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# Localized Data for Decision-Making: Implementing a Nurse-Led Data System for Maternal and Newborn Health in Tanzania

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## Abstract

**Background**: Health information systems are integral tools that strengthen (and ideally drive) decision-making related to delivery of healthcare services and health outcomes in lower-income countries. However, often these data systems remain underutilized in local healthcare facilities. In sub-Saharan Africa, many countries are seeing an increasing number of facility-based births but not necessarily a corresponding improvement in outcomes, indicating that maternal and newborn health is an area in which better health information is needed to inform quality improvement initiatives. The purpose of this project was to design, implement, and evaluate a localized HIS to build capacity for quality improvement and research in maternal and newborn health at Muhimbili National Hospital in Dar es Salaam, Tanzania.

**Methods**: Through a collaborative partnership between Muhimbili National Hospital and Emory University, a data collection system using REDCap was developed to provide sustainable, high-quality data on in-patient maternal and newborn health services. Called the Obstetric and Neonatal Database, this project was led and implemented by nurses at MNH with support from staff obstetricians, IT personnel, and the hospital's Training, Research, and Consultancy Unit. Four months after its launch, we conducted a mixed-methods evaluation that used quantitative methods to assess data capture and quality, and qualitative methods to elicit perceptions and experiences of users.

**Results**: The project demonstrated significant successes overall and continues to be used as a means of assessing quality on the maternity wards today. Although data accuracy was high, the evaluation revealed large discrepancies in data capture; specifically, data from labor and surgical wards were >97% complete versus only about 20% complete in postnatal and newborn wards. This inconsistency is attributed to differing degrees of hands-on training and efforts to promote ownership and investment among nursing staff. On the other hand, most nurses overwhelmingly reported positive experiences with the database, describing unanticipated benefits that ranged from enhanced workflow efficiency to improved data security to updated technology-related skills.

**Conclusion**: To effectively provide local health facilities with critical information for evaluating and improving outcomes, health management information systems must be closely tailored to the needs of specific contexts and for the benefit of all users.

**Keywords:** Maternal and newborn health; Health Information Systems (HIS); Quality Improvement (QI); Tanzania

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## 1. Introduction

A health information system (HIS) integrates data generation and processing/analysis with communication and use of findings to improve health service effectiveness and efficiency at all levels of a healthcare system. Often referred to as one of the essential building blocks of health system strengthening, it is a vital tool designed to support planning, management, and decision-making involving health programs and services [1]. The World Health Organization (WHO) and other organizations concerned with healthcare delivery have widely acknowledged the need for facility-level data to drive local decision-making and support quality improvement (QI) initiatives [2]. Valuable as these systems are, the literature suggests that they are not reliably utilized in health facilities across a range of low-income settings. In sub-Saharan Africa, HIS tend to focus more on assessing population-level indicators rather than informing decisions and improving outcomes in specific health facilities [3-5] Although many countries have decentralized their HIS, lack of coordination between Ministries of Health, donors, and health facilities has often led to fragmented or incomplete data systems that may not strengthen operational and clinical decision-making [6-9]. Indeed, a large body of work has demonstrated the logistical complexity of HIS implementation in the region [10-12].

Tanzania has made QI in health facilities a priority since the 1990s, when the Tanzania Development Vision 2025 imagined that all citizens would have access to quality primary health care [13]. In 1993, a national-level HIS was introduced called Mfumo wa Taarifa za Uendeshaji Huduma za Afya (MTUHA) – a paper-based system that aims to conduct health facility and outcomes surveillance on broad indicators, including vital registration. However, weaknesses in the system resulted in hospitals attempting to creating their own paper registries, leading to data fragmentation, increased workload, and information that is often underutilized [14-16]. The Tanzanian Ministry of Health, Community Development, Gender, Elderly, and Children (MoHCDEC) has recognized the need to strengthen integrated routine HIS and expand the use of facility-based data for local planning – as evidenced in the Tanzanian National QI Framework (2011-2016) and a more recent effort to scale up a QI process in district hospitals [13, 17]. To date, no comprehensive evaluation of MTUHA has been conducted and few targeted QI interventions have been systematically implemented and evaluated nationwide [18].

One space in which HIS is greatly needed to support a wide range of QI initiatives is maternal and newborn health. This area is a major focus of Tanzania's MTUHA, which has 4 separate registries designated for maternal and newborn reporting. Despite government-led programs and drives from non-governmental organizations, Tanzania fell short of achieving Millennium Development Goal #5 – to reduce the maternal mortality ratio (MMR) by 75% from 1990 to 2015 [19]. Although the country reduced

its MMR by an estimated 47% during this period, maternal and newborn mortality remain high, at an estimated 524 maternal deaths per 100,000 live births and 20 newborn deaths per 1,000 live births [20-21]. To address this persistent problem, many maternal and newborn programs have successfully sought to improve access to health facilities; from 2010 to 2016, facility-based birth (vs. home birth) in Tanzania jumped from 50% to 64% [19]. However, this achievement did not correspond with a decline in mortality, suggesting that improving access to care alone is not a sufficient strategy [22]. With more births taking place in health facilities, strengthening quality of care in these settings through routine monitoring and evaluation of locally relevant indicators is a critical part of making sustainable advances in maternal newborn health and survival.

The goals of this project were to design, implement, and evaluate an innovative, nurse-led HIS to inform QI, planning, and decision-making for maternal and newborn health services at Muhimbili National Hospital (MNH) in Dar es Salaam, Tanzania. This work was undertaken as part of the Emory-Muhimbili Partnership for Health Administration Strengthening and Integration of Services (EMPHASIS), which seeks to collaboratively strengthen capacity for QI, research, and clinical training at MNH.

## 2. Subjects and Methods

### 2.1 Project setting

MNH is the largest public referral-level hospital in Tanzania. Located in central Dar es Salaam, it has a 1,500-bed capacity that attends between 1,000 to 2,000 outpatients and roughly 1,000 to 1,200 inpatients each week. With 25 clinical and operations departments, MNH is an expansive organization that offers a wide range of medical services. The maternity block has 120 beds and is comprised of 10 distinct wards, including labor and delivery, obstetric operating rooms, a maternal intensive care unit, antenatal wards, and postnatal wards. Housed within the block is also a large newborn unit with wings for neonatal intensive care and pre-term babies. Maternity block staff attend over 9,000 births annually and include physicians, nurse-midwives, nurses, and residents.

Between 2012 and 2015, the MMR at MNH increased from 96 to 146 deaths per 100,000 live births, whereas early newborn morality fell from 27 to 16 per 1000 births [23]. One reason for this rise may be a higher number of complicated referrals over this time period, as more women seek care in health facilities. However, the literature also indicates some degree of substandard care – specifically in terms of cesarean section indication, which suggests a need for stronger QI processes related to surgical and other outcomes [24-28]. Although MNH did have its own partially-electronic medical record system for patient charting prior to implementation of the current project, neither the hospital as a whole nor the

maternity block in particular had an HIS designed to provide real-time, easily accessible data to support QI processes, research, and operational decision-making.

### 2.2 Project Design and Implementation

As part of an initial assessment, EMPHASIS partners and members of MNH's maternity block staff identified establishing an HIS for inpatient maternal and newborn services as a priority action item, and as a first step towards improving QI processes and streamlining routine reporting throughout the hospital. Due to their constant presence on the wards and integrative work with QI processes, nurses and nurse-midwives (collectively referred to as "nurses" in this article) were invited to lead and implement the project. Both MNH and Emory IRBs determined the project to be program evaluation, and therefore exempt from ethical review.

REDCap (Research Electronic Data Capture) was selected as the data collection system for the HIS, which was called the Obstetric and Neonatal (OBNN) Database. REDCap is a secure, web-based software platform designed to support validated data capture [29]. It has a highly intuitive interface and runs on different operating systems (Linux, Unix, Windows, and Mac). In addition to modest hardware and software requirements, its free access and free technical support for REDCap Consortium Partners made it a good choice for this project [30]. REDCap uses PHP + JavaScript programming languages and a MySQL database engine and is compatible with Microsoft Windows IIS or Apache web server environments with PHP 7.2.5 and higher (at MNH, the MySQL database is integrated with Apache). Project setup requires little resource investment beyond creation of the instrument(s) and data dictionary, and data export includes seamless download to common statistical packages [29].

Data collection occurs via web browser or the REDCap mobile application, which connects directly to the REDCap server and is installed on mobile devices such as iPhone, iPad, and Android phones and tablets. Data entered on a web browser is saved to the system at the time of entry, while the app allows for offline data collection with later upload in the event of poor internet connectivity. Internet security at MNH is protected by Sophos Firewall, and remote access to the organizational network requires multi-factor authentification. The MNH REDCap server is cloud-based and hosted by TMDHosting, which has its own security configuration design. Finally, REDCap itself offers a number of security features, such as user passwords, access authentification and authorization, user privileges at the project level (including role-based access and data export controls), automatic session termination, and a built-in audit trail for tracking data manipulation and export.

The OBNN Database REDCap project was developed by a team of nurses, physicians, and information technology (IT) staff, with support from MNH's Training, Research, and Consultancy Unit

(TRCU). It is structured according to 5 separate instruments that each capture a different aspect of patient care: maternal background, labor and delivery, cesarean section, postnatal, and newborn. Indicators included standard as well as MNH-specific items and were designed to replace hard copy reporting (MoHCDEC and hospital-required). iPad tablets with SIM-card capability were purchased for data entry in all 10 wards and a process was developed to ensure their correct storage, safety, and maintenance. All aspects of data collection included input from staff nurses and were carefully designed to fit with the workflow of each ward.

### 2.2.1. Training (January-June, 2019)

Basic REDCap training sessions were offered to all hospital staff from January to April 2019, which included any interested maternity block staff members. Specialized training of maternity nurses on the OBNN Database then occurred over 4 sessions from May to June. Each of these classroom sessions lasted 1.5 hours and included an overview of the database, demonstration of how to use the tablets, and training on data entry. Ongoing training took place on the wards, which created an opportunity to improve the database on demand as well as immediately address questions and concerns. Such training also facilitated identification of nurse super-users – those who were able to quickly and adeptly integrate data entry into their workflow. These users were promoted as "project champions" and given additional time and training to provide 24-hour troubleshooting support and assist staff members who were less comfortable with the technology.

### 2.2.2. Pre-Test and Pilot Period (June-August, 2019)

A pre-test of database indicators was conducted in June with nurse leaders, where the instruments were reviewed and critiqued for inclusion, order, wording, and streamlining with required reporting items. Several changes were made at this point to increase efficiency and improve data quality and usability. In addition to improving the instruments, incorporation of feedback proved an important way to demonstrate staff ownership of the data and elicit buy-in. One of the barriers discovered during the pre-test involved access to reliable internet connection on the MNH network. This problem was resolved through a combination of keeping internet data added to the iPad SIM cards (using broader networks) and working with REDCAP's offline application.

A four-week pilot period occurred in July, during which time roughly 65% of all data (from 572 births) were recorded by nursing staff, with the remaining 35% completed by project team members. The high volume of births made keeping up with data checks and cleaning challenging, and it became clear that ideally data needed to be entered accurately in real time. To motivate the nurses to accomplish this

goal, some nurse leaders suggested permanent removal of the manual-entry data books so that the tablets were the sole means of data entry. Enacting this solution was complex in that it had implications for workflow beyond the maternity block and revealed ambiguity in leadership at the operational level – including the ability to provide clear directive for change. To overcome this obstacle, hospital leadership was engaged through individual meetings and group presentations that demonstrated the utility of the dataset. Project champions also assisted by providing invaluable information about workplace norms, culture, and resources. By the time of the official launch on September 1st, the manual-entry book had been removed and all data entry was occurring electronically.

#### 2.2.3. Mixed-Methods Evaluation (January-May, 2020)

A quantitative evaluation was conducted on all data gathered during the first 4 months of full OBNN Database implementation (September-December, 2019). Data were first checked for completeness by examining data from each instrument for missing values, which provided information on how well the nurses in different areas of patient care (intake, labor ward, surgical ward, postpartum wards, and newborn wards) were performing in terms of data entry overall. The database was then examined using REDCap's data quality functions to run data cleaning queries ("Data Quality Rules"), which involved checking for missing values and identifying out-of-range values and outliers.

To explore perceptions of and elicit feedback on the OBNN Database, a qualitative evaluation based on content analysis was conducted in January 2020 with maternity staff. After developing and pretesting a semi-structured interview guide, members of the project team purposively sampled staff members to include a range of user perspectives. Even though physicians did not play a role in data collection, they were included in the evaluation because they are important users of the database and their buy-in is important to its sustainability. Interviews were conducted in English (in which all participants were fluent), and took place in a private office during regular work hours at participants' convenience. Participants were made aware of the purpose, risks/benefits, and protections to confidentiality during an informed consent process that occurred prior to the interview. Each interview lasted up to 60 minutes and was audio-recorded; brief checks were performed at various points throughout to ensure correct interpretation. Interviews and early coding of de-identified transcripts were conducted in iterative fashion until team members determined data saturation was reached. MAXQDA 2020 qualitative data analysis software was used to create code and make code comparisons [31]. Other team members assisted in reviewing and refining these codes before final themes were abstracted, detailed descriptions written, and inferences made.

## 3. Results

### 3.1. Data Capture and Quality

From September through December of 2019, nurses in the maternity wards recorded all births occurring at MNH during this period, which totaled 2,193. Nurses on duty entered data during the course of regular workflow and by end-of-shift. The results for data capture were highly variable by REDCap instrument, which reflected different wards. Of the total records, only 2.9% of maternal background data were missing, and less than 0.1% of data for cesarean sections. However, the labor and delivery instruments were 26.2% incomplete. On closer analysis, most missing values were related to length of labor and state of the perineum among women delivered by cesarean section – a finding that provided valuable information about how to better order these items within the instrument so they might be more reliably entered. In contrast with these first 3 instruments, 1,717 (78.3%) of postnatal instruments and 1,863 (85%) of newborn instruments were incomplete. Further examination of missing values in these instruments did not reveal discernable patterns by question type, but it did highlight challenges related to data collection processes and engagement among nurses working on these wards.

In terms of other quality-related data queries, no validation errors of incorrect data types were found across the entire dataset. In total, just 39 values were returned as outliers. Review of these data points showed that 12 were obviously incorrect values (likely reflecting a typo), 3 were incorrectly inputted weights (units reported in grams instead of kg), and the remainder were true outliers. As designed, the existing data were usable almost immediately after entry. For example, an early analysis revealed that estimated blood loss at cesarean sections was likely being inadvertently minimized, as reported values were far below average for this procedure. Inaccurate estimation could lead to undertreatment of this condition – a finding that demonstrates the ability of HIS to help rapidly identify clinical issues that should be targeted for quality improvement.

### 3.2. In-Depth Interviews

Interviews were conducted with a total of 18 purposively-selected staff members in the maternity block, including 9 nurses (4 nurses and 5 nurse-midwives), and another 9 physicians. Two of the nurses interviewed were currently working in a supervisory role in the wards, while the remaining nurses and nurse-midwives were regular staff members. Of the physicians, 7 were MNH attendings on the maternity block (one supervisory) and 2 were residents. The participants' average time of experience working at MNH was 13.2 years.

According to participants, benefits of using the OBNN Database clearly outweighed the challenges it presented. Most spontaneously recognized that electronic data collection in real time facilitates analysis that is essential for better understanding quality-related problems and for making decisions about how to

improve services. But beyond this issue, many participants also reported that electronic data entry reduced their daily workload and increased efficiency, in that having tablets in each ward eliminated the need to prepare manual entry books and to walk back and forth between wards to document information in these books. In addition to streamlining workflow, staff viewed the REDCap project as a way to substantially boost data quality. Several explained that having a set data entry instrument provides a structure that helps ensure that information is recorded accurately and completely – in contrast to manual-entry books, where data might be entered incorrectly or illegibly, or fields could be accidentally overlooked or intentionally skipped.

*It helps us do our job because in the years back with no database, we just skip the delivery, we go into the labor ward, maybe we're just writing, writing, writing, sometimes we forget it. But now, here it is, another delivery, just put the file in here. (Nurse-Midwife)*

Other reported benefits that were unanticipated included ideas related to data security and being up-to-date with the latest technology. Most participants saw the electronic database as a safer alternative to paper-based reporting, in that user restrictions and password protections permit more control over who can access the data. This issue stood out as being particularly important, as several participants described ways in which MNH has experienced a great deal of unauthorized data use by outside entities seeking to conduct their own research without proper permissions. Finally, participants expressed an overall sense of appreciation for being current or "updated" (vs. "left behind") with respect to technology. This finding concurs with our observation that having new iPads on the wards seemed to motivate staff support – although a few expressed concerns regarding the sustainability of the tablets with respect to updates, repairs, and maintenance.

*It [OBNN Database] protects the information. Because having written in the books, the books can get lost or misused. But this way, I feel that the information is securely stored. It's easily accessible and it also helps us...um...keep record of what the outcomes are, what exactly is happening. (Physician)*

Opportunities notwithstanding, the staff experienced several challenges to electronic data collection, the greatest of which was access to network connectivity. Slow or interrupted internet was identified as a cause of major disruptions to both data entry and staff workflow. Without reliable internet connection, participants described being unable to initiate new patient records in the database (which occurred through an automatically generated number for each admission) as well as difficulty continuing data collection for patients already admitted. Also discussed was how an inability to enter data due to poor connectivity could prevent nurses from timely presentation of the "bed state" report that facilitates shift

change. During periods of high volume, any delay caused a backlog of data not entered, which became a burden once connectivity returned.

*That's a very big challenge because you can have a queue of patients... particularly in the labor ward. You have a delivery, maybe four deliveries, and they want to take this patient to other wards. So, you need to fill [in the data for] each patient and if you miss, if there is network problem, they cannot proceed because the data is not there. (Nurse-Midwife)*

Technological skills were also seen as a barrier to successful data collection. Participants explained that some staff were slow to learn iPad functions and unfamiliar with certain features of REDCap, which prevented smooth workflow. Due to the flow of patients between the wards, failure to follow branching logic or otherwise correctly enter data in one ward could negatively affect the ability of staff in other wards to do the same. This "system breakdown" could temporarily cause missing data, at times prohibiting staff who encountered patients later in the course of admission from producing accurate data themselves.

*For example, when we discharge babies in my unit, when I enter data at discharge, you can see some files from post-natal wards that are not entered in database. So, when the postnatal nurse doesn't enter the data, I won't succeed. (Nurse)*

When problems with data collection arose, participants were pleased with the support they received from members of the project team and from the project champions designated to assist. Those who expressed frustration or continued to experience challenges of this nature felt that these problems could be reduced or eliminated with the proper inputs, and often provided suggestions for solutions, primarily involving more one-on-one training. Two nurses mentioned that staff occasionally had to resort to using personal devices such as computers or cell phones during the workday if other equipment was not available. Other recommendations involved ideas for more convenient storage and access to the tablets, as well as minor revisions to the ordering of indicators for improved workflow integration.

**4. Discussion**

The effort to design and implement an electronic HIS in MNH's maternity block had mixed results, but its successes have been sustained to date. Given that this type of system was relatively new for most nurses involved, initial discomfort with respect to the technology is not surprising. However, with nearly 100% data capture of births just 4 months after launch and little intervention from the project team, it is clear that nursing staff on the labor and surgical wards were able to work through any ongoing challenges and incorporate use of the OBNN Database as a routine activity.

Part of this positive outcome can be attributed to repetitive, hands-on training prior to launch and intensive troubleshooting assistance in the first few weeks afterwards. Establishing a new HIS in a high-volume referral hospital is a remarkably complex task that requires a significant time commitment and continuous support. This lesson is apparent in the discrepancy between the progress of the labor ward and operating theater vs. the postnatal and newborn wards, where the project did not deliver on its goals. Due to limited project resources and lack of project champions, the nurses responsible for data entry on the latter wards received less training and support – which resulted in less effective integration into workflow and lower uptake. The current priority for this project is to bring these wards on par with the others, and to offer further training on data analysis for all interested staff.

Another pivotal factor in database acceptance involves work done at the cultural level in terms of understanding and operating within existing roles, relationships, and power structures (both formal and informal). Stakeholder involvement in the project design and implementation was a fundamental component of the project's overall purpose, and engagement of leadership at all levels was identified as an integral factor for project success. It is likely this work would not have gotten off the ground were it not for buy-in from key personnel, including project champions and support from higher-level administration. Just as critical was the promotion of nursing ownership of the database (as opposed to work that serves to further someone else's agenda), which was clearly reiterated at every stage of the project. The nurses understood that the data they produced would not only facilitate more efficient MoHCDEC reporting, but could also enable development of their own QI activities and research.

The OBNN Database project has served as a model for HIS projects in other parts of the hospital. Since its initiation, electronic data capture with REDCap has expanded throughout MNH, including operations work in administrative offices as well as QI and reporting activities in various clinical units (pediatric and adult intensive care, burn, oncology, haemotology). The TRCU has also improved its capacity to support these databases through ongoing training and consulting. More recently, MNH has greatly strengthened its network capacity and extended access to all staff, making data collection with REDCap even more feasible.

## 5. Conclusion

Effectively functioning HIS are imperative to advancing the quality of maternal and newborn health services in sub-Saharan Africa, where births in health facilities are increasing but outcomes are not consistently improving. As efforts are made to achieve the new Sustainable Development Goal of reducing global maternal mortality to 70 deaths per 100,000 live births by 2030 [32], it is essential that capacity for HIS is strengthened in facilities where these systems are lacking. Apart from ensuring access to care, goals

for maternal newborn health are unlikely to be achieved unless quality of care is better understood and addressed. To provide health facilities with reliable, real-time information for evaluating and improving their outcomes, HIS must be closely tailored to the needs of specific contexts and for the benefit of all users. More innovative approaches that focus on HIS capacity building in health facilities are needed to inform local decision-making for improvements in processes and outcomes.

## 6. Declarations

### 6.1 Abbreviations

| | |
|---|---|
| **EMPHASIS:** | Emory-Muhimbili Partnership for Health Administration Strengthening and Integration of Services |
| **HIS**: | Health Information System |
| **MoHCDEC:** | Ministry of Health, Community Development, Gender, Elderly, and Children |
| **MMR**: | Maternal Mortality Ratio |
| **MNH**: | Muhimbili National Hospital |
| **MTUHA**: | Mfumo wa Taarifa za Uendeshaji Huduma za Afya |
| **OBNN Database**: | Obstetric and Neonatal Database |
| **QI:** | Quality Improvement |
| **TRCU**: | Training, Research, and Consultancy Unit |
| **WHO**: | World Health Organization |

### 6.2 Conflict of Interest Statement

The authors declare they have no competing or conflicts of interest. The project funders were not involved in any part of the study design, implementation, or analysis.


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