Public Health Action

International Union Against Tuberculosis and Lung Disease
Health solutions for the poor

VOL 10 NO 1 PUBLISHED 21 MARCH 2020

Effects of real-time electronic data entry on HIV programme data quality in Lusaka, Zambia

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http://dx.doi.org/10.5588/pha.19.0068

Setting: Human immunodeficiency virus (HIV) clinics in five hospitals and five health centres in Lusaka, Zambia, which transitioned from daily entry of paper-based data records to an electronic medical record (EMR) system by dedicated data staff (Electronic-Last) to direct real-time data entry into the EMR by frontline health workers (Electronic-First).

Objective: To compare completeness and accuracy of key HIV-related variables before and after transition of data entry from Electronic-Last to Electronic-First.

Design: Comparative cross-sectional study using existing secondary data.

Results: Registration data (e.g., date of birth) was 100% complete and pharmacy data (e.g., antiretroviral therapy regimen) was >90% complete under both approaches. Completeness of anthropometric and vital sign data was <75% across all facilities under Electronic-Last, and this worsened after Electronic-First. Completeness of TB screening and World Health Organization clinical staging data was also <75%, but improved with Electronic-First. Data entry errors for registration and clinical consultations decreased under Electronic-First, but errors increased for all anthropometric and vital sign variables. Patterns were similar in hospitals and health centres.

Conclusion: With the notable exception of clinical consultation data, data completeness and accuracy did not improve after transitioning from Electronic-Last to Electronic-First. For anthropometric and vital sign variables, completeness and accuracy decreased. Quality improvement interventions are needed to improve Electronic-First implementation.

Global antiretroviral therapy (ART) scale-up in response to the human immunodeficiency virus (HIV) pandemic has enabled 67% of people living with HIV (PLHIV) in Eastern and Southern Africa to now access treatment.[1] In Zambia, approximately 960 000 PLHIV are currently accessing ART out of an estimated 1 200 000 PLHIV nationally.[2] The Centre for Infectious Disease Research in Zambia (CIDRZ) is a key partner in Zambia's national ART scale-up, and supports HIV-related service delivery in two provinces, including Lusaka, the capital city (estimated population: 2.6 million).[3]

The Zambian public health system consists of three levels of care—first level (health posts, health centres and district hospitals), second level (provincial and general hospitals) and tertiary level (central and teaching hospitals). ART services are offered free of charge at all levels and in all public health facilities. As national ART scale-up has accelerated since 2002,[4] and the number of patients on treatment has grown, challenges have emerged with the management of ART programme data. Initially, paper-based registers and treatment cards were used to monitor PLHIV on ART, but as the number of patients and the variety of service delivery outlets grew, it became increasingly difficult to maintain completeness and accuracy of data with these monitoring tools.[5] Reliable medical records data are critical for good clinical practice, programme management, and decision making.[6]

Electronic medical records (EMRs), first developed in the early 1970s,[7] facilitate the collection of complete, accurate, and timely data. EMR systems have the potential to improve the quality of patient care, reduce the workload for healthcare workers, strengthen the monitoring and evaluation of health programmes and provide information for decision-making.[8–11] However, realizing this potential depends on the completeness and quality of data entered into the EMR, with the possibility that health facilities can misreport performance on key programme indicators.[12]

The EMR system used throughout Zambia is the SmartCare system, a Windows-based platform developed by the Zambian Ministry of Health (MoH) in collaboration with the Centers for Disease Control and Prevention (CDC). The SmartCare EMR was first introduced in 2004 to capture individual-level HIV patient data and programme indicators, but was later expanded to include other health facility services (e.g., outpatient care, laboratory testing, etc.). The system has become an integral part of the Zambian ART programme, serving as a clinical information management system to promote care continuity, and is vital to national and PEPFAR (President's Emergency Fund for AIDS Relief) monitoring and evaluation.

The SmartCare system has evolved over time. A paper-based patient file was part of the initial implementation of SmartCare, with data clerks entering all information from the paper-based file into the EMR at the end of the clinic day: this was called Electronic-Last. In 2015, the Zambian MoH introduced a direct entry system for SmartCare, with healthcare workers entering the data in real-time over a local area network: this was called Electronic-First. CIDRZ has been an implementing partner for SmartCare roll-out since the system's inception. Following this shift from retrospective to real-time data entry, vital questions have arisen about the impact of this new methodology

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KEY WORDS
anthropometry; EMR; data quality; HIV; SORT IT

Received 6 November 2019
Accepted 9 January 2020

PHA 2020; 10(1): 47–52

upon the completeness and quality of data entered in the SmartCare EMR.

The aim of the present study was to understand the effects of SmartCare transition to Electronic-First by comparing data completeness and accuracy for key HIV-related variables following change in data entry methodology from Electronic-Last to Electronic-First in selected high-volume facilities in Lusaka, Zambia, over the period of SmartCare transition (2017 and 2019).

METHODS

Study design

We conducted a comparative cross-sectional study using existing secondary data.

Setting and study sites

The study was conducted in Zambia, a landlocked country in southern Africa with a population of approximately 13 million.[13] In this population, HIV prevalence is estimated at 12.3% nationally and 16.1% in Lusaka.[2] Over 90% of the population is serviced by primary healthcare facilities, with higher-level hospitals such as district, central, and teaching hospitals receiving referrals and providing curative and specialized health services.[13]

The study included HIV clinics within health facilities from Lusaka Urban District, Zambia, with real-time SmartCare data entry, which had been implemented for at least 6 months between 2017 and 2019, and had between 5000 and 12 000 patients registered to receive ART. Five first-level hospitals and five health centres met the inclusion criteria.

Data collection, variables and analysis

Data entered retrospectively into the SmartCare system was defined as Electronic-Last, while real-time data entry by healthcare workers was defined as Electronic-First. We selected key programme variables for our analysis based on 1) their utility for providing direct clinical care; and 2) their high frequency of entry to ensure a large sample size of observations representative of data in the SmartCare EMR (Table 1). We extracted de-identified patient data for these variables from the last 6 months of data entry for Electronic-Last and the first 6 months of entry for Electronic-First using an SQL script from the main SmartCare EMR server, and assessed these for completeness and accuracy. Completeness was determined by confirming whether data for each of the required variable fields had been checked or entered into the electronic patient file. Data accuracy was evaluated through logic checks and assessment of whether there were outliers from normal accepted ranges. Frequencies and proportions of completeness and errors were calculated for each variable during the periods of interest for Electronic-Last and Electronic-First implementation. Variables for each model and between facilities and service delivery areas were compared by calculating proportions. All analyses were conducted in Microsoft Excel (Microsoft; Redmond, WA, USA) and STATA v15 (Stata Corp, College Station, TX, USA).

Ethics approval

Ethical approval was granted by the University of Zambia Biomedical Research Ethics Committee (UNZA-228/2019), the National Health Research Authority, the Lusaka District Health Office and the Ethics Advisory Group of the International Union Against Tuberculosis and Lung Disease, Paris, France (EAG 17/19).

RESULTS

Completeness of data

Completeness of data in the transition from Electronic Last to Electronic First is shown aggregated for all 10 health facilities in Table 2.

At the point of registration, data (patient identifier, ART number, date of birth, date of enrolment and scheduled appointment date) completeness was 100% in Electronic Last and Electronic First at all health facilities.

For anthropometric and vital signs, overall completeness ranged from 28% to 69% with Electronic Last and from 17% to 65% with Electronic First, with decreases in completeness for every variable as Electronic Last transitioned to Electronic First. At the hospital level, there was a similar pattern in findings, except that completeness for weight increased during transition from Electronic Last to Electronic First. At the health centre level, there was a similar pattern in findings, with decreases in completeness of variables from Electronic Last to Electronic First.

With regard to data on clinical consultation (clinical appointment dates, TB screening and WHO clinical

ACKNOWLEDGEMENTS

This research was conducted through the Structured Operational Research and Training Initiative (SORT IT), a global partnership led by the Special Programme for Research and Training in Tropical Diseases at the World Health Organization (WHO/TDR). The model is based on a course developed jointly by the International Union Against Tuberculosis and Lung Disease (The Union) and Medécins Sans Frontières (MSF/Doctors Without Borders). The specific SORT IT programme which resulted in this publication was jointly organised, implemented and mentored by the Centre for Operational Research, The Union, Paris, France; MSF-Luxembourg (MSF LuxOR); MSF-Belgium (MSF-OCB); the University of Bergen, Bergen, Norway and the London School of Hygiene & Tropical Medicine, London, UK. Funding was from the United Kingdom's Department for International Development (London, UK) and La Fondation Veuve Emile Metz-Tesch (Luxembourg). The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

Conflicts of interest: none declared.

TABLE 1 Variables assessed from available SmartCare EMR data by service delivery area, Lusaka, Zambia, 2017–2019

Registration	Anthropometry and vitals	Clinical consultation	Pharmacy
Patient ID (de-identified)	Height	Clinical appointment dates	ART regimen
ART number	Weight	TB screening	Next appointment date
Date of birth	Temperature	WHO staging	Dispensations
Enrolment date	Pulse		ART regimen components
Appointment date	Respiratory rate		
	Blood pressure		

EMR = electronic medical record; ART = antiretroviral therapy; TB = tuberculosis; WHO = World Health Organization.

TABLE 2 Entry completeness for key HIV-related variables during 6 months of Electronic-Last and 6 months of Electronic-First in 10 facilities between 2017 and 2019 in Lusaka urban district, Zambia

		All facilities			Hospitals			Health centres		
Category and type of HIV-related variables	Assessment of the variables	Electronic-Last %	Electronic-First %	% difference	Electronic-Last %	Electronic-First %	% difference	Electronic-Last %	Electronic-First %	% difference
Registration (IHAP), *n*		10 597	13 355		6 783	9 003		4 927	6 128	
Patient ID Number	% completeness	100	100	0	100	100	0	100	100	0
ART number		100	100	0	100	100	0	100	100	0
Date of birth		100	100	0	100	100	0	100	100	0
Enrolment date		100	100	0	100	100	0	100	100	0
Appointment date		100	100	0	100	100	0	100	100	0
Anthropometry and vitals, *n*		116 228	175 998		74 767	99 319		41 521	76 679	
Height	% completeness	53	41	–12	55	46	–9	48	35	–18
Weight		69	65	–4	64	66	+2	77	64	–13
Temperature		51	35	–16	49	31	–17	45	41	–14
Pulse		38	37	–1	40	40	0	32	33	+1
Respiratory rate		28	17	–11	28	15	–13	27	19	–8
Blood pressure		45	42	–3	44	47	+3	48	37	–11
Clinical consultation, *n*		63 106	86 452		39 653	52 711		23 453	33 741	
Clinical appointment dates	% completeness	100	100		100	100		100	100	0
TB screening		42	57	+15	49	58	+9	30	58	+28
WHO staging		73	80	+7	72	80	+8	74	80	+6
Pharmacy		139 820	184 581		57 254	97 646		77 403	86 935	
ART regimen	% completeness	95	93	–2	94	92	–2	95	95	0
Next appointment date		99	99	0	99	99	0	99	99	0
Dispensations, n		174 636	338 964		80 378	186 344		94 258	152 620	
Quantity, frequency and dosage		99	99	0	99	99	0	99	99	0
ART regimen components		95	97	+2	95	96	+1	94	98	+4

HIV = human immunodeficiency virus; IHAP = initial history and physical examination; ART = antiretroviral therapy; TB = tuberculosis; WHO = World Health Organization.

staging), overall completeness ranged from 42% to 100% with Electronic Last and 57% to 100% with Electronic First. Clinical appointment dates were always at 100%, but completeness for TB screening and WHO staging increased from Electronic Last to Electronic First. This pattern was similar in hospitals and health centres.

For pharmacy visits and dispensations, overall completeness ranged from 95% to 99% with Electronic Last and from 93% to 99% with Electronic First. Generally, the changes from Electronic Last to Electronic First were small and varied from being more to less complete, and this pattern was found in both hospitals and the health centres.

Errors of data entry

Errors of data entry in the transition from Electronic Last to Electronic First are shown for all 10 health facilities in Table 3. At the point of registration (ART number and scheduled appointment date), errors ranged from 2% to 39% with Electronic-Last and from 1% to 21% with Electronic-First, with errors decreasing from Electronic-Last to Electronic-First. A similar pattern was observed for hospitals and health centres. For anthropometric and vital signs, errors ranged from 33% to 76% with Electronic-Last and from 36% to 87% with Electronic-First, with errors all increasing from Electronic-Last to Electronic-First. A similar pattern was observed for hospitals and health centres.

With clinical consultation dates, the proportion of errors decreased from 25% to 11% overall when moving from Electronic Last to Electronic First, with a similar pattern being observed in hospitals and health centres.

DISCUSSION

We assessed the completeness and accuracy of data for key HIV programme variables needed for monitoring the health of PLHIV when starting and sustaining ART in Lusaka, Zambia. We observed important differences in data completeness and accuracy for these variables when transitioning from Electronic-Last to Electronic-First data capture at all health facilities. This information may be useful to clinicians, health facilities, implementing partners and the MoH for improving patient management, the ART programme, and planning the scale-up of Electronic-First across all health facilities in Zambia.

There was no difference in data completeness at registration service points at all health facilities when compared before and after the transition. Completeness of data at these registration service points has been of consistently high standards during both Electronic-First and Electronic-Last implementation. However, there was a slight improvement in registration data accuracy with the change to Electronic-First, particularly for appointment dates.

TABLE 3 Entry errors for selected key HIV-related variables based on specific logic rule sets during 6 months of Electronic-Last and 6 months of Electronic-First in 10 facilities between 2017 and 2019 in Lusaka urban district, Zambia

		All facilities			Hospitals			Health centres		
Variable assessed	Assessment of variables	Electronic-Last %	Electronic-First %	% difference	Electronic-Last %	Electronic-First %	% difference	Electronic-Last %	Electronic-First %	% difference
Registration, *n*		10 597	113 355		6 783	9 003		4 927	6 128	
ART number	% error	2%	1%	–1	2	1	–1	1	1	0
Appointment date		39%	21%	–18	36	17	–19	47	36	–11
Anthropometry and vitals, *n*		1 116 228	175 998		74 767	99 319		41 521	76 679	
Height	% error	48%	60%	+12	53	55	+2	52	65	+13
Weight		33%	36%	+3	24	35	+11	23	37	+14
Temperature		49%	65%	+16	45	70	+25	55	59	+14
Pulse		64%	65%	+1	68	62	–8	66	68	+2
Respiratory rate		76%	87%	+11	77	89	+12	73	86	+13
Blood pressure		57%	61%	+4	55	56	+1	52	66	+14
Clinical consultation		63 106	86 452		35 959	40 421		23 453	33 741	
Clinical appointment dates	% error	25%	11%	–14	21	8	–13	31	14	–17

HIV = human immunodeficiency virus; ART = antiretroviral therapy.

There was an increase in the completeness and accuracy of clinical consultation data observed at all health facilities. This is similar to what was found in Haiti during a quality assessment of their EMR, and in Ethiopia following transition from a paper-based registry to an EMR.[14,15] However, the completeness of data for TB screening was still poor, at 58%. This could be an indicator that TB screening is not being routinely performed or that it is taking place but not being recorded. Routine TB screening in PLHIV is recommended by the WHO and is important for early detection and treatment of the disease.[16,17] PLHIV are at greater risk of TB, with TB being the leading cause of death amongst those with HIV.[18] Zambia is a high TB burden country, with 59% of patients with new or relapse TB having HIV infection.[19] It is therefore vital that TB screening is performed and recorded at every clinic interaction.

Overall completeness of ART regimen data at pharmacies slightly decreased following the transition; this was in line with reports from in Ethiopia.[15] This incompleteness, while involving small margins, can nonetheless lead to critical misreporting, which might impact programme implementation, leading to potential stock outs of commodities. The impact of incomplete data at facility level cascades upward to the national level, and affects the procurement, planning and budgeting of drugs for health services.[20] Data from SmartCare EMR is used by the MoH and other implementing partners to report to donors, and this can also affect overall planning for health services across Zambia.

Anthropometric measurement and vital sign data did not improve in completeness, and in fact became more inaccurate following transition in data entry methodology from Electronic-Last to Electronic-First. Similar findings of missing and incorrect anthropometric and vital sign data in an EMR were reported in Mozambique.[21] Although anthropometric and vital sign data may not influence programme management, it is still critical that these data are accurate for monitoring a patient's clinical status. Changes in a patient's clinical indicators may be an early sign of ART failure or the development of new opportunistic infections or malignancy. Monitoring a patient's blood pressure is important for the early detection of hypertension. PLHIV on ART are at a higher risk for cardiovascular disease (CVD) because of a number of traditional and non-traditional risk factors.[22–24] As access to ART increases and virologic suppression is achieved, HIV-infected patients will live longer,[25] and experience a longer life expectancy with increasing risk of CVD such as coronary heart disease.[23] The estimated prevalence of hypertension in Zambia is 25.9%.[26,27] It is therefore vital that blood pressure be monitored accurately and routinely as part of a comprehensive hypertension management in PLHIV.

Growth monitoring (height and weight) is an essential part of providing care for children living with HIV. Poor growth could indicate ART treatment failure, or the presence of TB, opportunistic infections, malnutrition, or malignancy. Weight is also critical for drug-dose calculations in children and for monitoring progress of adults on ART. In Mozambique, height and weight data were the most commonly missed and inaccurate variables.[21]

Anthropometric and vital sign data may be missing or inaccurate due to lack or limited availability of equipment, such as a sphygmomanometer or weight scale. Inadequate lay health worker training and supervision on taking anthropometric and vital sign measurements, and entering these data into SmartCare, may also have contributed to poor data quality due to the limited understanding of normal anthropometric ranges among this cadre. Task shifting to lay health workers has become a normal part of care across the health care sector and is a well-established practice in HIV clinics in Lusaka.[28,29] As discussed above, the collection of anthropometric and vital sign data is important for clinical decision-making, and lay health workers who have been tasked with this responsibility need to be adequately trained and mentored on the importance of accurate and well-recorded data.[22]

An important strength of this study was the analysis of a large data set representative of key programme variables used in the SmartCare EMR for "real world" management of PLHIV in Zambia. This strength notwithstanding, our study had several limitations.

First, at the time of analysis, only 10 health facilities were eligible to participate in the Lusaka Urban District. Restricting our analysis to Lusaka hindered our ability to detect important differences in data accuracy and completeness in other districts, limiting the generalisability of our findings. Second, because of our pragmatic, before-after descriptive approach, we could not account for factors in our analysis that may have influenced data accuracy and completeness during the transition from Electronic-Last to Electronic-First, such as health worker training on data management.

Based on our study findings, we make the following recommendations for improved SmartCare EMR implementation under the Electronic-First strategy: 1) improve comprehensive training and mentorship of lay health workers in task-shifted anthropometric and vital sign data capture and entry; 2) remind clinicians and nurses about the importance of conducting and documenting routine TB screening; 3) incorporate automated data validation checks into the SmartCare EMR to only accept inputs within logical numerical data ranges; 4) regularly supervise and mentor staff on complete and accurate data entry; and 5) conduct routine data audits to assess the completeness and accuracy of SmartCare EMR data. Finally, additional implementation research should be performed to identify human-centred strategies to improve the user-friendliness of the SmartCare EMR and the data management systems built around it to enhance overall HIV programme data quality.

CONCLUSION

With the notable exception of clinical consultation data, there was no discernable improvement in the completeness or accuracy of data following the transition of data entry method from Electronic-Last to Electronic-First at the health facilities studied. Quality improvement interventions should be undertaken to ensure that the data entered into the SmartCare EMR is complete and accurate across all health facility levels and departments. These findings may be useful for other health actors looking to implement similar EMR systems in Zambia and other low and middle-income country settings.

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Contexte : Les dispensaires VIH (virus de l'immunodéficience humaine) de cinq hôpitaux et de cinq centres de santé de Lusaka, Zambie, où l'enregistrement des données est passé d'une entrée quotidienne de rapports papier à un registre médical électronique (EMR) ; parallèlement, on est passé d'un personnel dédié aux données (Electronic-Last) à une entrée directe en temps réel des données dans l'EMR par des travailleurs de santé de première ligne (Electronic-First).
Objectif : Comparer l'exhaustivité et l'exactitude des variables clés relatives au VIH avant et après la transition des données de Electronic-Last à Electronic-First.
Schéma : Etude comparative transversale basée sur des données secondaires existantes.
Résultats : Les données d'enregistrement (par exemple, la date de naissance) ont été complètes à 100% et les données de pharmacie (par exemple protocole de traitement antirétroviral) ont été $>$ 90% dans les deux approches. L'exhaustivité des données anthropométriques et des signes vitaux a été $<$ 75% dans toutes les structures sous Electronic-Last, et ceci s'est aggravé après Electronic-First. L'exhaustivité des données du dépistage de la TB et des stades cliniques de l'Organisation mondiale de la Santé a été également $<$ 75%, mais s'est améliorée avec Electronic-First. Les erreurs d'entrée des données d'enregistrement et des consultations cliniques ont diminué avec Electronic-First, mais les erreurs ont augmenté en ce qui concerne toutes les variables anthropométriques et les signes vitaux. Les profils ont été similaires dans les hôpitaux et les centres de santé.
Conclusion : À l'exception notable des données de consultation clinique, l'exhaustivité et l'exactitude des données ne se sont pas améliorées avec la transition d'Electronic-Last à Electronic-First. En ce qui concerne les variables anthropométriques et les signes vitaux, l'exhaustivité et l'exactitude ont diminué. Des interventions visant à l'amélioration de la qualité sont nécessaires afin d'améliorer la mise en œuvre d'Electronic-First.

Marco de referencia: Los consultorios de atención de la infección por el virus de la inmunodeficiencia humana (VIH) en cinco hospitales y cinco centros de salud de Lusaka, en Zambia, donde la informatización del registro de datos evolucionó de la introducción diaria de los registros llevados en papel en las historias clínicas electrónicas (EMR), por parte de personal dedicado a los datos (electrónico final), hacia la introducción inmediata y directa en las EMR por parte de los profesionales de salud que atendían a los pacientes (electrónico inicial).
Objetivo: Comparar la exhaustividad y la precisión de las principales variables relacionadas con el VIH antes y después de la transición del método electrónico final hacia la introducción electrónica inicial de los datos.
Método: Fue este un estudio transversal comparativo a partir de datos secundarios existentes.
Resultados: Los datos de la inscripción (por ejemplo, la fecha de nacimiento) fueron completos en el 100% de casos y los datos de farmacia (por ejemplo el esquema de tratamiento antirretrovírico) en más de 90% con ambos métodos. La exhaustividad de los datos antropométricos y de los signos vitales fue inferior a 75% en todos los establecimientos con el método electrónico final y se agravó después de instaurar el método electrónico inicial. La integridad de los datos de detección de la tuberculosis y de clasificación según la escala de la OMS también fue inferior a 75%, pero mejoró con el método electrónico inicial. Con el método electrónico inicial disminuyeron los errores de introducción de datos relacionados con la inscripción y las consultas médicas, pero aumentaron los errores sobre todas las variables antropométricas y los signos vitales. Se observó un perfil equivalente en los hospitales y los centros de salud.
Conclusión: Con la excepción notable de los datos sobre la consulta médica, la exhaustividad y la precisión no mejoraron tras cambiar el método electrónico final por un método de introducción electrónica inicial. Disminuyó la exhaustividad y la precisión de las variables antropométricas y los signos vitales. Es necesario adoptar intervenciones de mejora de la calidad, con el fin de optimizar la introducción electrónica inicial de los datos.

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e-ISSN 2220-8372
Editor-in-Chief: Dermot Maher, MD, Switzerland
Contact: pha@theunion.org
PHA website: http://www.theunion.org/what-we-do/journals/pha
Article submission: http://mc.manuscriptcentral.com/pha