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Strengths, pitfalls, and lessons learned in implementing electronic collection of childhood vaccination data in Zambia: The SmartCare experience☆

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Abstract

Background: Despite widespread interest in computerized vaccination information systems, evaluation of the data quality in these systems and their acceptability to frontline healthcare workers in low and middle-income countries aren't well addressed in the literature.

Objectives: Evaluation of vaccination data quality and facility-level staff perspectives on the strengths and challenges of a vaccination data module in a widely used electronic health record (EHR) system in Zambia.

Methods: After a desk review of data from two provinces, a cross-sectional mixed methods study was designed, including quantitative analysis of data quality and qualitative analysis of the module's acceptability to facility staff, using the Information System Success model as the framework for evaluation of system quality, service quality, and information quality. Data were collected from 10 purposively sampled health facilities.

☆The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the US Centers for Disease Control and Prevention.

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Author statement

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Declarations of interest

None.

Results: There was low current use of the vaccination module by facilities in the study area (2%). Daily power outages presented a practical challenge. Staff who had used previous EHRs had concerns about sustainability.

System quality: While the module was user-friendly, there were concerns about EHR compatibility with vaccination workflow and outreach settings, where vaccines are commonly administered to older children.

Service quality: The module was viewed as dependable; perceptions were influenced by computer literacy.

Information quality: The database contained incomplete and incongruous data. Staff perceived data as accurate but incomplete; easy access to data was a strength.

Conclusions: Potential benefits of the vaccination module were frequently unrealized due to infrastructure, workflow, and data flow challenges that resulted in low module use and poor information quality. Elements to optimize vaccination information system implementation could include robust engagement of facility-level staff in system design, system suitability to the vaccination setting and workflow, and comprehensive planning for data flow, sustainability, data monitoring and feedback. Adaptability to the outreach setting might be increasingly important as vaccination schedules extend past infancy.

Keywords

Data quality; Vaccination records; Electronic health records; Data collection; Registries

1. Background

Reliable longitudinal vaccination records are a crucial component of the Expanded Programme on Immunization. Limitations of traditional paper-based records include challenges in tracking children who receive vaccinations at multiple facilities and redundant data entry on multiple forms. There is widespread interest in leveraging technology to improve vaccination records. However, published studies evaluating the use of computerized vaccination information systems in lower and middle-income countries are lacking.

In 2005, the Republic of Zambia, in collaboration with the U.S. President's Emergency Plan for AIDS Relief (PEPFAR) partners, implemented SmartCare, an integrated electronic health record (EHR) originally designed to provide continuity for antenatal care, and later for HIV treatment. SmartCare has been launched in about 1000 health facilities, approximately one third of health facilities in Zambia. Each client is issued a 'SmartCard', a chip-based card containing the client's medical records. The client presents the SmartCard at each visit, allowing staff to access and add to the medical record. Data are archived in the facility's SmartCare database, which is later merged via data transfer by portable USB drives at the district, provincial, and national levels. At the time of the study SmartCare was run on desktop computers at each health facility; mobile platforms have now been implemented.

In Zambia, vaccination data are typically recorded on paper-based forms at the health facility, including both a daily activity sheet where staff record all vaccinations administered each day and a longitudinal paper register which tracks the total number of vaccinations

given to an individual child over time. Monthly facility totals are sent on paper forms to the district, where data are entered into the Health Management Information System (HMIS), which utilizes DHIS-2 software. In the HMIS, aggregate data are merged at the provincial and national levels; the HMIS does not include longitudinal records for each child. In 2011, a SmartCare module was created which keeps longitudinal childhood vaccination records. SmartCare has been evaluated generally as an electronic health record (EHR) [1], however the vaccination module and its acceptability to facility staff has not been previously evaluated.

The objectives of this study were to evaluate the quality of vaccination data in the SmartCare system in Lusaka and Southern Provinces, and facility staff perceptions of the strengths, challenges, and acceptability of the SmartCare module for vaccination data.

2. Methods

This study used a cross-sectional mixed methods design with purposive sampling. Lusaka and Southern provinces were studied due to the large number of SmartCare-enabled health facilities. The study was a collaboration between the Zambia Ministry of Health and the US Centers for Disease Control and Prevention (CDC). Ethical approval was granted by the University of Zambia Biomedical Research Ethics Committee (#FWA00000338).

2.1. Desk review

Administrative data were extracted and reviewed for a total of 103 facilities in 8 districts across 2 provinces; all SmartCare-enabled government health facilities in four districts of Lusaka province (n = 47 facilities) and four districts of Southern province (n = 56 facilities) were included in the desk review. These districts were included due to the high concentration of SmartCare-enabled facilities and feasibility of subsequent fieldwork, as the desk review results were subsequently used for field site selection. Vaccination coverage data for first (Penta1) and third dose pentavalent vaccine (Penta3) and first dose measles-containing vaccine (Measles1) for October-December 2015 were extracted from the HMIS and, if available, from the national SmartCare database. Aggregate data from the HMIS were considered the official or ‘gold standard’ record of vaccination doses administered. Low use of SmartCare for vaccination data noted on desk review prompted the investigation to focus on reasons for its limited use.

2.2. Site and sample selection

After the desk review and exclusion of pilot sites for other vaccination data systems, 10 facilities were purposively selected for field data collection in order to ensure inclusion of quantitative and qualitative data from sites representing a wide variety of key health facility characteristics. Four sites were high volume (> 100 children under 1 year of age in monthly target population), while six were lower volume; four were rural and six were urban; four had used SmartCare 5 or fewer years, while six had > 5 years of SmartCare experience. Three facilities had mean Penta1 coverage < 85% over the previous 3 months, indicating low coverage, while five had coverage between 85–100%. Two facilities had reported Penta1 coverage > 100%, indicating a likely issue with either the numerator (through improper

recording of immunizations administered) or the denominator (due to an underestimate of the target population). In each province the two facilities with the most recent vaccination data in the national SmartCare database were selected, while three were selected that had not used SmartCare for vaccination data to include perceptions of potential users. Between 2011 and 2015, three facilities had 3–5 years with vaccination data recorded in the national SmartCare database, one facility had data from one year in the database, and six facilities had no vaccination data in the database. In keeping with qualitative research standards, non-probabilistic purposive sampling was used to select interviewees for in-depth interviews (IDIs). Nineteen staff members in clinical, administrative, or data management roles at nine facilities were interviewed. Sample size was determined inductively; after the lack of newly emerging themes confirmed that saturation of themes was achieved [2] no further interviews were conducted.

2.3. Field data collection

In March 2016, a 4 person data collection team from the CDC visited each District Health Office to extract district-level administrative data for the selected facilities over the target months (October-December 2015), including aggregate vaccination data from the HMIS and, if applicable, the district-level SmartCare database.

At each health facility, the team gathered information about general operations and vaccination clinics. Monthly vaccination data for Penta1, Penta3 and Measles1 were extracted directly from facility paper and electronic registers, as available, for the target months. Twenty unique vaccination administration entries were randomly selected from the paper daily activity sheet and checked against the longitudinal paper register and, if applicable, facility SmartCare records.

The theoretical framework of the DeLone & MacLean Information System Success (ISS) model [3] was used as the basis for the qualitative evaluation. Three main ISS model domains that are significantly associated with the success of an information system include system quality (ease of use), service quality (capacity to respond to malfunctions), and information quality (perceptions of the accuracy, completeness, usefulness, and ease of access to data). This model has been studied in the context of low-resource settings with validation of its constructs [4], and the majority of relationships posited within the model were supported on meta-analysis [5].

At each facility, individual IDIs were conducted with 1–3 staff members in a private area. IDIs were audio recorded with interviewees' consent. Interviews followed a semi-structured guide informed by the ISS model domains.

2.4. Data analysis

Quantitative data were analyzed using SAS version 9.3 (SAS Institute, Inc., Cary, NC) and Microsoft Excel. Qualitative in-depth interview recordings were transcribed, with identifying information removed. Two CDC investigators agreed upon coding themes. Transcripts were coded, and a thematic analysis was conducted using NVIVO 10. Common themes and illustrative quotes are presented.

3. Results

3.1. Context

Although SmartCare was installed in all 103 facilities included in the desk review and other SmartCare modules (e.g., HIV treatment module) were being used, only 10 facilities (10%) had any vaccination data in the national SmartCare database and 2 (2%) were currently using the SmartCare vaccination module at the time of data collection. The two facilities currently using the module each had a strong history of SmartCare vaccination module use, with vaccination data entered for at least 80% of months since January 2011. One was a high volume clinic that had been designated a model clinic for the SmartCare system, while the other facility was a rural clinic with a smaller client population.

Power outages were a daily problem at all facilities. Hydroelectric dams provide over 98% of Zambia's electricity [6], and the region was experiencing severe drought. One facility had discontinued use of SmartCare after being disconnected from the power grid. In the other nine facilities, rolling power outages (locally called 'load-shedding') ranged from 4%–38% of core operating hours (median = 20%). One facility was not using SmartCare because load-shedding had forced cancellation of training. In addition, all facilities offered immunization services on a regular basis in at least one outreach setting. Outreach posts did not have desktop computers available for data entry into the SmartCare system, and frequently did not have access to electricity due to a rural or remote setting.

IDI respondents represented a variety of characteristics with regards to job, setting, and computer use (Table 1). Eleven (58%) interviewees worked at one of the 5 facilities at which another EHR system had been used before SmartCare. One interviewee had kept electronic primary care records through the Better Health Outcomes through Monitoring and Assessment project [7]; ten others had used electronic perinatal care records through the Zambia Electronic Perinatal Record System [8], which included functionality to store data on vaccinations offered to pregnant women and newborns. Both EHR systems had been discontinued.

On qualitative interview, staff were enthusiastic yet cautious about use of electronic vaccination data. Most respondents preferred a computerized system to a paper system; however, it was common for the same interviewee to make conflicting statements, expressing both enthusiasm for computerized records and practical challenges (Box 1; Quote A). Load-shedding dampened staff enthusiasm for use of SmartCare (Box 1; Quote B).

Most respondents that had used a discontinued EHR before SmartCare mentioned concerns about sustainability, even though the interview guide did not mention this topic (Box 1; Quotes C and D). They expressed hesitance to rely on SmartCare or other electronic records. Many emphasized the importance of long-range planning and government ownership, rather than time-limited pilots centered on donor priorities (Box 1; Quote E). In contrast, none of the staff at facilities without previous EHR use mentioned sustainability as a concern. This disparate finding between the two groups on an unprompted topic is indicative of strong concern among staff that had used a discontinued EHR.

When asked about staffing, several interviewees suggested training additional staff because turnover among trained staff caused temporary discontinuations of SmartCare use (Box 1; Quote F).

3.2. System quality

The vaccination module in SmartCare was perceived to be user-friendly by almost all respondents, and automated features and step-wise interfaces were viewed positively (Box 2; Quotes A and B). Clinicians recognized that a computerized system could potentially resolve the problem of redundant data entry on paper forms (Box 2; Quote C). However, most staff who had used SmartCare for vaccination data mentioned a net increase in data entry as paper and electronic records were maintained simultaneously, resulting in duplication of effort or “double work” (Box 2; Quote D).

In facilities where vaccination sessions were observed, one clinician vaccinated while another staff recorded data on paper forms. Where SmartCare was used, paper vaccination cards were passed to a colleague in another area of the clinic for electronic data entry after the vaccines were administered. As a result of this clinic workflow, most clinicians with experience using the SmartCare vaccination module felt that client wait time increased because clients waited for electronic data entry before retrieving their vaccination cards (Box 2; Quote E). Delays were sometimes exacerbated by lack of trained staff or slow data entry. A few respondents stated that sometimes data were not entered in SmartCare on high volume days in order to expedite clinic.

When asked whether it would be possible to address these issues by recording the vaccinations at the time and place where vaccines were administered, most vaccinators and administrators felt that even if desktop computers were accessible in the vaccination clinic workspace, it would not be feasible for a vaccinator to simultaneously enter data in SmartCare. Staff had concerns about data entry duties interrupting workflow and potentiating errors (Box 2; Quote F) as well as hygiene concerns (Box 2; Quote G). From their experiences with other modules, many clinicians also expressed worry that their relationships with clients suffer when they use computers (Box 2; Quotes H and I).

When asked what additional system features would be useful, staff desired functionality to ease their administrative workload, allowing clinicians to focus more of their time on client care. Suggested features included automated reporting, clinical decision-making support, and automated ordering of vaccines. When queried about desired hardware for module use, most interviewees preferred either a mobile device or a mobile device/desktop combination for vaccination data so that devices could hold a charge during load-shedding and be used during remote outreach sessions (Box 2; Quote *J*). Since desktop computers, and frequently electricity, were not accessible at outreach locations, data collected at these sessions would have to be entered into the system after the outreach team returned to the clinic; this created an additional step in the workflow to complete entry of these doses.

On quantitative analysis, the proportion of vaccines administered at outreach reinforced the need for a system usable during outreach sessions. In our sample, 4% of Penta1 doses (n = 1669) were administered at outreach sessions, as were 10% of Penta3 doses (n =

1397), and 22% of Measles1 doses (n = 1459). In Zambia, Penta1 is recommended at 6 weeks, Penta3 at 14 weeks, and Measles1 at 9 months [9]. In our sample, the type of vaccine was significantly associated with administration in outreach (X^2, $p < 0.0001$). As the recommended age at administration increased, there was a tendency for a higher proportion of vaccinations to be given during outreach sessions. Even at health facilities, vaccines were typically given in an area without access to an electrical outlet. SmartCare's reliance on a desktop platform may have been due to its origins as an EHR for antenatal care and HIV management, as these encounters commonly take place in private rooms. SmartCare has since been modified to be used on mobile platforms.

3.3. Service quality

Most staff viewed the SmartCare system as dependable. However, several respondents were more comfortable keeping backup paper records in case of malfunctions (Box 2; Quote K). Staff at four facilities reported occasional "freezing" of the system. Technical support response time was highly variable between facilities, however staff at both of the facilities currently using the SmartCare vaccination module reported very quick response times to their requests for assistance.

Interviewee computer literacy influenced feedback on service quality. Some of those with higher self-reported computer literacy expressed an interest in training to increase facility self-sufficiency in trouble-shooting common issues (Box 2; Quote L). Staff with high computer literacy who felt empowered to provide feedback to developers expressed more ownership and pride in SmartCare. One of the facilities currently using the system was a model clinic, where staff expressed confidence that their feedback was taken into account as system updates were planned; the other facility had a staff member who was comfortable with computers and served as a facility-level champion, mentoring fellow staff on its use. A few interviewees suggested more actively engaging diverse frontline clinical staff in system design and updates (Box 2; Quote M).

3.4. Information quality

3.4.1. Accuracy—Overall, accuracy of the vaccination data in SmartCare is viewed positively (Box 3; Quote A). Auto-checks to question improbable values at data entry and user guidance built into the interface were perceived to improve accuracy (Box 3; Quote B).

3.4.2. Completeness—All staff from facilities with a history of SmartCare use for vaccination felt that these data were less complete than paper records and therefore used paper records to generate reports (Box 3; Quote C). Challenges to SmartCare data completeness included load-shedding and insufficient manpower. System inaccessibility during load-shedding coupled with incomplete retrospective entry of missed data and outreach data contributed to low completeness (Box 3; Quote D).

Several staff expressed enthusiasm for the potential for electronic vaccination records to enhance continuity of care for clients who visited multiple facilities. However, barriers to realizing this potential included load-shedding and system inaccessibility during outreach (Box 3; Quotes E and F). Among the two facilities currently using the module, both

expressed that retrospective entry of doses after power interruptions and outreach sessions was a challenge. One facility had a high client volume and a larger number of data entry staff compared to other clinics; the other facility had a lower client volume and expressed that this made it more feasible to retrospectively enter vaccination data when needed.

Quantitative data confirms the perception of incompleteness. In the two facilities that were using SmartCare for vaccination data, consistently more doses were reported on paper records than in facility-level SmartCare data (Fig. 1). Comparing SmartCare data on facility computers with data for the same facility in the national database revealed data incongruency that could be due to a parallel data flow, or problems with data transfer (Fig. 2).

3.4.3. Usefulness—Motivation to use the system was linked to the ability to use the data (Box 4; Quote G). Several participants noted that the potential usefulness of SmartCare data was unrealized due to incomplete records (Box 3; Quote H). This lack of completeness made features like report generation unusable. Data analysis and use at the local level is important in vaccination programs. Several staff expressed interest in training on vaccination data analysis using SmartCare. Perceptions of usefulness varied by role; while administrative and data entry staff frequently knew how vaccination data in SmartCare could be used by the facility, most vaccinators did not.

3.4.4. Ease of access—Almost all staff reported that data were easier to access in SmartCare than from paper records and less prone to loss (Box 4; Quote I). Other strengths of SmartCare included data security and access to data from other facilities. Challenges to data access included load-shedding at the time that data were needed.

3.5. Study strengths and limitations

Strengths of this study included in-depth incorporation of the first-person perspectives of current and potential end-users. Where applicable, these perceptions were interpreted in light of quantitative data. Purposive selection of facilities and interviewees resulted in a wide range of perspectives from those working in different roles, community settings, and facility types to reflect the possible diversity of end-user opinions. At the same time, the semi-structured questionnaire guided by a specific theoretical framework resulted in responses with high content relevance.

Limitations include the inability to fully assess impact on clients, as client interviews were not performed. District, provincial, and national staff were not interviewed. This exploratory study did not employ representative sampling, so quantitative findings may not be generalizable. The sample size of facilities and interviewees who had used SmartCare for vaccination data management is limited, which made findings in some domains less robust or specific to the vaccination module.

4. Discussion

While staff recognized many potential benefits of the SmartCare vaccination module, such advantages were frequently unrealized due to challenges that resulted in low module use.

Consequently, incomplete and incongruent data diminished the system's usefulness and further decreased staff motivation to use the module. Ideally, a well-functioning information system would be a source of health worker empowerment [10]- provision of staff with the tools they need to attain performance standards and to use their time efficiently on their core job functions by streamlining administrative requirements. In this case, there were several barriers to this outcome. Study findings yielded lessons learned that are applicable to future efforts to inform vaccination data innovations in Zambia and beyond.

Load-shedding in Zambia magnified a problem generalizable to many settings- temporary system outages due to power loss, system maintenance, or turnover of trained staff. Contingency planning could include alternative power sources, mobile data collection, and established procedures and resources for entry of retrospective data. Training more staff would lessen unscheduled downtime. Staff frustration with sustained data entry into both the paper and electronic systems reinforces the need for a feasible transition strategy to a new system, ensuring that logistical requirements are met. While consistent electricity would address some challenges for this system, other issues, such as staffing and workflow, would remain.

Incompatibilities of the SmartCare module with vaccination workflow and setting could have resulted from adding a vaccination module to an EHR originally designed for other clinical services. While vaccinations for pregnant women were included in the antenatal care module of SmartCare, childhood vaccination clinics have a unique and high-volume workflow, are often held in remote outreach settings, and require an easily accessible longitudinal record. These aspects should be carefully considered when a pre-existing system is adapted for vaccination services. During system design and updates, decision-makers and developers should thoroughly understand vaccination-specific needs, incorporating robust input from diverse frontline staff. To improve data completeness and system quality, vaccination information systems should be feasible for use in outreach settings, aligning with recommendations to document vaccinations as close as possible to the time and place of administration published by the PanAmerican Health Organization and presented in World Health Organization fora [10,11]. The need for a system that can be used in less traditional settings is reinforced by the increasing proportion of vaccinations that were given in outreach with increasing child age. As countries introduce vaccinations in the second year of life and beyond [12], it will be important to implement data systems adaptable to outreach posts and schools.

The sustainability concerns of staff who had previously used a discontinued EHR reflect a potential drawback of pilot EHR projects; negative discontinuation experiences could cause staff skepticism and impede future efforts. Although pilot programs are sometimes necessary, investigators should transparently manage staff expectations. To minimize data loss, health records should not be fully transitioned to an electronic system without a clear plan for data migration, data back-up, and long-term sustainability. Scale-up and running costs are significant, but limited funding opportunities are available to countries for these long-term, expensive endeavors, which can stretch ministries as they seek to allocate limited resources most effectively [10]. Staff experiences during and after previous EHR use by a facility could influence staff acceptance of a new system. It is important that any

initiative is driven by the vision and agenda of a country's Ministry of Health, rather than external initiatives by stakeholders that may not be completely aligned with this vision [10]. Sustainability and interoperability of electronic health information systems are enhanced through the formulation of and adherence to strong national eHealth strategies.

Provider trepidation regarding computer use during client encounters is seen in Zambia and beyond. Clinicians in the USA express similar concerns [13], reinforced by some studies reporting decreased eye contact and verbal communication with EHR use [14,15]. Some healthcare systems are even employing medical scribes to facilitate communication and ease clinicians' administrative workload [16,17]. Given the well-documented importance of provider-client trust and communication to vaccination uptake [18,19], system design should maintain and foster these relationships. Incorporating client communication techniques into training on any computerized system could enhance staff acceptance. Studies of system impact on client flow during a piloting period could manage expectations regarding client wait times.

The perceived usefulness of system data was an important factor influencing module use, and the presence of highly motivated, engaged and computer literate staff was observed in facilities with sustained module use. Regular communication between administrators and clinical staff on how data in the system are used may help to increase provider engagement. Establishing a clear and responsive channel for facility-level staff to provide feedback would increase morale and engagement with the system. Service quality is key; rapid responses to requests for technical support was noted in facilities with sustained module use. Empowering staff with training in basic system trouble-shooting would increase facility self-sufficiency. Where feasible, incorporation of work-saving features to automate administrative tasks would enhance staff acceptance. Finally, routine data monitoring with triangulation of data at different administrative levels would enable rapid detection of low system use and data completeness or congruency issues.

The quantitative findings of low use and insufficient data quality in the SmartCare vaccination module were explained by challenges identified in all three ISS model domains on qualitative interview. Load-shedding and incompatibility with vaccination clinic setting and workflow were foundational problems that had sequential cascading negative effects on the system. Due to these problems, data were incomplete, resulting in lower perceived usefulness of data and subsequent lower perceived net benefit of the module. Ultimately, this resulted in low motivation to use the module, which perpetuated and worsened issues with the completeness of data. These findings illustrate the interconnectedness of systems issues that can lead to suboptimal use. While load-shedding was the most immediately apparent problem, compatibility with workflow was a deeper issue that would take more intensive system reconfiguration to resolve. Lessons learned may be applicable to a wide variety of contexts as countries consider implementation of electronic vaccination records.

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Summary Points:

What was already known:

- Electronic immunization information systems are being implemented in an increasing number of countries worldwide, including lower and middle income countries
- High quality immunization data are fundamental to the optimal effectiveness of a national immunization program.

What this study adds:

- The DeLone and McLean Information System Success (ISS) model can be used as a framework to evaluate the quality of immunization information systems.
- Reasons for low use of an immunization information system in Zambia included challenges in three key ISS model domains; these lessons learned could be useful to other countries or organizations planning or implementing an immunization information system.
- In our sample, vaccines scheduled for administration at a later age were more likely to be given in outreach settings; this emphasizes the need for attention to immunization information system compatibility with a variety of settings as vaccination schedules expand.

Box 1

In-depth interview quotes related to general use and context of SmartCare for vaccination - Zambia, 2016.

Quote ID	Subject	Participant role	Quote(s)
A	Contrasting sentiments about electronic data collection from same interview	Vaccinator	(**Q: What do you know about Smart Care?**) *"Ah! I don't even have interest in this... it has given us headache each time we don't have power ... So I feel it has also brought a lot of work on us."* (***Q: How do you feel that using only a computer... for immunisation records would compare to using only paper records?***) *"Of course, the computer is always better. Anything computerized."*
B	Context of load-shedding	Data Entry Clerk	*"So when power goes, it means that you go back now, start reentering those people from scratch using paper. That has caused... people to like, eh, lose that interest and then they're no longer looking forward to using Smart Care..."*
C	Experience with previous electronic health record (EHR) use	Vaccinator (previous use of discontinued EHR)	*"And the other disadvantage is that this thing, for how long will it be there. From experience I've seen these projects, they come and go- ... We had to enter information in those computers but we just didn't know- ... they have retrieved all the computers. Imagine some of the information we depended on those computers – they have gone with them! Mmm-hmm. So you can imagine if you had to again stop this thing..."*
D		Data Entry Clerk (previous use of discontinued EHR)	*"You might bring that system, it will be working, but once you withdraw we find that because of government of lack of priority, you find the system, again, it collapses, especially in terms of logistics, ehm, repairs of the software and all those things. So how sustainable will it be, your program?"*
E	Sustainability	Data Entry Clerk	*"I think there should be more effort by all stakeholders... We are talking about the district itself and the ministry together with our cooperating partners... because if we just put this all project in the hands of our stakeholders and maybe government is not paying particular attention, then we are not talking about seeing these things succeed anymore. Yes, because if it is one-sided, Smart Care can't work. We just need all our efforts together."*
F	Training adequate staff	Administrator	*"They should train many people. Like here, there are very few that are trained. If they are not here, meaning we are stuck. So if they can train as many people as they can so that everyone is exposed"*

Box 2

In-depth interview quotes related to system quality and service quality of SmartCare - Zambia, 2016.

Quote ID	Subject	Participant role	Quote(s)
A	User-friendliness	Data Entry Clerk	*"I might say it's user friendly. It doesn't need that much knowledge in computers and how to do certain things."*
B		Administrator	*"No, it's not difficult 'cause the goodness about the computer is they will guide you, yeah they will show you which step to take next"*
C	Potential of electronic systems to reduce duplicate data entry; interaction with history of SmartCare use for vaccination	Vaccinator (No experience with SmartCare vaccination module)	*"...computer will make your work easier. You won't spend most of your time on paper doing... the same... thing. For example, maybe use three papers or three- uh, registers."*
D		Data Entry Clerk (experience with SmartCare vaccination module)	*"Because it's, because people would say, now (sigh)—even, even me, I would say then what's the use of Smart Care... I'm duplicating my work. I use Smart Care, then I use paper. Smart Care, paper. Then there's no need forme to be using Smart Care."*
E	Wait times	Vaccinator	*"The only complaint they have was long waiting hours, the mothers... The mother complains 'we didn't eat, we are hungry, we have to eat and we are tired of sitting, you've kept our cards long'".*
F	Vaccinator workflow concerns	Vaccinator	*"I feel you can make a lot of mistakes. I feel I would get confused, mmm? Because I'd be handling a lot of things... Give this site, give this site, give this site.... And then, again, you add again data."*
G	Vaccinator hygiene concerns	Vaccinator	*"You know, the nature of the vaccine, we don't want to contaminate again. That's a sterile procedure. You can't touch a computer and give a vaccine. Hand-washing, you touch a client, you go and wash, you go to the computer. Yeeh! It would be a lot of work."*
H	Concerns for loss of provider-client connection	Vaccinator	*"I feel like you lose that contact with the patient, like the concentration goes on the computer so much."*
I		Vaccinator	*"Now, the problem we have is the nature of the work we do. Us nurses, the work is more on hands...The patents, we need to touch them... so you see? So if I'm seated there at the computer, they would think I have nothing to do or I'm wasting their time."*
J	Advantages of mobile platform	Vaccinator	*"Even maybe when you go for outreach, you are able to enter data just there. Yeah. But with the computer you have to come back and start entering data."*
K	Paper system as backup to electronic system	Data Entry Clerk	*(How would you feel about having a Smart Care immunization record on the computer* versus *on paper.....?) "I think one should supplement the other...It should be both, yeah, in case of, uh, any malfunction, you should be able to rely on what other, uh, system. So, they should be run concurrently. Not just one."*

Quote ID	Subject	Participant role	Quote(s)
L	Desire for on-site technical support	Data Entry Clerk	*"We don't have anybody technical stationed here in case you have a problem... You would have the knowledge to do certain things but the fact that you are not tasked to do certain things, you cannot. So it's difficult, because the time it takes for aproblem to be sorted out, uhh, it tends to be a bit long... You cannot proceed with your work. You need to make a phone call..."*
M	Need to involve clinical staff in design and updates	Data Entry Clerk	*"I don't know whether on the upgrades you are working hand-in-hand with the doctors or clinicians who understand better what happens... [I] recommend you involve also the clinicians from clinics, not from the hospital... the challenges could be different."*

Box 3

In-depth interview quotes related to information quality of SmartCare - Zambia, 2016.

Subject	Quote ID	Participant role	Quote(s)
Accuracy	A	Vaccinator	**(Q: Do you think that the information that does make it into Smart Care is accurate?)** *"Yes, yes, it's true, mm-hmm I have verified that if we enter a certain entry and check it, that I would find that it is there."*
	B	Data Entry	*"... if it's supposed to read 23rd October and then maybe you make a mistake, you write 32, the computer will automatically reject that date ... it will correct you. So in accuracy, I will say it's okay, mm-hmm."*
Completeness	C	Administrator	*"...it [SmartCare] will give us something maybe way, way, way below. Then we go back to our hard copies. That's where we get the actual."*
	D	Administrator	*"when we are here, if we have power constantly? It would be easier and there would be less data to enter after we comefrom outreach because what was done here is already in the system."*
	E	Data Entry	*"...the biggest challenge is—we talk of continuity of patient records but when there is no power, you cannot achieve that..."*
	F	Data Entry	*"you will not enter them [clients at outreach] in Smart Care, you just give them appointments to say come to the clinic.... Maybe out often only one would come...."*
Usefulness	G	Vaccinator	*"...if you're not using the data you're entering, so it's much work. But if you're using data, then... it becomes very easy, everything becomes easy."*
	H	Data Entry	*"for now I wouldn't say it's useful because if I'm going to print a report based on what I just entered in Smart Care, it will be an incomplete report. because some babies came when there was no power... or when there was only one person in MCH... So it will print out something that is not complete. So for now... when there is no power and the manpower is short, also it's not useful.."*
Ease of access	I	Data Entry	*"...on a computer it's access to the data which will be instant, and like, uh, in the books where you need to be flipping, you don't even know pages or when that particular person came back... the information is just instant. That's the advantage of this system, yeah."*

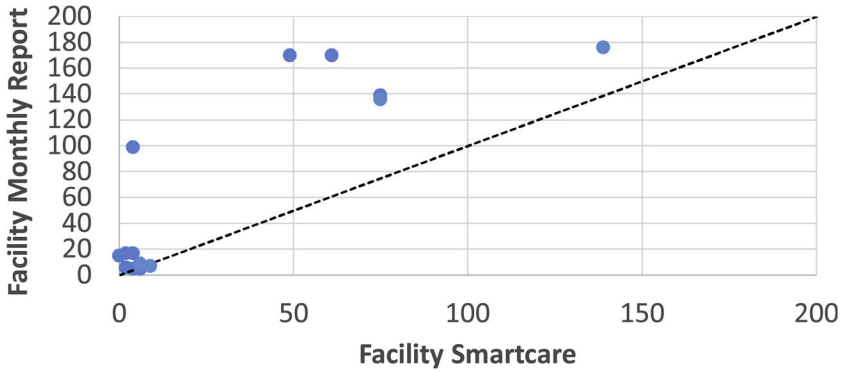

Fig. 1.

Comparison between the number of vaccinations (Penta1, Penta3, and Measles1) recorded on facility monthly report and facility SmartCare for selected facilities in Lusaka and Southern Province—Zambia, Oct-Dec 2015 Dotted diagonal line represents expected location of data points if data in the traditional paper facility monthly report and facility SmartCare database were a perfect match. Each data point represents the doses recorded for a single antigen over a single month at a health facility simultaneously using traditional paper records and SmartCare records for vaccination data. Data points above the line indicate that more doses were recorded on the facility monthly report than in the facility SmartCare database.

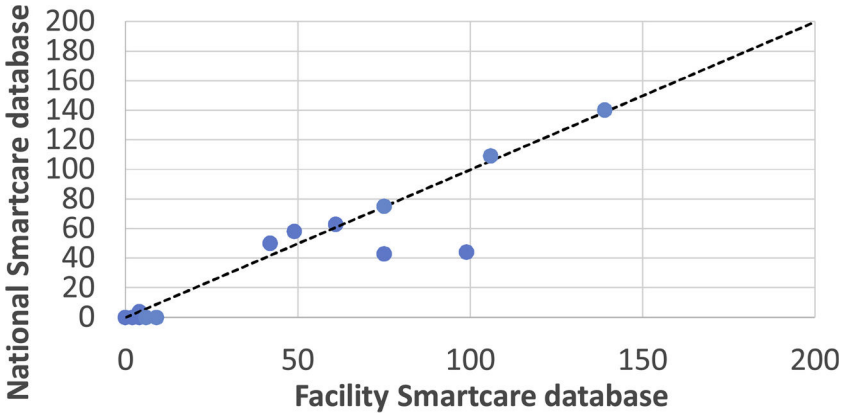

Fig. 2.

Comparison between the number of vaccinations (Penta1, Penta3, and Measles1) recorded in the national SmartCare and facility SmartCare for selected facilities in Lusaka and Southern Province—Zambia, Oct-Dec 2015 Each data point represents the doses recorded for a single antigen studied in a single month at one facility. Data points above the dotted line indicate that there were a greater number of doses in the national database as compared to the facility database. Data points below indicate that there are more doses recorded in the facility database than those reflected in the national database.

Table 1

Characteristics of Interviewees for In-Depth Qualitative Interviews - Zambia, 2016.

Primary job type		**# (out of 19)**	**Percentage**
	Vaccinator (nurse, midwife)	11	58%
	Data entry clerk or Data manager	5	26%
	Facility administrator (‘In - charge’)	3	16%
Community type			
	Rural	6	32%
	Urban	13	68%
SmartCare vaccination module use			
	Current SmartCare vaccination module use	6	32%
	Past SmartCare vaccination module use	2	11%
	Never used SmartCare for vaccination records *	11	58%
Previous use of another electronic health record			
	Yes	11	58%
	No	8	42%
Province			
	Lusaka	11	58%
	Southern	8	42%
Computer Literacy			
	Low	5	26%
	Moderate	8	42%
	High	6	32%

* Among these interviewees, all but one had used SmartCare in the past for another module, such as antenatal care or HIV treatment.