</sup> First Author is employee of the university.

In order to organize and analyze the material, we employed both inductive and deductive approaches. For the first level of analyses, we prepared “ethnographic descriptions” (Emerson et al, 1995) of work practices within and across health facilities in order to foreground collaborative practices. We then created narrative descriptions (Emerson et al, 1995) of work practices in maternal and child health settings that focused on how information artifacts in different units were used in the collaborative process. To prepare ethnographic description, we have worked with a characterization strategy (Van Maanen, 1988). We have combined the stories of multiple clients into the character of Joyce, obtained from our interviews with clients and our observation of interactions of nurses and clients for successful cases of clients’ compliance. In addition, we also used stories from interviews and observations to construct the characters of Prisca and MdalaMatonya. These two women’s stories showed different trajectories and exemplify unsuccessful cases of coordination. Van Maanen (1988) argues that this strategy makes it easier to tell fieldwork tales (p. 104). Thus we believe that the narrative descriptions and the way they are constructed improve readers’ understanding about the interactions between different units involved in PMTCT care, the use of coordinative artifacts and how they facilitate collaborative work.

#### 4 Case Description

This section describes how PMTCT service delivery is organized in practice and which coordinative artifacts are in use. Tanzania’s policies both for HIV and RCH indicate how clients should be attended by different health providers, and health authorities have provided specific coordination protocols. Yet, our description shows how protocols and coordinative artefacts are not always sufficient to coordinate work.

PMTCT interventions include testing and counseling for HIV, antiretroviral prophylaxis for HIV-infected pregnant women (and their partners) in antenatal care and their exposed children in maternity wards, treatment of eligible women, counseling and support for infant feeding, safer obstetric practices and family planning to prevent unintended pregnancies in HIV-infected women. The actual treatment of HIV/AIDS is conducted in cooperation with the general HIV/AIDS Care and Treatment Clinics (CTC). Not all health facilities would offer ANC, PMCTC and CTC services, and patient will then be referred to other facilities for one or more of these services.

In this context, PMTCT providers have three main information and coordination needs. First, as the PMTCT program covers the pregnancy and the first 18 months of a children’s life, PMTCT providers need to keep track of information over time. Second, during pregnancy HIV-positive women may also develop other diseases, for instance TB and may need to enroll in and comply with other health services providing testing, visits and counseling. In such cases PMTCT providers need to be informed about these services in order to adjust their treatments accordingly or to check that clients attend them. Third, attending PMTCT services often requires women to travel because many facilities do not host all sections. For instance a woman may attend services in a facility that has a maternity care clinic but not a CTC clinic. In addition a woman may prefer to attend a CTC clinic that is not in her residential area to avoid meeting familiar people. In these cases, health providers need to be informed also of the services delivered in other facilities. Thus PMTCT services are not delivered at the same point of care but across facilities and over a period of some years (from pregnancy and until the child is 18 months of age, and can continue to family planning services in the family planning section). The information and coordination needs are addressed by using various coordination artefacts, protocols and procedures. However, breakdowns in how information is recorded, updated, transmitted undermine coordination.

To show the complexity of PMTCT service delivery we have organized our case material according to the chronological order of events (HIV diagnosis, pregnancy, delivery and postnatal care) and we have used the stories of three women enrolled in the PMTCT program: Joyce, Prisca, and MdalaMatonya. Our main character is Joyce, a woman who is tested HIV positive and is enrolled in CTC services. Afterwards she becomes pregnant and is enrolled in ANC and PMTCT services. Next Joyce develops tuberculosis and is enrolled in TB services. In addition we use vignettes of other characters - Prisca and MdalaMatonya –two HIV-positive pregnant women who are enrolled in the PMTCT program but have a different trajectory than Joyce. In our description we focus on movements across programs and facilities, on instances of coordination work needed to deliver PMTCT services, and on information artefacts used to coordinate work. We also include in our description instances of breakdowns that we have observed during fieldwork. Our aim is to make visible the complexity of clients’ trajectories, the structure and use

of coordinative artefacts, the coordinative work performed by health providers and the coordination challenges leading to breakdowns.

#### 4.1 Diagnosis: from Outpatient to Voluntary Counseling and Testing (VCT) to Care and Treatment Clinics (CTC)

Joyce is a housewife living in the catchment area of H facility. In the year 2006 her health condition deteriorated and she decided to seek help. Joyce decided to go to the outpatient clinic at facility D, which was not located in her residential area but offered higher level services. The doctor at facility D suspected that she could be infected with HIV and referred her to the voluntary counseling and testing (VCT) section within the same facility. After a counseling session, Joyce was tested and diagnosed HIV positive and referred to the CTC unit (i.e. the HIV clinic) within the same facility. The providers suspected that she might not be well prepared psychologically to deal with the diagnosis and that she could opt out of the service. Thus, one nurse personally escorted her from the VCT room to the CTC section.

At the CTC section she was given a CTC client retained card (CTC card) with a unique identification number. Then a patient folder (CTC folder) was created for her, with her name and the unique CTC number written on top of the folder. The folder was stored in the facility's archive. The folder contained Joyce's residential tracking form with contact information such as her treatment supporter name, community health workers name and phone contact, residential area, household leader, facility name and district name. Over time, whenever Joyce attended her visits, information about specific HIV care provided was recorded chronologically on the CTC2 patient record form, and doctors' notes about diagnosis and treatment (usually written on plain paper) were added in the CTC folder. In the folders, the clients would have multiple CTC2 forms and it is likely the clients will have multiple client retained cards since HIV requires life long service provision. This folder stored also results from lab test that were prescribed when required, for instance TB or malaria tests (one paper sheet per test conducted).

The CTC folder is a central artefact for coordination on various levels. First, some information is used for coordinating activities across services: some forms are used to record– and thus make visible – information about services from other sections involved in treating the client. For example, in the CTC2 form client's status with respect to pregnancy and TB services are recorded. Second, the patient folders' information is used for tracing defaulters (i.e. clients who do not show up for their appointments): the folders contain forms that trace attendance of clients in the CTC clinic and they can be browsed in order to identify clients who had missed their appointment. Once the clients are identified, the folders can be sorted according to reasons for missed appointments.



**Fig. 1.** Example of patients' folders grouped according to their status.

For instance, figure 1 shows how patient folders are stored on a shelf in one of HIV clinic section. The folders are organized in three groups: deceased, transferred, and missed appointments (called “lost to follow up”). This sorting of the folders makes visible the load of patients not coming to appointments and that need to be traced. Nurses can trace them by using the contact information form. They may call mobile phones or ask the community HBC provider to contact them.

Third, information contained in the clients' folders is also used as a resource for reporting both locally and across levels. For instance, aggregated reports are created on quarterly basis and sent to district coordinators for monitoring, evaluation and planning purposes. In addition, facility reports are used locally for coordinating health service provision within the facility. For instance Figure 2 shows a report with the overview on clients' appointments and registered attendance in one facility. The local reports are used by facility management for getting overview of defaulter tracing activities and coordinating appointment and attendance of clients.

S/NO.	ARV STATUS						GRAND TOTAL
	ADULT CTC			PAEDIATRIC CTC			
	Y	N	TOTAL	Y	N	TOTAL	
1. Scheduled Clients (Adult and Children)	1212	117	1329	50	31	111	1440
2. Scheduled Attended	1064	71	1135	20	22	42	1177
3. Unscheduled Enrolled Attended	251	27	278	11	4	15	293
4. Unscheduled New cases	0	24	24	0	1	1	25
5. Unscheduled Transfer In	11	3	14	1	1	2	16
6. Unscheduled On transit	72	14	86	1	0	1	87
7. Total attended	1407	145	1552	33	27	60	1612
8. Transfer Out	18	0	18	1	0	1	19
9. Missed Cases	136	20	156	1	0	1	157
10. Clients returned in this month	17	2	19	0	0	0	19
11. DEATH			3				3
12. PMTCT							

Handwritten notes below the table include: 'SCHEDULED TIME AS REBLOCKING SYSTEM 1157', 'UNSCHEDULED TIME 84', and 'F. Planning Rep'.

**Fig. 2.** Sample page of a report used locally in one facility

The above description illustrates how the patient folder functions as a coordinating artefact for treatment, as well as a resource for tracking and reporting. The description also shows how providers may need to engage in additional coordination work in the form of extra activities to take into account contextual issues and support the collaboration between services. For instance, Joyce was not sent alone with the referral form to the CTC section, rather a nurse chose to escort her so that she should not abscond. The act of escorting implies extra use of resources: the nurse escorts the client instead of attending clients sitting in the waiting area.

A different trajectory to CTC services was that of Prisca. Prisca is a client who attended facility S for her antenatal care. She was diagnosed HIV positive and since S facility did not host a CTC unit, she was referred to R for CTC care (5 kilometers away). She was given a referral form. However, Prisca did not accept to be labeled as HIV positive. She stopped going to antenatal care at S and she did not go to R. Unfortunately, her health condition worsened and she decided to seek medical services. Remembering her case at S, Prisca decided to go to R to get treated but acting as a new client, not referred from S. The doctor on duty suspected that she might have HIV, and decided to conduct provider-initiated HIV testing. Prisca then confessed that she had been diagnosed positive earlier at S antenatal care. Through more questions, doctor learned that Prisca had torn the referral form. He further counseled and directed her to CTC unit escorted by a nurse. However, Prisca informed the providers that she would have preferred a distant CTC where she would not meet familiar people. Unfortunately, in that area like in most rural area

there was only one CTC and it meant that using other CTC would cost more in transport and time. Later Prisca attended PMTCT unit at S facility after providers at R linked her with provider at S.

This vignette illustrates not only the challenge of tracking patients due to the distributed and fragmented organization of the service, but also how service delivery relies on clients as carriers of information. Clients take actively part in the coordination of their care trajectories by carrying referral forms between facilities. However, if they do not comply with their schedules and treatments they also hinder coordination practices.

#### **4.2 Pregnancy: from Care and Treatment Clinics (CTC) to Antenatal care and PMTCT**

In 2009 Joyce, who had two children, became pregnant again. During one of her visits to CTC in the D facility, the provider realized that she was pregnant and inquired about her adherence to the antenatal care program. The provider learned that Joyce had not been to any antenatal checkups. The D facility had no antenatal care unit, and he advised her to attend antenatal care at her residential area, facility H, in order to facilitate frequent visits with low costs for transportation. The CTC provider then filled a referral form and gave it to her so that she could bring it to the antenatal clinic in her residential area (H). The referral form consisted of two parts on a single page. The first upper part was filled by the provider at CTC: the doctor wrote which health services Joyce needed. He also recorded on the form that Joyce had been on anti-retroviral therapy (ARV).

Afterwards Joyce went to H facility bringing with her the referral form and her CTC card. At H facility she gave the form to the health provider at the antenatal care unit, who, by reading the information on the form, enrolled her into the antenatal care (ANC) program. Enrollment consisted of creating a patient-record in the antenatal register which was kept locally in the unit, and issuing an antenatal card which was given to Joyce to keep it herself. Information from the referral form and CTC card were transcribed in the antenatal register and card, and specifically, her CTC number and information about ARV use. Joyce was also enrolled into the PMTCT program and her information registered into the PMTCT care register which was kept in the PMTCT unit. The unique number from her CTC1 card was transcribed into her record in the PMTCT care register. The alpha-numeric code generated by enrollment into PMTCT (PMTCT code) was also noted on the antenatal card. The presence of the PMTCT code on this card will indicate her positive HIV status to ANC staff. At the end of the visit, the health provider filled in the second part of the referral form and gave the form to Joyce to bring back to the CTC unit at the D facility.

Back at H facility, Joyce then had to undergo some tests related to antenatal care such as urine and blood check ups. Facility H has no laboratory and their clients are usually sent to perform blood and urine checks up at facility J. Joyce was given a laboratory request form and told to go to J facility or any nearby hospital that had a laboratory for analysis. Joyce opted to go to J facility and took the tests. The results were recorded on the laboratory form that Joyce passed back to facility H.

At one time during Joyce's pregnancy, providers at the CTC clinic in facility D suspected her to have tuberculosis (TB) symptoms. She was then referred, using a laboratory request form for TB testing, to another facility which had laboratory and X-ray units for testing TB infection. Joyce went to the TB testing facility, the test was performed and she was diagnosed TB positive. She brought back the form with her results to the CTC unit together with her X-ray picture. Providers at CTC then filled another referral form for TB care, and gave it to her to take it to TB clinic in another facility (the only one with TB services in the area). She then went to the facility with TB services and presented the referral form to the TB clinic providers. There at the TB clinic, she was enrolled into TB care. She was provided with TB1 card (tuberculosis identification card) and a record on her name was created in the TB register. In the TB register was also recorded information about her HIV status, ARV drug dose and pregnancy status. As part of the TB treatment regime, she had also to bring with her a treatment supporter who was given a treatment supporter card for monitoring Joyce's drug adherence during the treatment at home. Lastly, the care provider at the TB clinic completed the second part of a referral form which Joyce took back to the CTC clinic in facility D.

The above description illustrates how Joyce moves between facilities and health programs and related services. For instance when the practitioner saw that Joyce was pregnant, he started the process for enrolling her in both antenatal services and PMTCT services. First of all he interrogated Joyce about her status and her attendance to antenatal services. Then, he used the referral form to inform the antenatal service providers of the need to enroll Joyce, and he used Joyce to carry the form to its intended receiver.

Also, clients take actively part in the coordination of their care trajectories by carrying referral forms and laboratory results between facilities. Both referral and laboratory forms are examples of inter-facility coordination artifacts that are used to coordinate service provision across multiple facilities. These forms are particularly important in a context where facilities do not provide all services and do not frequently have laboratories for analysis. For example, a referral may be sent from PMTCT to CTC or from CTC to TB unit. These forms provide visibility of the services which has been done from the referring units and what needs to be done in the recipient unit. In addition, the forms provide a feedback channel. The second part of the form, which clients return to the referring facility, makes the provider aware that visits and tests have been performed in the recipient units. Thus, some information from the referral feedback form is used to update the client status, for instance regarding pregnancy or TB, in the facility register at the referring unit. Importantly, we saw the crucial role of Joyce for enabling the actual flow of these coordination artefacts. The client's compliance with the requirements and directives are fundamental if the coordinative artefacts shall work.

#### **4.3 From Antenatal to Delivery to Postnatal Care and Enrolling the Infant in the PMTCT and Vaccination Programs**

Antenatal care is scheduled with four visits during the course of a pregnancy. Whenever Joyce attended antenatal care at H facility, providers were alerted of her HIV status through the PMTCT code written on her antenatal card and they would remind her to attend the PMTCT clinic, located in the same facility. Also, whenever Joyce attended PMTCT services, the provider would inquire about her attendance to CTC at facility D. And whenever she attended visits at the CTC unit in facility D, the care provider by reading her pregnancy status from CTC2 form in the patient folder, would inquire about her attendance to antenatal clinic at H clinic. At one time, the care provider even asked Joyce to show her antenatal card in order to ascertain that she was attending antenatal visits as required.

At Facility H, the Reproductive and Child Health (RCH) service had no delivery unit. Thus, Joyce had to deliver at facility E. The nurse at E facility, by recognizing her PMTCT code on her antenatal card asked about ARV drug treatment. Joyce showed her the CTC card and the nurse read on her CTC card about her visits and ARV drug administration. The nurse concluded that according to the Tanzanian PMTCT protocol, Joyce would not need to take ARV during labor since she was already on ARV treatment. Joyce delivered safely a baby boy who was provided with ARV syrup. The nurse recorded into the delivery register the following information (but not limited to): ARVs dispensed during labor, infant's ARV doses, newborn feeding practice, and linkage to CTC. Joyce's antenatal card which had a section to record information about the delivery and child conditions was filled in. Finally, the nurse filled a referral form with information about the delivery and gave it to Joyce to bring it back to the CTC unit at facility D.

After the delivery, Joyce attended postnatal care at her residential facility H. The nurses used her antenatal card to copy information and fill her postnatal register including her and child's PMTCT and delivery information. Following the protocol, after six weeks the child was enrolled into the child health clinic in facility H. The child was registered into the children register and issued with a child health card. The providers on duty after recognizing PMTCT code in Joyce's ANC card also filled information related to PMTCT services to children. The child was also enrolled into PMTCT child follow-up health services and a record created in the PMTCT child follow-up register. Some information from Joyce's ANC card delivery section was transcribed into the PMTCT register. The child health card also contained a code (generated in children clinic) which communicate that the child is in PMTCT services (HIV exposed child).

The services of the children health clinic are offered for five years and include services such as vaccination, vitamin A, growth monitoring, and mosquito net distribution. Whenever Joyce attended the clinic as scheduled, providers by seeing the child's PMTCT code would remind her to attend also the PMTCT clinic. In PMTCT services, infants are tested for HIV infection at age of 4-6 weeks, 9 month and 18 month. Children are supposed also to continue with ARV drugs during breastfeeding time. In the PMTCT room, providers would also enquire about Joyce's attendance in CTC clinic. Sometimes they would ask her to show her CTC card so that nurses could verify what Joyce told them.

Joyce's baby was tested and diagnosed HIV negative at the first test. The PMTCT services were also challenged by resource shortage including shortage of referral forms which is one of coordinative

artifacts. However, during the time when the second test was supposed to be performed for Joyce's baby at facility H, there was neither HIV testing kits nor ARV drugs. This implied that Joyce had to be referred to another facility for her treatment. This was combined with shortage of referral forms. The breakdown was resolved by the nurse who instructed Joyce to tell the provider what services she needed at the other facility. Thus, Joyce went to the other facility where she was attended, and brought back the feedback to facility H.

The description above illustrates how providers articulate the collaborative work through various coordinative artifacts (e.g. PMTCT codes and CTC cards). The health workers practice of interrogating and reminding is an example of how coordinative work can be supported through coordinative artifacts. For example, PMTCT codes provide awareness of the HIV status and the linkage with CTC and PMTCT services. The patient card offers an overview of activities that have to be performed or that have already been performed in either this provider's section or in another section. The PMTCT code also facilitated nurses' awareness of tasks to be done in their location, e.g. in the delivery ward, and trigger coordinative practices such as reminding or inquiring clients. We also see how PMTCT information is recorded into different facilities' registers: antenatal, delivery, postnatal and children. Information recording in registers provides an overview of clients' usage of other health services: nurses can know that clients are attending PMTCT services or vaccination/antenatal services by using facility registers.

A different trajectory about reminding practices was that of MdalaMatonya. MdalaMatonya is a mother of twin boys who are PMTCT clients. She was diagnosed HIV positive during her pregnancy in the antenatal section of facility P and was enrolled into their PMTCT program. However, facility P offered limited PMTCT services due to lack of training to providers and does not have an HIV clinic, hence referring their clients to facility Q. MdalaMatonya was referred to Q and was enrolled into their HIV clinic, meanwhile she was attending PMTCT services at antenatal section of Q. After delivery, her boys were enrolled into the children clinic program in facility P and into PMTCT program in facility Q. In the meantime since pregnancy, MdalaMatonya had been attending facility Q for CTC services. One day when MdalaMatonya was attending CTC, a nurse (who also was responsible for PMTCT) inquired about the boys' attendance in PMTCT services. The nurse learned that the boys had not done a third HIV test and instructed the mother to bring the boys to PMTCT services the next day. The boys' children's card showed that they had attended all children visits in facility P. However, at the age of 20 months the boys had had only two HIV tests, while according to the PMTCT protocol they should have had three HIV tests. MdalaMatonya explained that no one had told her to bring the children for a third test. Through our studies in four children clinics (including facility P) and HIV clinics, we learned that nurses might forget to remind clients about their visits and tests due to high workload, and this may create breakdowns.

#### 4.4 Enrolling the Infants in the HIV Program

Joyce's baby was due for a third test and was diagnosed HIV negative. Because by the third test Joyce's child was 18 month, the nurse recorded 'discharged' on the remark column in the register. This meant that the child would no longer need to visit PMTCT. The nurse also informed Joyce that whenever nurses in children's clinic would ask her about PMTCT service, she was supposed to inform them that the child had been discharged from PMTCT services and that he resulted negative in all three tests. Nurses at the children's clinic used the child card to record the results.

The different trajectory was observed on the same day where another child (Baraka) of nine months tested HIV positive. This information was recorded in the child register and in the PMTCT child follow-up register. In addition, the nurse filled an infant referral form from PMTCT to CTC services. In the same town area there were four CTC units whereby one was just half a kilometer from H facility. Nurses advised the mother of the child who tested HIV positive to attend CTC in the clinic nearby. In this way she could conveniently combine children and CTC clinics on the same day. However, the mother disapproved of using the nearby facility since she would probably meet people she may be familiar with. She preferred to attend a more distant facility where she would also receive her CTC services. She proposed to ask the provider to combine her and child CTC clinics dates.

However, there was a problem regarding the infant referral form due to a mismatch between its design and existing work practices. The infant referral form had no feedback part, such as what the general referral form had. Figure 3 shows a form with a feedback part (on the left), and the infant referral form without a feedback part (on the right).

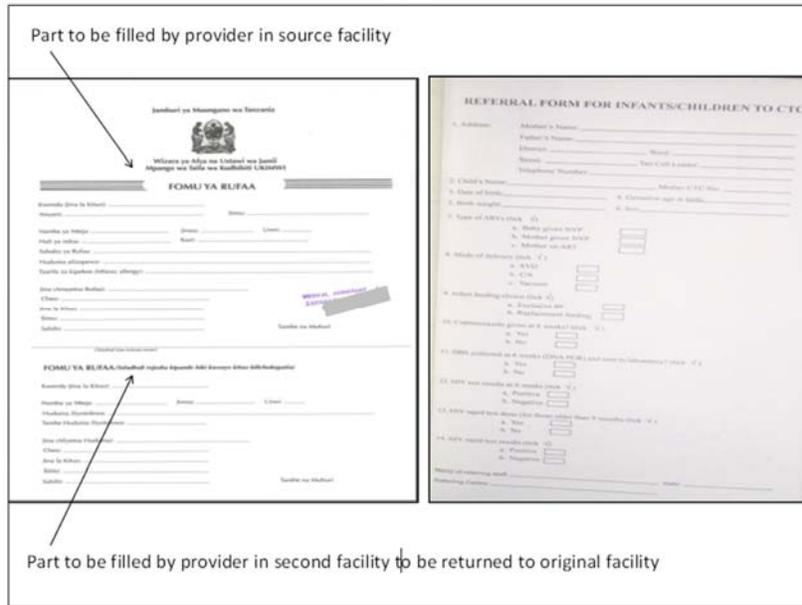


Fig. 3. General HIV form (left) and infant referral form (right).

The infant referral form has specific information about PMTCT services. The absence of a second part for feedback was not supporting collaborative practices. Despite the form not supporting it, feedback was assumed to happen; the registers had space for recording CTC number which would make visible that a client had been enrolled into HIV care. In Baraka’s case, the providers told the mother to come back with the CTC card so that information could be recorded in the register. The mother passed the infant referral form to the CTC unit and she came back with the child CTC card. Information such as CTC unique number was transcribed into the PMTCT child follow up register. From that time nurses in PMTCT were also inquiring about child attendance in CTC unit by seeing her records in PMTCT register.

As a result of this lack of feedback section in children’s referral form, in one urban facility with high number of clients, new information practices emerged. The health workers started to record all referred clients and their enrollment into the HIV/AIDS clinic even though these were recorded on papers. One health worker explained: “Some mothers do not come back to ascertain that they have joined the HIV/AIDS clinic. We have started to record their names so that we can make a follow up of their enrollment to HIV/AIDS clinic”. Figure 4 shows a page of referred clients in one register.

WATOTO WAUROPATA RUFUA				CTC			
TARUHU YA RUFUA	Namba ya DBS	TARUHU YA RUFUA	Majina ya watoto	Majina ya mama	Majina ya mama	Namba ya CTC	Other info
15/02/2013	[Redacted]	27/11/2012	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]
21/01/2013	[Redacted]	02/10/2011	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]
05/02/2013	[Redacted]	26/09/2012	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]
22/02/2013	[Redacted]	11/02/2012	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]

**Fig. 4.** A local registry to support tracking of children from PMTCT to the HIV clinic.

In other two facilities (located in the outskirts of the town), the practice was to combine in one register information about home based care services (for HIV/AIDS clients) and PMTCT information so that all children clients born from HIV positive mothers would be tracked in the community across time, along schedules of PMTCT services in case they do not show up to the original facility.

## 5 Discussion

In the previous sections we have described several trajectories of HIV-positive pregnant women and how information is collected, organized, stored and eventually retrieved by health providers. In the different stages of the trajectories, whenever a woman contacts or is contacted by a health provider, information is produced and correlated with previous collected information. For health providers is critical to be able to track women and monitor how their pregnancies and their HIV conditions are developing, and how well they comply with the PMTCT program. For instance, health providers check if women are attending their counseling sessions and periodical visits, if they are regularly tested, and if they are taking the prescribed drugs.

We have also described challenges in tracking women along their trajectories. Specifically we have focused on two main challenges. First, we have described how women visit several facilities when attending PMTCT services. This happens for different reasons. For instance in the case of Prisca, her home facility did not have a CTC unit and she was referred to another facility 5 kilometers away. In the case of Joyce her home facility did not have an antenatal care unit and again she was referred to another facility. In another case, MdalaMatanoya was referred to another facility because her home facility did not have a HIV clinic and trained personnel. Second, we have described how women receive care services from different programs. It is rare, especially in rural areas, that care facilities provide comprehensive services for CTC, TB care, antenatal and postnatal care, vaccinations and dispensation of ARV drugs. A pregnant woman who is tested HIV positive would need to be enrolled in both PMTCT and ANC, and perhaps other programs, such as TB. For instance Joyce was already enrolled in PMTCT services but needed also TB care. Her case illustrates how the work of tracking women's trajectories is usually performed within programs, and that there is little coordination across programs. In addition once the child is born he would also need care which belongs yet to another care program that may be offered in few facilities. This implies that women's information gets distributed across facilities and programs, and tracking becomes difficult. In this situation, health providers need to keep an overview of how services are interrelated, and where are they offered. For instance when possible they escort women to other parts of the facility offering another service. The case of Joyce describes how she was escorted from the VCT to the CTC section. Or they also give the option to choose a facility that is closer to the home area of the woman. In addition, women themselves collaborate in coordinating and supporting the communication across facilities and programs. As our analysis illustrates women carry referral forms, test results, and personal cards with them. They participate actively in the coordination of their own trajectories.

Our analysis also shows the different artefacts used to manage information in PMCTC services. Codes and unique patient numbers are important coordination artefacts that identify women and their diagnosis, and are copied from cards to referral forms to registers. For instance when Joyce went to delivery unit, the nurse was alerted by her PMTCT code on her card and inquired about her ARV drugs treatment. Other artefacts are referral letters which are used for ordering exams and visits in other facilities or units. These forms may also have a feedback part that is brought back to the health provider. For instance when Joyce was referred to a facility for antenatal care, she brought back the second half of the referral to her home facility. However, while artefacts are usually designed for tracking patients within programs and within a single facility, the design and use of cross-facility and cross-program artefacts meets challenges.

We have also described how breakdowns may happen and health providers may lose track of their clients. Women may intentionally not collaborate. For example, Prisca tore the referral form she was supposed to bring to a facility for PMTCT care. In another example Baraka's referral form did not have a feedback part. Thus the health provider had to ask the mother to come back again with the CTC card in order to register her CTC code and relevant information into the local register.

In the following section we discuss two key set of findings from our analysis of the case. First we discuss the complexities of coordinating work in a resource constrained setting and PMTCT care, and then we formulate implications for the design of patient information systems.

### 5.1 Complexities of Coordinating Work

As Schmidt states, people engage in cooperative work when they are mutually dependent in their tasks and therefore are required to cooperate in order to get the work done (Schmidt, 1991). In our study we have shown the collaboration required when managing patient trajectories of PMTCT patients across facilities and programs, and how contingencies may change the course of a trajectory. In the descriptions reported in our study it is evident that coordinating work across time (along clients' trajectories), across facilities (different locations), and across health programs (type of services) is crucial to PMTCT service delivery. However, patient trajectories are emergent and contingent, and in a resource scarce setting like in ordinary health provision in developing countries, coordination is challenging and prone to breakdowns. Furthermore, the nature of the disease contributes to the complexity of care delivery in PMTCT services, and to forming more intricate task interdependencies. HIV is a disease burdened with social stigma and some clients would rather travel to a distant facility than receiving care from their home health services. In addition other diseases are likely to develop, and requiring additional care, and the involvement of additional health providers. Thus, in our study we show how the complexity of cooperative work is increased not only by involving additional stakeholders from different health programs (for instance specialists in TB care), but also by stretching the trajectory to other facilities where clients would not be recognized. While the literature recognizes that the involvement of multiple stakeholders and diverse professional groups increases the complexity of cooperative work (Fitzpatrick & Ellingsen, 2013; Hartswood, Procter, Rouncefield, & Slack, 2003), and has examined the complexity of distributed settings (e.g. Hinds & McGrath, 2006; Olson & Olson, 2000), it has not addressed the challenge of unbounded distributed cooperative work. For instance the case of Baraka's mother, being in an urban setting, shows how clients can select one HIV clinic among many. However, the case shows also how it was complicated for the health provider to coordinate Baraka's mother's connection with her home HIV facility.

Coordination work relies on and it is mediated by artifacts and protocols (Bardram, 1998; Berg, 1999a, 1999b; Reddy et al., 2010). Our findings are in line with research showing the shortcomings of coordinative artifacts in complex healthcare settings (Cabitza et al., 2006; Gulube & Wynchank, 2001). In cases when coordinative artefacts fail to support cooperation, this might lead to the development of informal artifacts (Mellini, 2013). Differently, in our case additional coordinative work was needed due to the scarcity of resources (e.g. absence of referral forms, of test kit, of labs). There are cases when coordinative artifacts are just not available, and health providers have to come up with ways to deal with the situation. For example, in Joyce's case the health provider sent her to another facility for PMTCT testing services with oral instructions but without referral letter. Many studies point to similar challenges when discussing collaboration in developing countries (e.g. Geissbuhler et al., 2003).

### 5.2 Implications for Design

In this study we have foregrounded the complexities of collaboration and coordination. In this section we argue that based on our study we can draw important implications for the design of paper based and digital artefacts, and ultimately for improving health care provision. Specifically, we argue that some coordination breakdowns that we have observed could be avoided by improving those artefacts that are used in PMTCT health delivery.

First, the design of patient information systems should consider how patient artifacts support coordination work between different health programs. For instance, it is important that referral forms have a feedback part in order to support a two way communication between health providers and to ensure visibility between providers in involved facilities. Second, coordination work should be supported by improving coordination protocols and procedures. For instance, reminding practices should be enforced both within facilities and across health programs. This could be procedures where clients are required to show their different health services patients' cards where attendance is registered. Third, in the case of PMTCT services, we have showed how the coordination mechanism of clients carrying

information is vulnerable. In this case the coordination breakdowns observed in RCH, can not only be resolved through redesign of patient information systems tools (e.g. infant referral forms) or enforcing protocols (e.g. reminding practices for health workers). We suggest the need for creating complimentary coordination mechanisms based on a computerized patient system supporting horizontal coordination between health facilities. For example, the design of patient information systems would need to afford visibility and communication between groups involved in treating clients. In the case of the HISP program, the DHIS tracker, which is patient-oriented could facilitate users' communications through mailing lists i.e. queries for patients are sent to a list of all involved health workers in PMTCT care in different health facilities. The DHIS tracker displays (in a list) the email addresses of other users in other facilities so that a worker can find the address of someone and write to ask if the patient has come or not. The same strategy can be implemented at the district and regional levels where health facilities communicate to each other about clients' status on attending maternal and child healthcare.

## 6 Conclusion

Our study has addressed the following research question: what are the challenges to coordination in collaborative practices and what are the implications for the design of patient information systems as coordinative artefacts? Taking a CSCW approach we have described and analyzed several challenges. We have provided a rich empirical description of coordination work in a resource constrained setting and we have proposed improvements to the design of both computer and paper-based information systems. Our findings have contributed to understanding the coordination work to facilitate collaboration around health care provision. Future research could investigate more concrete solutions to the needs for appropriate coordination mechanisms through participatory design with the end users, in order to generate well-working solutions to the very practical and significant challenges we have started to illuminate in this paper.

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## Towards Networked eHealth: OMAT Project (Phase I)

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**Background and Purpose:** A longtime ago, malaria was one of the most challenging infectious diseases caused by the parasite called Plasmodium and localized in areas of Asia, Africa, and Central and South America. It has affected developing countries' human resources and directly lowered its annual economic growth. The project OMAT is an online system, eHealth networked, to assist physicians at medical consultation in order to optimize the quality of care of the patients with malaria disease.

**Methods:** Our clinical decision support system for treatment of malaria is based on consensus guidelines and protocols for the management of malaria. Thus, the system only deals with medical theory and practice identified in advance, limited and structured so for its efficiency and completeness. The OMAT system provides the diagnosis and therapy aids of malaria's disease. But also, a Geographic Information System database that will store and will provide relevant information on malaria's patient case of different regions for the optimization of malaria's treatment.

**Results:** The prototype system presented is related to the phase I of the OMAT project. The proposed solution, in form of web applications includes a Generic Medical Decision Support System and is expected to assist Healthcare Professionals at medical consultation and decision of the patients with malaria disease. The prototype are developed using PHP, XML, HTML, JavaScript and CSS as front end and raw files, MySQL and NoSql Data base as the backend.

**Conclusions:** The OMAT Project under the decision support system is expected to optimize quality of care. The solution we offer meets several requirements such as the reliability of the information entered, protection against handling errors and lack of dangerous results, with respect to confidentiality and anonymity. We envisage again to proceed to the integration of smart technologies that can allow remote clinical examination, complementary examination and tests.

**Keywords:** Optimization of Diagnosis and treatments of Malaria, Networked eHealth and Interoperability, Geographic Information System, Smart healthcare technologies

### 1 Introduction

A long time ago, malaria was one of the most challenging infectious diseases caused by a parasite called plasmodium. The overall disease burden is devastating youth, women and health systems. It has affected developing countries' human resources and directly lowered its annual economic growth.

Nowadays, it is recognized in most modern hospitals and public health systems, an increasing concern to measure the quality of care. The quality of care [1], can be focused on the characteristics of hospital production and the indicators of performance. These indicators of performance will permit to decrease complication rate, morbidity, mortality and cost of care. One of the ways to optimize the quality of care is to use medical decision support systems [2-5] based on eHealth and mHealth to serve the unserved [6]. "E-health is commonly understood as the application of Internet and other related technologies to improve the health status of patients. It covers a broad range of tools such as electronic medical records (EMRs), Telemedicine, online or e-Learning tools, and Decision Support Systems." [7].

Thus, the emergence of Internet and others related technologies such as mobile devices and particularly medical devices allow, more and more, the development of the paradigm of globalization. In

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this context, Mars et al [8] argue that “the globalization is no longer driven by power full governments, Countries or large multinational companies, but by the new-found of individuals to collaborate and complete globally. “ And also, talking about the so-called a "Glocal Perspective" they say: "the inherent networked and virtual nature of eHealth that enables it to transcend geopolitical barriers does not fit easily with traditional domestic or local health systems. In this sense, in the magazine “The Economist” [9], it is stated that “considering the massive challenges facing Africa's healthcare systems, several major reforms will be need continent-wide to ensure their viability in long term: tightening controls over medicines, medical devices, and improving their distribution."

This paper discusses our project called OMaT for Optimization of Malaria’s Treatment, which is an online system, an eHealth networked, to assist physicians at medical consultation and decision of the patients with malaria disease. The proposed solutions, in form of web applications include anonymous medical records, a Geographic Information System and other relevant services such as remote complementary examination and tests.

The project is subdivided in three main phases. On the first phase, the system provides a medical consultation of malaria from clinical examination, complementary examination to treatments. It is, at this stage, a generic decision support system without optimization.

The second phase concerns the GIS that allow the optimization of medical decisions. And the third phase is dedicated to the remote laboratory that can integrate medical devices for complementary examination and tests, and telemedicine.

## 2 Materials and Methods

Many existing systems of malaria decision support, we have served as the basis for our study. We quote: Malaria Decision Analysis Support Tool (MDAST) [10], Geographical Recognition [11] Malaria Decision Support System (MDSS) [12], Web-Based Medical Assistant System for Malaria Diagnosis and Therapy [13].

### 2.1 Malaria's Medical Diagnosis

In the following purpose we outline the generic protocols that are used in OMaT system for medical decision support.

#### Protocol 1: Clinical Diagnosis.

1. Patient available for consultation
2. Inquire about clinical history and symptoms
3. Make investigation
4. Probably malaria
  - (a) Yes, observe complication clinical features. Uncomplicated cases or Severe or complicated cases
  - (b) Ask a laboratory test to confirm the hypothesis
5. Probably not malaria
  - (a) Ask for a complementary examination
  - (b) Continue with others investigations

#### Protocol 2: Laboratory and Complementary Examination Diagnosis.

1. Patient available for testing
2. Testing is performed to help diagnose malaria, to monitor for relapses, and to determine drug susceptibility of the parasite causing the infection. It can be one of the following:  
Thick and thin blood smears and/or Rapid diagnostic tests (antigen testing) and/or Molecular tests (Polymerase chain reaction, PCR) and/or Antibody tests (serology) and/or Rolling Circle-Enhanced Enzyme.
3. Are malaria parasites present?
  - (a) If yes, which species and stages do they belong to?

- (b) If yes, how many of them are present?
4. Patient with complicated cases
- (a) Yes, do others laboratory tests and complementary examination following investigations

### **Protocol 3: Treatment.**

1. Patient available for treatment
2. Which species of malaria is reveal by the test? Plasmodium vivax or Plasmodium ovale or Plasmodium falciparum or Plasmodium malariae or mixed species
3. What is type of malaria is confirmed? Uncomplicated malaria or Severe malaria
4. Prescribe drugs following: Location of the patient, Condition disease (Pregnancy, Traveler, Newborns, Recurrent, ...), Age, Weight, Past medication and Allergy
5. The response to therapy is dependent generally:
  - (a) Medicines used (direct or indirect schizontocides), their dosage and route of administration;
  - (b) The parasite involved and the sensitivity of this parasite towards the schizontocides;
  - (c) The clinical and immunological status of the subject.
6. The characteristics of drugs are: - Name's drug - Presentation - Dosage - Duration of treatment - Indications – Drug incidents.

## **2.2 Optimization of Malaria Treatment**

The optimization of malaria's treatment is based on a Geographic Information System database that can stores and provides relevant information on malaria's patient case of different regions. The method is developed in [14] and consisted of height main steps: specification of the case, indications or problems, actions or treatments strategies, estimative outcomes (benefit and risk), performance measure, decision, result and optimization.

1. Specification of the case: case description relative to a particular patient in consultation.
2. Indications: a set of information related to problems concerning a particular patient.
3. Actions: The actions are different possible treatments referring to the given indications.
4. Estimative Outcomes: The estimative outcomes depend on the information related to similar patients' cases provided by clinicians. There are two kinds of estimative outcomes: the outcome with benefit and the outcome with risk.
  - Outcome with Benefit: expresses the degree to return to normal health.
  - Outcome with Risk: expresses the complication or the death.
5. Performance Measure: is a benefit-risk ratio referring to the action chosen by the clinician. This is obtained after computation of available information in the database.
6. Decision: The benefit-risk ratio can permit the clinician to make a decision. Practically, if the ratio is  $> 1$  then the action can give benefit otherwise, if the ratio  $< 1$  then the action has a risk.
7. Result: is the objective consequence of the decision chosen at the light of the performance measure. The patient can be in the following situation: a. Benefit, b. Risk. The physician can vote for one of the presented situation and the system automatically will be updated. This information may be considered sufficient and trusted.
8. Optimization: allows the clinician to analyze the results and if needed to readjust the actions.

## **2.3 Formalization of Reasoning in OMaT**

### **Formalization of Diagnosis and Therapy Aids.**

The diagnosis and therapy aids of OMaT are carried out using mainly the heuristic and the rule-based systems. The general form of rules is:

- Type of rule:  $R_n$
- Rule syntax: IF <CONDITIONS> THEN <CONCLUSIONS>  
CONDITIONS: <CONDITION1> [OPERATOR]

<CONDITION2> ...  
 CONCLUSIONS: ACTION1, ACTION2, ...

- Operator: OR, AND  
 - Criteria of condition: <=, >=, <, >, <>

This is below the basic rules:

1. Clinical Diagnosis Rules (CDR): represent the effects of a specific profile and a symptom or a set of co-occurring symptoms with respect to a hypothesis.

CDR: IF PROFILE AND (<SYMPTOM> AND <SYMPTOM-CONDITION>)  
 THEN <INITIAL- DIAGNOSIS>

2. Test Rules (TR): represent the effects test analyzed with respect to a test result.

TR: IF <TEST> AND <TEST-CONDITION> THEN <TEST-RESULT>

3. Medical Decision Rules (MDR): represent the effects of clinical diagnosis and test results with respect to a hypothesis.

MDR: IF < INITIAL-DIAGNOSIS> AND <TEST-RESULT> THEN  
 <DIAGNOSIS>

4. Therapy Rules (ThR): represent the effects of diagnosis with respect to a prescription

ThR: IF <DIAGNOSIS> AND <THERAPY-CONDITION> THEN  
 <PRESCRIPTION>

### **Formalization of Optimization.**

The pre-processing of optimization can be doing as following:

- Each patient case at time t is represented by an attribute-value vector:  
 P= [UserId : V1, PatientId: V2, Sex:V3, AverageAge:V4, AverageWeight: V5, Country: V6, Status: V7, Conditions/Diseases: V8, PastMedications: V9, Allergies: V10, Symptoms: V11, ...]
- A patient case is n-dimensional vectors where each dimension corresponds to a distinct attribute and n is the total number of possible attributes.
- Identification of different patient communities in a population of patient cases.
- For that, two issues are suggested:
  - Determine meaningful subsets (communities/patients with similar case)
  - Determine meaningful concepts for each subset (stereotypes)
- The communities' stereotypes are built up by trying to identify patterns.
- Incrementally generates clusters (patient with common characteristics) representing patient communities as following:
  - Creating a new cluster
  - Placing a new patient case into an existing cluster
  - Combining two clusters into a new one
  - Dividing an existing cluster.
  - Extracting representative information

## **2.4 eHealth Networked Architecture**

The system architecture is developed a round of three phases: Decision Support System, Geographic Information System (GIS) and Remote Laboratory (ILab).

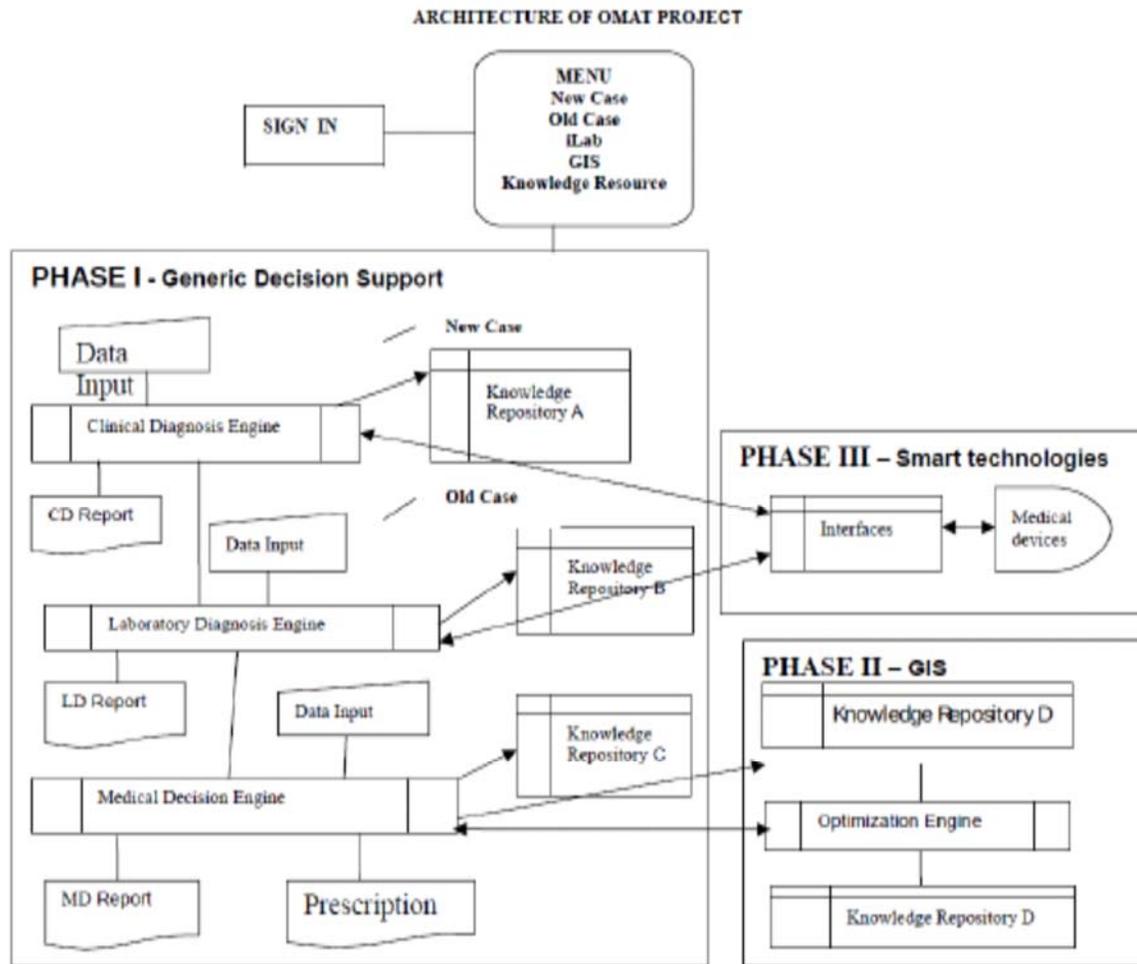


Fig. 1. Architecture of the OMaT project

### 3 Results

#### 3.1 Phase I Implementation

In this section, we present the basic functionalities and show how they act in the OMaT system. The actual website for OMaT Project[14] is developed using Php, XML, HTML, JavaScript and CSS as front end and raw files, MySQL and NoSql Data base as the backend.

The OMaT system contains five basic components that constitute the main menu:

- newCase Component;
- openCase Component;
- iLab Component;
- GIS Component,
- Knowledge Repository.

We present in the following specifically the components that allow medical consultation saying the newCase and openCase components. These two components allow medical decision support.

The newCase, as its name indicated, creates a new patient record in four steps:

1. Clinical Examination: Patient Profile and Signs and symptoms
2. Laboratory examination and Generated clinical diagnosis report
3. Treatment and generated reports of laboratory test, symptomatic treatments and treatment proposal, and the proper prescription of the Physician.
4. Generation of the full report of the case

The openCase is like the Newcase to the difference that the records already exist. It is recognized that the Healthcare Practitioner (HCP) to use our system must register himself and wait for the approval of the committee that granting the access identifier, figure 2.

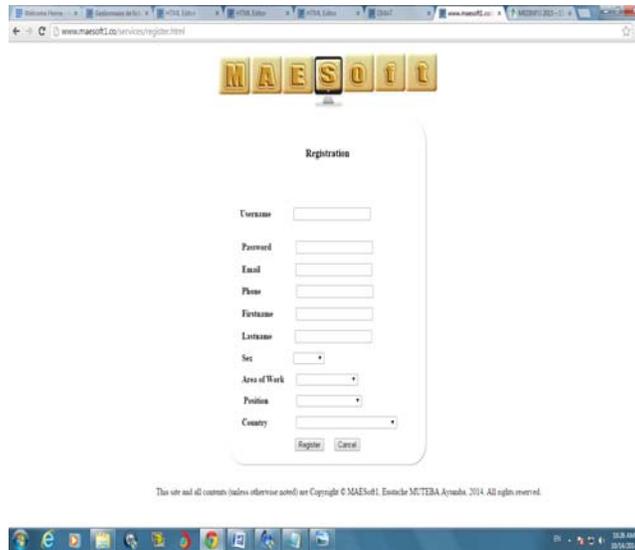


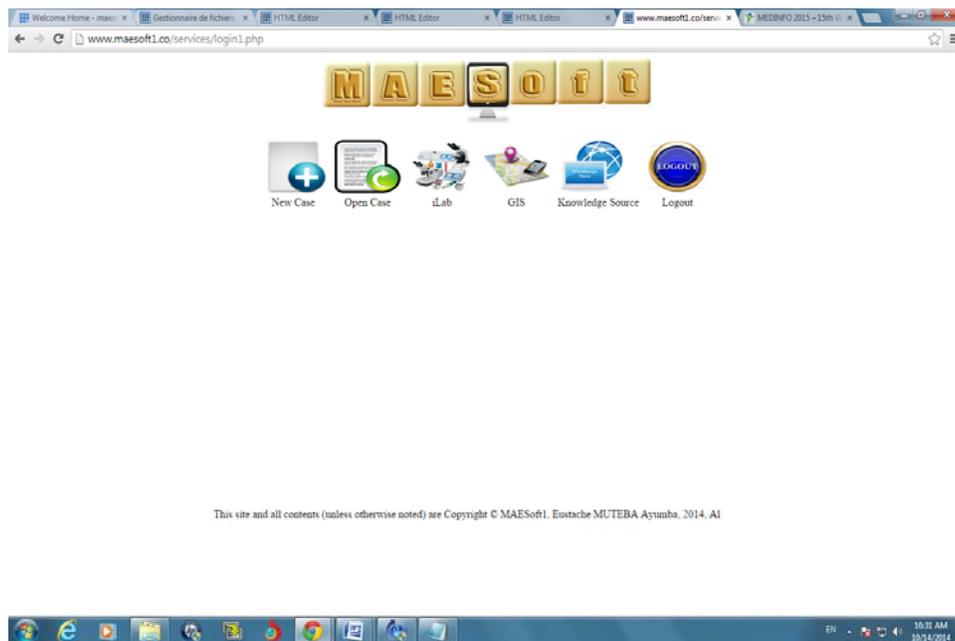
Fig. 2. Interface of Registration



Fig. 3. Login interface

After that the HCP can login into the system via the Login interface, figure 3. If the login is successful then the HCP can accessed to the main menu and begin to interact with the system. The main menu, figure 4, has five options:

- newCase: allows the HCP to supplied information related to the clinical consultation (first consultation);
- openCase: allows the HCP to progress with the consultation and possibly optimize if needed the treatment. This allows the HCP to benefit added value of the GIS and the iLab components;
- iLab: allows the HCP to remotely access to distance laboratory or to submit image of species of Plasmodium for laboratory diagnostic;
- GIS: it is a Geographic Information System of case of patient with malaria in different area and it allows to the HCP advices by searching similar case;
- Knowledge Resource: allows the HCP to learn more about matter related to malaria by different articles or documents.



**Fig. 4.** Main Menu Interface

We describe in the following only the functioning of the system in the component newCase that allows the HCP to supplied information related to the clinical and laboratory consultation (first consultation).

The component newCase is a succession of sub components namely:

newCase1, newCase2, newCase3, and newCase4.

The newcase1, figure 5 & figure 6, allows the HCP to supply first information on the clinical consultation.

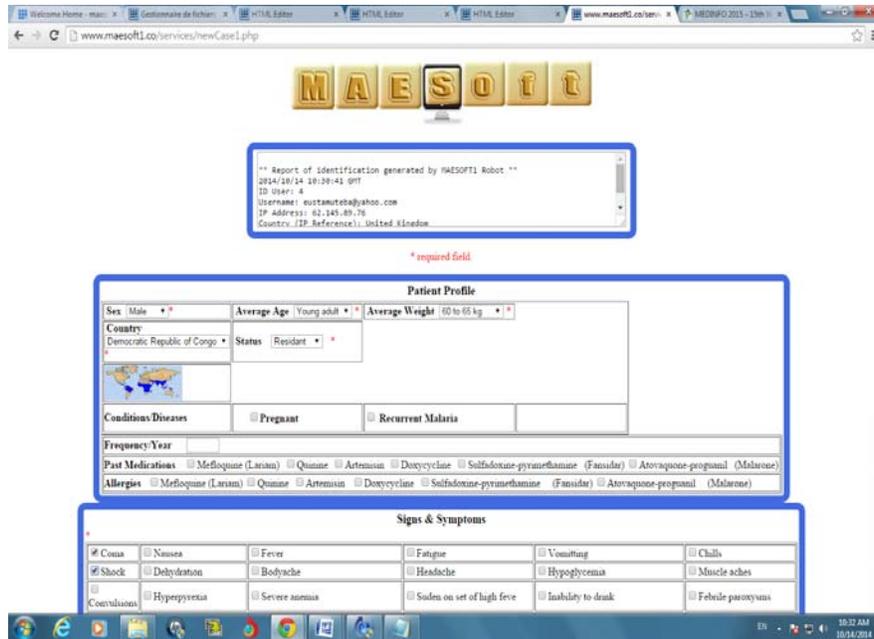


Fig. 5. Clinical consultation



Fig. 6. Clinical consultation

The newcase2, figure 7, generates a Clinical Diagnosis Report and allows the HCP to supply information relative to the Laboratory Test.

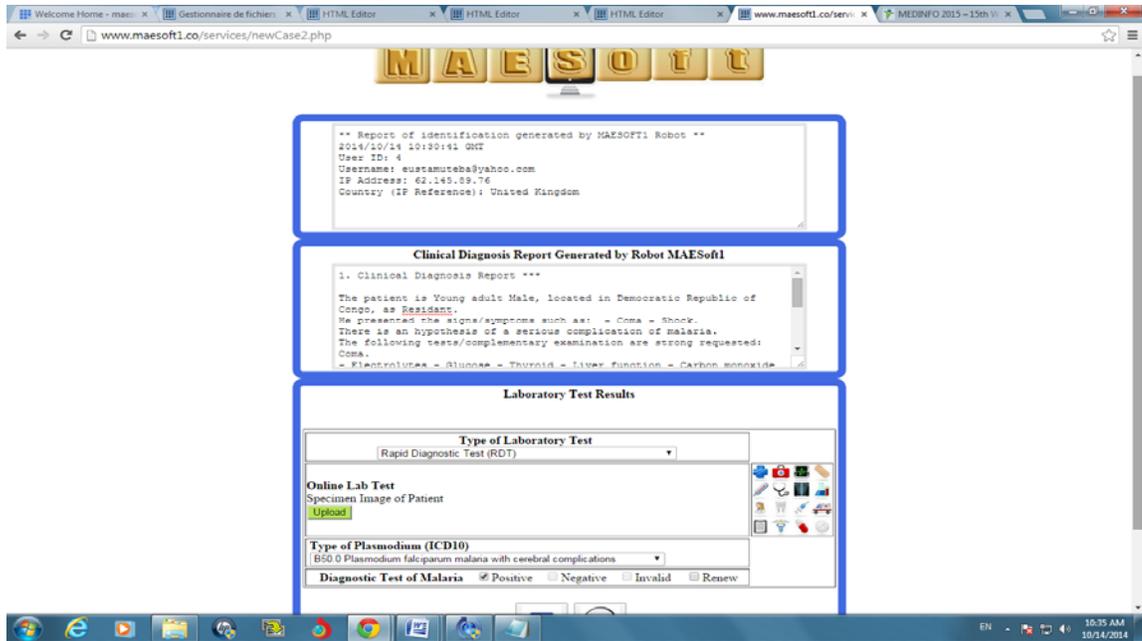


Fig. 7. Generated Clinical Diagnosis Report and Interface for Laboratory Diagnostic

The newCase3, figure 8 and figure 9, generates the Reports of Diagnosis, of Symptomatic Report and of Therapy Strategies. And it allows the HCP to write his own medical Prescription based on the reported information.

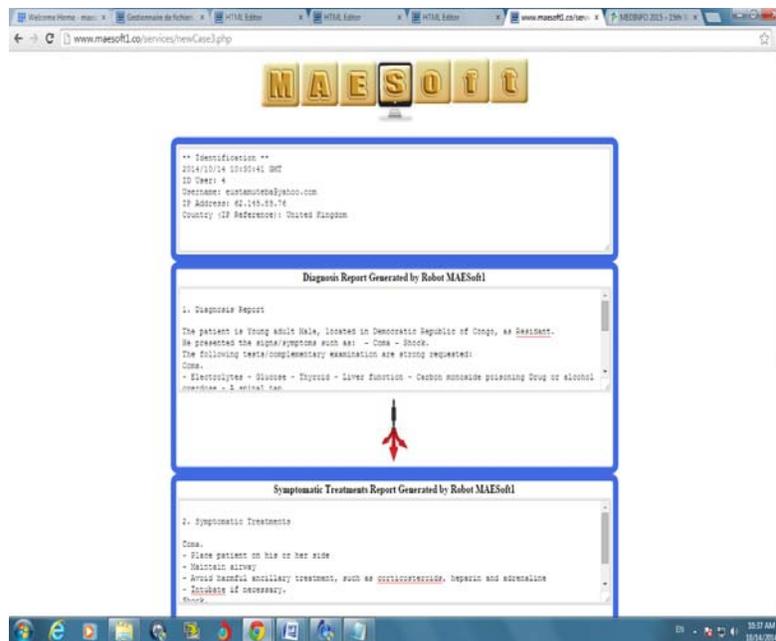
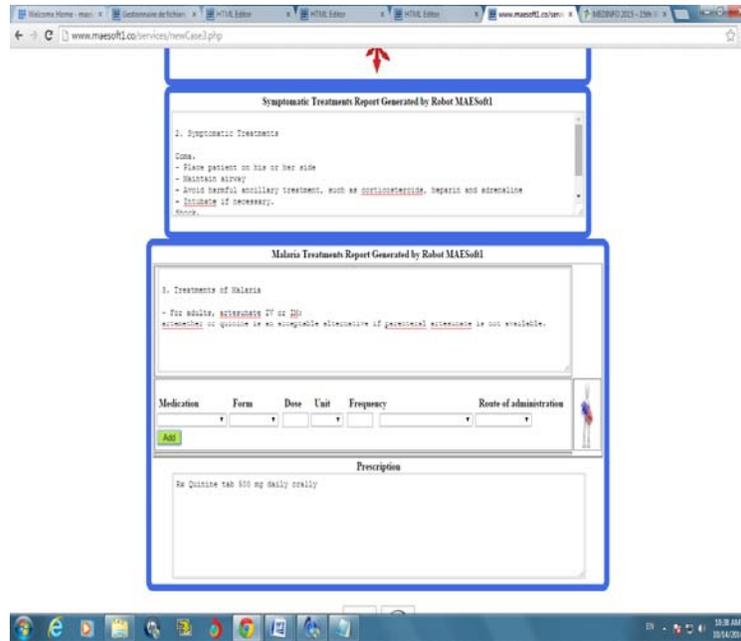


Fig. 8. Generated Reports of: Diagnosis, Symptomatic Treatments and Malaria Therapy Strategies, and Prescription



**Fig. 9.** Generated Reports of: Diagnosis, Symptomatic Treatments and Malaria Therapy Strategies, and Prescription

The newCase 4, figure 10, allows the HCP to print the Medical Decision Report and to receive an email with an attached file in form of Electronic Medical Record (csv format).



**Fig. 10.** Medical Decision Report

## 4 Discussion

The evaluation of our system as a medical decision support covers several aspects that we discuss below. The quality of the system depends on the reliability of the information entered, protection against handling errors and lack of dangerous results. Therefore, the human machine interface that we have proposed is quite responsive and easy to use to facilitate the work. A click allows the user to enter data. Error checking handling is based on internal constraints such as "a newborn cannot weigh more than 10 kg", or, for example, "a man cannot be pregnant." The Smart healthcare technologies [15-18], can be added to our system as active devices for diagnosis that are the key to enable people greater and more equitable access to health services and facilitate to collect and share health both in urban and rural areas. And the interoperability is a hottest issue challenging the Internet for interconnecting heterogeneous objects (systems, software components, devices). For the lack of dangerous results, it is to ask the following questions:

- Does the system do what I want it to do?
- Does what I want it to do work?

The methodology adopted to address these major constraints is the formalization of reasoning such as:

IF < INITIAL-DIAGNOSIS> AND <TEST-RESULT> THEN <DIAGNOSIS>

expresses as "If (Malaria is Severe And Plasmodium is Suspected) And (Location is Central Africa And Condition Disease is Recurrent malaria And Age is Adult And Weight is 65 to 70 kg) Then Quinine is recommended".

It turns that our clinical decision support system for treatment of malaria is based on consensus guidelines [19] and protocols for the management of malaria. Thus, the system only deals with information theory and medical practice identified in advance, limited and structured so for its efficiency and completeness.

The prototype system presented above is suitable for case of emergency and it is available online [20]. The proposed solution, in form of web applications includes a Generic Medical Decision Support System and is expected to assist Healthcare Professionals at medical consultation and decision of the patients with malaria disease.

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## Competencies and Barriers to the Use of Nursing Informatics among Nurses in Primary, Secondary and Tertiary Healthcare Facilities in Nigeria

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**Background and Purpose:** Nurses have always been at the forefront of patient's care and are expected to provide safe and quality care that is moderated by technology to consumers of health care. To meet these expectations, nursing informatics competencies are critical and essential for nursing practice. This study explored nurses' knowledge, perception of their competencies and the barriers to the use of nursing informatics at the three levels of care in a State in Nigeria. This was done with the purpose of collecting baseline data to inform intervention for knowledge update and enhanced use of nursing informatics in practice.

**Methods:** Adopting a cross sectional survey design, data was collected from 350 nurses from 1 tertiary, 6 secondary and 30 primary health care facilities using multistage sampling technique from 6 towns that have at least two out of the three categories of health care facilities in the State,. Proportionate samples were drawn based on the population of nurses in the 3 categories of health facilities with 175 from tertiary, 115 from secondary, and 60 from primary health care facilities.

**Results:** The result showed a fair knowledge of nursing informatics by 55.4% of the respondents. In each of the three levels of competency, respondents perceived themselves as 'competent' and 'not competent' based on their self assessment. 'Limited access to computer' was the most perceived barrier by 55% of respondents to the utilization of nursing informatics.

**Conclusions:** The study concluded that the competency of nurses in nursing informatics is poor due to various perceived barriers.

**Keywords:** Competencies Informatics Barriers Nurses Nigeria

### 1 Introduction

Nurses have always been at the forefront of patient's care and are expected to provide safe and quality care to consumers of health care, as an integral aspect of nursing practice in a technical and digital environment [1]. To meet these expectations of providing safe and effective patient care in the healthcare environment, nursing informatics competencies are critical and essential for nursing practice [2].

Studies have shown that nurses are key stake holders in developing, implementing and evaluating informatics solutions for many years. They have taken up various roles beyond care giving: they integrate the services of virtually every other discipline in the health care system, they organize, plan and support the care of patient populations and communities, they are also committed to ensuring that the care given to patient comes together in timely and appropriate ways [1,3,4]

Health care is an information intensive industry, in which quality and timely information is a critical resource [5]. Information is the key to effective decision making and integral to quality nursing practice. Much of what nurses do involves information, which starts from assessing health care needs of patients, to developing nursing care plan, to implementing the actions, to evaluating the outcomes and to communicating patient's information to other health care professionals [6]. Beyond information management in day-to-day practice, in the 21st century, information is doubling every five years, if not

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tripling in quantity and quality. It is therefore crucial that nurses have access to the latest scientific information to support the delivery of high quality care and the development of nursing knowledge and theory [4]. These have given rise to the emergence and increasing prominence in the field of nursing informatics.

Nursing informatics is a product of combination of computer, information and nursing sciences. It has emerged to assist in the management and processing of nursing data, information, and knowledge to support nursing practice, education, research, and administration. Information intensive disciplines like nursing require careful investigation into the application of computers to process nursing information [7].

As the use of information technology further developed in nursing, conceptually oriented definitions emerged, such as the widely applied definition by Graves and Corcoran [8] who proposed that nursing informatics is a combination of computer science, information science, and nursing science designed to assist in the management and processing of nursing data, information, and knowledge, to support the practice of nursing and the delivery of nursing care. This definition and emphasis on nursing data, information and knowledge was a new change in direction in the late 1980s and others immediately adopted the definition.

As soon as nursing informatics gained recognition as a nursing specialty, the Council of Computer Applications in Nursing of the American Nurses Association (ANA) [9] provided a new definition for the field. The ANA expanded the previous definitions by incorporating the role of the informatics nurse specialist into the definition of nursing informatics as a specialty that integrates nursing science, computer science, and information science in identifying, collecting, processing, and managing data and information to support nursing practice, administration, education, and research and to expand nursing knowledge. The purpose of nursing informatics is to analyze information requirements, design, implement and evaluate information systems and data structures that support nursing, identify and apply computer technologies for nursing.

This definition has however been further refined over the years in line with progressive efforts aimed towards an accurate description of the scope and standards of the practice of nursing informatics. The latest of this was by American Nurses Association which states that;

Nursing informatics is a specialty that integrates nursing science, computer science, and information science to manage and communicate data, information, knowledge, and wisdom in nursing practice. Nursing informatics facilitates the integration of data, information, knowledge, and wisdom to support patients, nurses, and other providers in their decision-making in all roles and settings. This support is accomplished through the use of information structures, information processes, and information technology. [10, p.65]

Nurses have received noteworthy opportunities to be aware of current information when making decisions as a result of improvement in information technology over the years. This has accelerated efforts to implement information system such as the electronic health record, which has the potential to enhance nurses' decision-making regarding the delivery of care by supplying access to health information about clients, allowing data entry, and offering electronic access to scientific knowledge, also it has created new roles for nurses. This raises a greater need for all nurses to integrate nursing informatics competencies into their practices [6].

Over the years, various groups of theorists and educators have proposed essential competencies and literacy skills for nurses in practice, research, education and administration [7]. Despite the fact that nursing informatics is a highly specialized field, there are foundational informatics competencies that all graduating nursing students and practicing nurses should possess to meet the standards of providing safe, quality, and competent care [1]. The need to adopt a culture in nursing that promotes acceptance and use of information technology has been identified as an imperative initiative to establishing nursing informatics competencies and educational strategies [7].

Various emerging taxonomies for describing nursing informatics competencies have been discussed in the literature. The TIGER Nursing Informatics Competencies Model [1] consists majorly of three parts: Basic computer competencies, information literacy and information management. Kaminski [7] also identified three levels of competencies as: beginner, entry or user level, intermediate or modifier level and advanced or innovator level of competency. Each of the three competency levels explained by TIGER [1] and Kaminski [7] include both knowledge and skills required to: use information and communication technologies to input, recover and maneuver data; interpret and organize data into information to affect

nursing practice; and combine information to contribute to knowledge development in all areas of nursing.

A "User" level of competency as described by Kaminski [7] indicates nurses who demonstrate core nursing informatics competencies. This is the basic level that all nurses should minimally demonstrate, no matter what area of practice he or she works in. A "Modifier" level of competency includes nurses who have mastered basic skills and use technology in inventive ways in their practices. The "Innovator" level of competency indicates practicing nurses, nursing administration, nurse researchers and educators who demonstrate advanced and specialized nursing informatics competencies, and have mastered expert skills and use technology in design, plan and coordinate the use of technologies and informatics theory in nursing.

All proposed frameworks include competencies that describe:

- the use of information and communication technology (technical competencies),
- the use of automated information in a professional context (utility competencies),
- decision-making with respect to planning for and using both the technology and information (leadership competencies) [7].

A good number of theorists have emphasized the need for every nurse whether employed in the practice or education setting, to develop a minimum of a "user" level in computer literacy and informatics theory [7]. Herbert (as cited in [7]) outlined some strategies for achieving nursing informatics competencies in the workplace, which include in-service training, intranet ready modules, access to online resources, opportunities for continuing education, availability of and access to resources needed for utilization of nursing informatics.

Herbert, further pointed out some barriers to achieving nursing informatics competencies in nursing practice, and this includes restricted access to training and training systems for nurses and nursing students, few leaders and educators with nursing informatics skills, and limited empirical support for the contributions that Information Communication and Technology (ICT) can or will practically make to nursing and patient outcomes.

While nursing informatics competencies hold a very significant place in the provision of safe and quality care to patients and consumers of healthcare, there is a dearth of information on the competencies of nurses in utilization of nursing informatics in providing nursing care in Nigeria, hence this study attempt to assess the perceived competency level of nurses' in nursing informatics in Osun State, Nigeria.

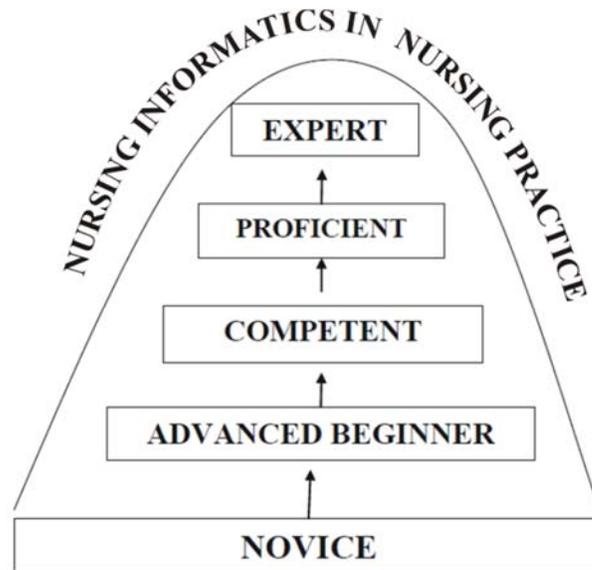
### **Theoretical Framework - From Novice to Expert Theory**

The Novice to Expert theory as the underpinning construct theory used in this study was first proposed by Dreyfus and Dreyfus [11] as the Dreyfus Model of Skill Acquisition, and later applied and modified to nursing by Benner [12], it is a very useful and important theory that clearly applies to nursing informatics.

The currently accepted five levels of development within the Novice to Expert theoretical model as presented by Benner start from the bottom rung at the Novice level and move upward through Advanced Beginner, Competent, Proficient, and Expert levels. Each level builds on the level before it as the learner advances from a beginner level then gains knowledge, skills, perceptions, intuition, wisdom and most important of all, experience in their given field of practice [13]. Every one of these five levels of skill acquisition has unique and different characteristics

**NOVICE:** With regards to nursing informatics, a novice nurse does not know anything about ICT and its application in nursing practice. He/she has to memorize the features and works within stated rules in the application of ICT. To improve, the novice nurse needs monitoring, either by self-observation or instructional feedback. For example, a nurse learning to use a new hospital information system needs explicit instruction and rules to learn to use the computer and manipulate the software, this most often is achieved by training in form of continuing education or workshop.

**ADVANCED BEGINNER:** An advanced beginner nurse in nursing informatics is still dependent on rules, but as he/she gains more experience with real life situations in terms of data gathering and processing for client/patient, he/she begins to notice additional aspects that can be applied to related conditions.



**Fig. 1** Novice to Expert theory

**COMPETENT:** At this stage, the competent nurse grasps all the relevant rules and facts of the field of nursing informatics and is, for the first time, able to bring his/her own judgment to each case. This is the stage of learning that is often characterized by the term “problem solving”. For example, a competent level nurse in nursing informatics would be able to use a hospital information system with ease, and know how to solve technical difficulties or interpret conflicting data. He/she is able to comfortably manage and extract information from software for storing client’s/patient’s electronic records.

**PROFICIENT:** This stage is referred to as fluency and is characterized by the progress of the nurse from the step-by-step analysis and solving of the situation to the holistic perception of the entire situation. The proficient nurse in nursing informatics would know how to interpret data from various departmental records and provide appropriate guidance to other members on the team as needed.

**EXPERT:** A nursing informatics expert has a vast range of experienced situations to the extent that each specific situation immediately dictates an intuitively appropriate action. After a great deal of experience actually using a system in everyday situations, the expert nurse discovers that without using any rules, situations simply elicit from his/her appropriate responses. The proficient nurse, immersed in the world of skillful activity, sees what needs to be done, and decides how to do it. The expert nurse does not only know what needs to be achieved, he/she knows how to achieve his/her goal.

This ‘expert’ level is the peak of the theory but it does not signify that development stops, the expert nurse needs to keep abreast of information, update and evaluate his/her skills in order to maintain the expertise.

## 2 Materials and Methods

### *SAMPLE AND SAMPLING.*

This study employed a cross sectional survey design using multistage sampling technique. It was conducted in government owned primary, secondary and tertiary health care facilities in Osun State, Nigeria. All the registered two thousand and eighteen (2018) nurses working in the three tier health care

facilities in the state formed the target population. Six major towns (Osogbo, Ile-Ife, Ikirun, Ede, Iwo and Ilesa) that have at least two out of the three categories of health care facilities used were purposively selected, from where the samples for tertiary, secondary and primary health care facilities were drawn. The sample for this study was determined using Yamane's formula [14]  $n = \frac{N}{1 + N(e)^2}$  where  $n$  is the sample size,  $N$  is the population size and  $e$  is the level of precision, which is usually set at 0.05. A sample size of 339 was obtained using this formula, which was rounded up to 350, given room for 5% attrition rate. Out of the six major towns that met the inclusion criteria, thirty seven health care facilities (1 tertiary, 6 secondary and 30 primary) were systematically selected. Samples from the three health care facilities categories were then proportionately drawn; 175, 115 and 60 nurses were randomly selected from tertiary, secondary and primary health care facilities respectively. The lists of all the nurses working in the facilities were collected as the sampling frame, from which the samples were drawn.

#### ***INSTRUMENT.***

The questionnaire was structured and self-developed from a review of literature on previous work on nursing informatics [5,7]. It has four parts; the first part contained nine questions and assessed the subjects' demographics, while the second part contained twelve questions which assessed the respondents' knowledge on nursing informatics. The third part contained thirty-one questions of 4-point Likert scale of Novice (N), Beginner (B), Competent (C), and Proficient (P) which were used to assess the perceived level of respondents' competency in the utilization of nursing informatics. The last section measured the perceived barriers of respondents using thirteen questions of 5-point Likert scale of Strongly Agree (SA), Agree (A), Uncertain (U), Disagree (D), Strongly Disagree (SD).

#### ***PILOT STUDY.***

The pilot study was conducted for two weeks in Ado - Ekiti, Ekiti State using 20 nurses. The reliability testing of the research instruments was done using split half reliability method. The responses to the test items were separated into odd and even numbers rated and correlated using spearman rho correlation coefficient. A correlation coefficient value of 0.9 was got affirming the reliability of the instrument and ensuring that the questions could be understood and answered by all.

#### ***DATA COLLECTION PROCESS.***

Data was collected within a period of three months, which allowed the researcher to move round the facilities in the six towns selected. An ethical clearance to conduct the study was obtained from the Institutional Review Board of Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC) Ile-Ife, and permission was obtained from the Director of Nursing Services in each of the health care facilities used. Informed consent to participate in the study was also sought from individual nurses' and their right to privacy was respected. Some questionnaire were collected on site, however copies were left with the head of the units or facilities as the case may be, for those who are too busy to answer the questionnaire immediately, and for those who were on shift duty, which were collected during the return visits.

#### ***DATA ANALYSIS.***

Data were gathered, sorted and entered into the Statistical Package for Social Sciences (SPSS) version 17. Descriptive and inferential statistics were carried out. Responses to test items on the knowledge scale were rated as 1 for each correct answer, and 0 for a wrong answer giving a total obtainable score of 12 (100%). Therefore, knowledge scores between 70-100% were rated very good, 60-69% as good, 50-59% as fair, and 0-49% as poor.

The Likert scale questions on competencies were scored as Novice (1), Beginner (2), Competent (3), and Proficient (4). Scores were later categorized as Competent (93-124), and Not competent (31-92). Perceived barriers were also scored as Strongly Agree (5), Agree (4), Uncertain (3), Disagree (2), Strongly Disagree (1), and then categorized as Agree (52-65) and Disagree (13-51).

### 3 Results

#### 3.1 Socio-demographic data

The respondents' age range was between twenty (20) and fifty nine (59) years. Majority of the respondents were females; 81.1% in tertiary health facilities, 73% in secondary health facilities while 78.3% in the primary health care facilities. Majority of the respondents were married; 68.6% in tertiary health facilities, 82.6% in secondary health facilities and 71.7% in the primary health facilities. Other correspondents' characteristics were shown in Table 1.

**Table 1.** Respondents' Socio-demographic data

Socio Demographic Characteristics	Tertiary Health facility Frequency n (%) N=175	Secondary Health facility Frequency n (%) N=115	Primary Health facility Frequency n (%) N=60
<b>Age Range (Years)</b>	Mean age= 35.8	Mean age= 39.9	Mean age= 38.2
20-39	SD= ±9.3	SD= ±12.5	SD= ±10.1
40-59	120 (68.6)	55 (47.8)	34 (56.7)
	55 (31.4)	60 (52.2)	26 (43.3)
<b>Sex</b>			
Male	33 (18.9)	31 (27.0)	13 (21.7)
Female	142 (81.1)	84 (73.0)	47 (78.3)
<b>Religion</b>			
Christianity	143 (81.7)	78 (67.8)	42 (70.0)
Islam	32 (18.3)	37 (32.2)	18 (30.0)
<b>Marital status</b>			
Single	55 (31.4)	18 (15.7)	15 (25.0)
Married	120 (68.6)	95 (82.6)	43 (71.7)
Widowed	0 (0.0)	2 (1.7)	2 (3.3)
<b>**Professional Status</b>			
NO II	73 (41.7)	25 (21.7)	21(35.0)
NO I	37 (21.1)	28 (24.3)	10(16.7)
SNO	19 (10.9)	9 (7.8)	7(11.7)
PNO	12 (6.9)	11 (9.6)	6(10.0)
CNO	18 (10.3)	39 (33.9)	14(23.3)
ADNS	16 (9.1)	3 (2.6)	2(3.3)
<b>**Professional/Educational Qualification</b>			
RN	38 (21.7)	24 (20.9)	20 (33.3)
RM	6 (3.4)	5 (4.3)	2 (3.3)
RN/RM	76 (43.4)	52 (45.2)	26 (43.3)
RPHN	5 (2.9)	4 (3.5)	6 (10.0)
B.Sc/BNSc	43 (24.6)	25 (21.7)	6 (10.0)
M.Sc	6 (3.4)	3 (2.6)	0 (0.0)
Others	1 (0.6)	2 (1.7)	0 (0.0)
<b>Years in Practice</b>			
0-5 years	72 (41.1)	33 (28.7)	21 (35.0)
6-10 years	41 (23.4)	22 (19.1)	14 (23.3)
11-15 years	25 (14.3)	2 (1.7)	6 (10.0)
16-20 years	12 (6.9)	13 (11.3)	6 (10.0)
Above 20 years	25 (14.3)	45 (39.1)	13 (21.7)

\*\*NO- Nursing officer, SNO- Senior Nursing Officer, PNO- Principal Nursing Officer, CNO- Chief Nursing Officer, ADNS-Assistant Director of Nursing Services, RN- Registered Nurse, RM- Registered Midwife, RPHN- Registered Public Health Nurse, BNSc- Bachelor of Nursing Science Degree, MSc- Master of Science Degree.

### 3.2 Knowledge of Nursing Informatics

Majority of the respondents had fair knowledge of nursing informatics across the levels of health facilities; 53.7%, 65.2%, 41.7%, in tertiary, secondary and primary health facilities respectively, with an overall mean of  $5.92 \pm 2.2$  (table 2)

**Table 2.** Summary of Distribution of Respondents' performance on the Knowledge of Nursing Informatics

LEVEL OF KNOWLEDGE	Health Facilities			Total
	TERTIARY	SECONDARY	PRIMARY	
	N=175 Mean=5.99 SD=± 2.2	N=115 Mean= 5.78 SD=± 2.1	N=60 Mean=6.00 SD=±2.5	N=350 Mean= 5.92 SD=±2.2
Very good (70-100%)	16 (9.1)	12 (10.4)	8 (13.3)	36 (10.3)
Good (60-69%)	53 (30.3)	24 (20.9)	22 (36.7)	99 (28.3)
Fair (50-59%)	94 (53.7)	75 (65.2)	25 (41.7)	194 (55.4)
Poor (0-49%)	12 (6.9)	4 (3.5)	5 (8.3)	21(6.0)
Total	175 (100)	115 (100)	60 (100)	350 (100)

### 3.3 Perceived Competency

The respondents' perceived level of competency was measured across the three health care facilities using the three broad levels of User, modifier and innovator. In each of the three levels of competency, respondents perceived themselves as 'competent' and 'not competent' based on their self-assessment. As shown in Table 3, more than half of the respondents (64.3%, 61.9% and 68%) in user, modifier and innovator levels of competency perceived themselves as 'not competent' (novice+beginner) across primary, secondary and tertiary health care facilities.

**Table 3.** Categories of Respondents' Perceived Level of Competency

Competency Level	Health Care Facilities			Total (%) N=350
	Frequency (%) N=175 TERTIARY	Frequency (%) N=115 SECONDARY	Frequency (%) N=60 PRIMARY	
User level				
<b>Not-competent</b>				
Novice	13 (7.4)	26 (22.6)	12 (20.0)	23 (14.6)
Beginner	93(53.1)	63(46.1)	28 (46.7)	174(49.7)
<b>Competent</b>				
Competent users	57 (32.6)	29(25.2)	18(30.0)	104(29.7)
Proficient users	12(6.9)	7(6.1)	2(3.3)	21(6.0)
<b>Total</b>	175(100)	115(100)	60(100)	350(100)
Modifier level				
<b>Not-competent</b>				
Novice	22(12.6)	28(24.4)	10 (16.7)	60 (17.1)
Beginner	77(44.0)	47(40.9)	33 (54.9)	157(44.8)

<b>Competent</b>				
Competent users	66 (37.7)	35(30.4)	16(26.7)	117(33.4)
Proficient users	10(5.7)	5(4.3)	1(1.7)	16(4.5)
<b>Total</b>	175(100)	115(100)	60(100)	350(100)
Innovator level				
<b>Not-competent</b>				
Novice	21(12.0)	35(30.4)	12 (20.0)	68 (19.4)
Beginner	85(48.6)	49(42.6)	36 (59.9)	170(48.6)
<b>Competent</b>				
Competent users	60(30.4)	29(25.3)	11(18.4)	100(28.6)
Proficient users	9(5.1)	2(1.7)	1(1.7)	12(3.4)
<b>Total</b>	175(100)	115(100)	60(100)	350(100)

### 3.4 Barriers to Nursing Informatics Competency

There were thirteen barriers perceived by the respondents that have contributed to their poor competency in utilization of nursing informatics in practice. Limited access to computer was the most perceived barrier to the utilization of nursing informatics by 55% of respondents while the thought of being too old to start learning computer was the least perceived barrier by 14.6% of respondents. Other perceived barriers were shown in fig. 2.

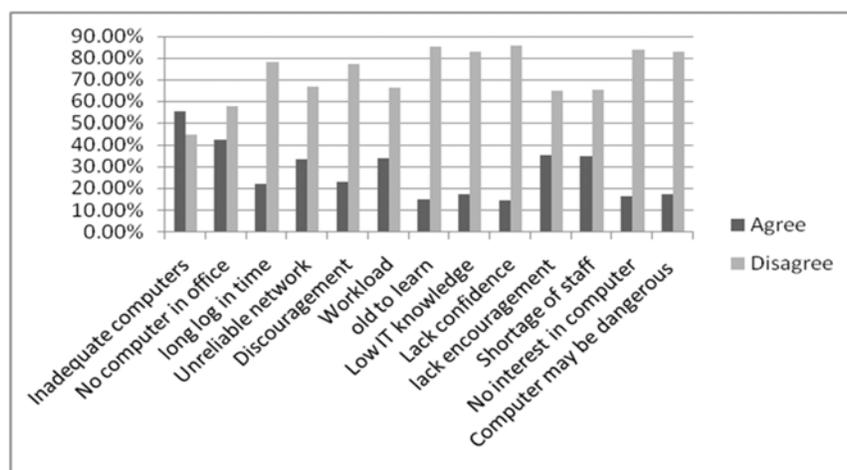


Fig. 2. Respondents' Perceived Barriers

### 3.5 Relationship between Nurses' Years of Experience and Levels of Competence

Correlation co-efficient was used to test the null hypothesis which states that there is no significant relationship between nurses' years of experience and their levels of competency in utilization of nursing informatics. The p values were less than 0.05 across the three levels of competencies (p=0.001) for user competency level, (p=0.002) for modifier level and (p=0.006) for innovator competency level. Therefore, the null hypothesis was rejected implying that the more the years of nurses' experience at work the higher their level of competency is likely to be in the utilization of nursing informatics. However, the r values were negative indicating an inverse relationship between the years of experience and levels of competency.

**Table 4.** Correlation Result of the Relationship between Nurses' Years of Experience and Levels of Competency

Competency level	R value	P value	Remark
User	-0.104	0.001	Significant
Modifier	-0.164	0.002	Significant
Innovator	-0.146	0.006	Significant

### 3.6 Relationship between Age and Levels of Competence

A significant relationship was found between age and each of the levels of competence, the p values across these levels were less than 0.05; p= 0.017 for user level, p=0.003 for modifier level and p=0.028 for innovator level of nursing informatics competence.

**Table 5.** Cross Tabulation of Age and Levels of Competence

Competency level	Age		Test of Statistical Significance
	20-39 n (%)	40-59 n (%)	
<b>USER</b>			
Novice	13 (6.2)	10 (7.1)	X <sup>2</sup> = 10.218 df= 3 p = 0.017
Beginner	93 (44.5)	85 (60.3)	
Competent	87 (41.6)	41 (29.1)	
Proficient	16 (7.7)	5 (3.5)	
<b>MODIFIER</b>			
Novice	25 (12.0)	32 (22.7)	X <sup>2</sup> = 13.980 df= 3 p = 0.003
Beginner	81 (38.8)	64 (45.4)	
Competent	84 (40.2)	33 (23.4)	
Proficient	19 (9.1)	12 (8.5)	
<b>INNOVATOR</b>			
Novice	28 (13.4)	35 (24.8)	X <sup>2</sup> = 9.070 df= 3 p = 0.028
Beginner	100 (47.8)	61 (43.3)	
Competent	67 (32.1)	33 (23.4)	
Proficient	14 (6.7)	12 (8.5)	

## 4 Discussion

The respondents were between age twenty (20) and fifty nine (59) years. This finding, corroborating Raja, Mahal, and Masih's [15] findings among nurses in hospitals in Ludhiana, India implies that the respondents were young, still within active age of government service and have more years to spend in professional practice. More anticipatory years of career growth in professional practice by young nurses makes demand for appropriate competence in informatics for efficiency and effectiveness in contemporary health care system moderated by technology. The study also revealed that majority of the respondents were females, still affirming the Royal College of Nursing [16] submission that conventionally, nursing is a female-dominated profession but there is need for the best of people from both genders to come into the profession.

The findings from this study, which showed that majority of nurses had fair knowledge of nursing informatics, could be said to be the effect of the recent inclusion of basic computer knowledge into the nursing education curriculum. The application of this with regards to nursing informatics in practice has not been well established. However, the result of a study by Raja et al. [15] in India revealed that majority

of the nurses had good computer knowledge. Effort should therefore be made to improve nurses' knowledge on nursing informatics, as this will go a long way to advance their competency in its utilization.

Majority of the nurses rated themselves as 'not competent' in the utilization of nursing informatics within each level of competency, this pattern of competence was similar across the three levels of health care facilities and it corroborates the findings in the study of Hwang and Park [17] on factors associated with nurses' informatics competency, which revealed that majority of the respondents considered their informatics competency to be below average. This finding is not unexpected; it may be traced to the insufficient knowledge exhibited by the respondents on nursing informatics. With these findings, it could be concluded that most of the nurses ( $\geq 60\%$ ) in this study could be categorized as either novice or beginners; this has a lot of implications for nurse administrators and managers. For nurses across the three level of care to move to the higher level within the context of the novice to expert theory (competent-expert), there is need for rigorous skill development for the nursing workforce in the use of nursing informatics to document and facilitate continuity of care.

A significant relationship was found between age and each of the levels of competency, this is not surprising because the younger generation of nurses are more receptive and exposed to technology than the older generation, however the older nurses are also encouraged to be more receptive to the use of technology to help in meeting the challenge of the 21st century in providing quality healthcare.

The study revealed an inverse relationship between nurses' years of experience and their competency in nursing informatics. This finding is anticipated due to the recent introduction of the 'use of computer' as a course into the nursing education curriculum, of which the older nurses may not have had requisite exposures to ICT knowledge and application.

Several reasons were presented as barriers to utilization of nursing informatics in practice across the health care facilities. Out of the thirteen listed barriers, the most perceived in the three levels of healthcare facilities was inadequate computers as reflected in Figure 2. Though lack of computer is a major barrier but the study also revealed that the respondents' knowledge is inadequate, the first challenge to resolve is the issue of inadequate knowledge which will empower the nurses to advocate for computers and other equipment needed for utilization of nursing informatics. A previous study by Hegney et al. [5] identified a similar result, hence, effort should be made to improve nurses' knowledge, and equipment should be at their disposal if they will ever be able to combat the problem of inadequate computers for utilization of nursing informatics in practice.

There were other barriers highly perceived by the respondents which are; too many work demand and shortage of staff which limits the time available for utilization of nursing informatics. This is not unanticipated in a developing country like Nigeria as most health facilities are short staffed. However, this is not the case in the Australia study by Hegney et al. [5] which reported that 'work demands' was less of a barrier in community health and in other public sector areas where it is speculated that information technology is seen by nurses and their employers to be an integral part of the role. Lack of encouragement by hospital management is another barrier identified by nurses to utilization of nursing informatics, this is in support of the findings of Estabrooks et al. [18] that barriers to internet use in the clinical setting include lack of administrative support, negative attitudes toward computer technology, lack of expertise and time constraints in the workplace. It is apparent from the results of this study that barriers vary from one health facility to another. Thus a single approach to overcoming the barriers identified in this report may not resolve the barriers. For competency in utilization of nursing information to increase in nursing, action must be taken on each of the barriers identified in this study regardless of the percentage of its occurrence in the various health care facilities.

#### 4.1 Limitation to the study

The major limitation of this study is the use of a self-report for measuring perceived competency which had the potential of yielding bias responses. This could have potentially affected results from this study and a more objective observation may yield different findings. Competency level as expert was not evaluated because this level requires advance education in Nursing Informatics at the Masters level and none of the institutions that offer postgraduate nursing degree in Nigeria currently offers postgraduate degree in Nursing Informatics. On the other hand none of the health facilities currently employ nurses who specialize in Nursing Informatics.

## 4.2 Implication for nursing practice

Despite the advancement in nursing practice as a result of nursing informatics in the developed countries, the reverse is the situation in Nigeria according to the report of this study. The study has also shown that nurses' knowledge of nursing informatics was only fair, with greater percentage rating themselves as 'not competent' coupled with various barriers limiting their competencies

These findings have great implication of poor nursing care of patients and can affect the continuity of care. There is also a tendency for nurses to lag behind while other health professionals move with the pace of 21st century in health care delivery. It is therefore imperative to address the limiting factors that were identified as it will promote increase competency in the utilization of nursing informatics in nursing practice.

As reviewed earlier in the literature, nurses are expected to provide safe, competent, and compassionate care in an increasingly technical and digital environment. To achieve this, there is a need for improving nurses knowledge in nursing informatics, resolving the issue of limited resources, and responding to various challenges as have identified, also nurses must be encouraged using diverse means to be willing users and creative operators of nursing informatics to improve the quality and safety of patient care. Essentially, specialization in nursing informatics must be seen as priority need in nursing education to have experts that will drive deployment of nursing informatics for quality nursing care in Nigeria in the 21st century.

## 5 Conclusion

The study concluded that nurses' knowledge of nursing informatics was just fair while majority rated themselves as 'not competent' in the use of nursing informatics, with various barriers identified.

**Conflict of Interest: We declare that there is no conflict of interest.**

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

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**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

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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) approach 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 workstation 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).

Antenatal Care Facility name: \_\_\_\_\_ Registration number: \_\_\_\_\_ ANC register page: \_\_\_\_\_ LMP: \_\_\_\_\_ EDD: \_\_\_\_\_

Obstetric History *Refer\** Medical History *Refer\** Examination *Refer\** Notes

Obstetric History: C-Sections: 3, Deliveries: 3, Abortions: 1, Still Births: NO, Vacuum Extraction: NO, Symphiotomy: NO, Haemorrhage: NO, Pre-Eclampsia: NO

Medical History: Asthma: NO, Hypertension: NO, Diabetes: NO, Epilepsy: NO, Renal Disease: NO, Fistula Repair: NO, Leg/Spine Deformation: NO, Age: 29

Examination: Height: 159, Multiple Pregnancy: No, WHO Clinical Stage: 2

Lab Results: Date: 2012/05/24, Result: Positive (HIV), Not Done (Syphilis, Hb1, Hb2)

Check at each visit: TTV status page 2, HTC status page 6

Planned Delivery Place: \_\_\_\_\_ Plan for Transport: \_\_\_\_\_

\*Indications for delivery at secondary health facility

Visit No	Visit Date	Gest. age	Fundal height	Position & Presentation	Fetal heart	Weight (kg)	B P	Urine prot.	Number of tablets / dose given					On CPT	On ART	Remarks / Medications	Next visit date	Sign
									SP	FeFo	NVP	AZT	AZT TEC					
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		

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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.

**Current Visit Activities**

Vitals Next ANC Visit

Lab Results Give Drugs

ANC Examinations Update Outcome

Print Visit Summary Print Lab Results Finish

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

Register new person

Date of registration\* 2012-10-31

**Demographics**

Full name\*

Gender\* [Please select]

Date of birth\* Verified

Mobile phone number

Has guardian

Check duplicate

**Person identifiers**

Health Passport Number

Village Health Register ID

**Other details**

Residential Village\*

Residential TA

Marital Status [Please select]

Education [Please select]

Occupation

Religion [Please select]

Add Back to registration

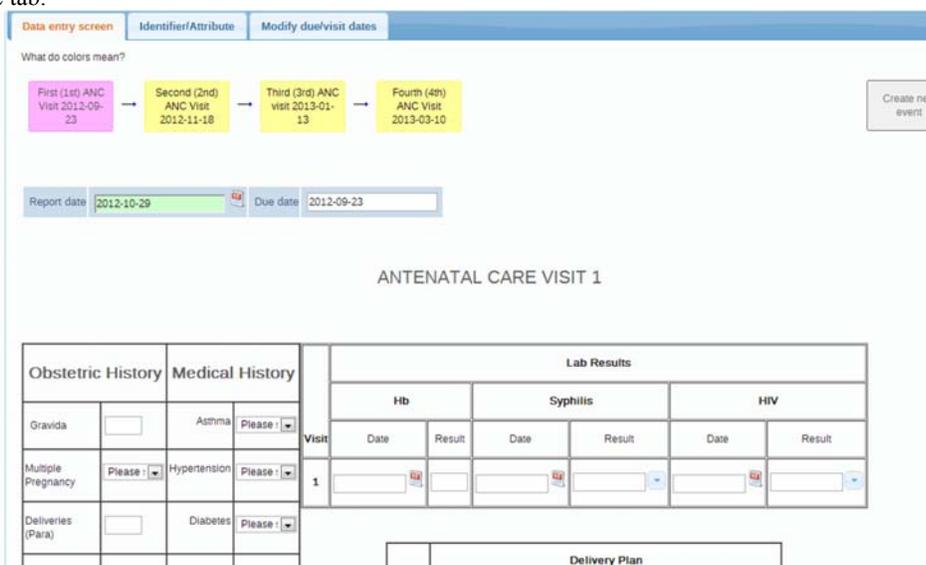
**Fig. 8.** Client Registration form in DHIS2 Tracker system

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

<b>Data Collection</b>	<b>Baobab ANC EMR system at Health Centre A</b>	<b>DHIS2 Tracker system at Health Centre B</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 Observations	ANC service observations for 6 days, 2 to 5 observation hours per day	ANC service observations for 6 days, 2 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 <sup>7</sup>

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

<sup>7</sup> No comparison with register data was done due to known gaps in data entry in the system

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 into the history-taking room where they would be registered, their weight and TTV entered into the EMR, and their patient history would be taken.

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 pregnancy (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, Misoprostal, 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 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 community.

*“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 system.

#### *Data storage.*

The health workers perceived that the EMR had improved the storage of data because with the registers, 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 registers’. 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 health 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 Castelnovo 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; Castelnovo 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 Castelnovo 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; Castelnovo 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; Castelnovo 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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