Electronic health records for better health in the lower- and middle-income countries

A landscape study

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Abstract

Purpose – Electronic health records (EHR) can enable collection and use of data for achieving better health both at the patient and population health levels. The World Health Organization's (WHO) draft 2019 four-year global digital health strategy aims to "improve health for everyone, everywhere by accelerating the adoption of appropriate digital health" and EHRs are key to achieving better health goals. Despite the fact that EHRs can help to achieve better health, there is lack of evidence explaining national and sub-national EHR development in the limited resource settings.

Design/methodology/approach – We conducted a landscape study to describe the EHR development and use in the low- and middle-income countries for achieving better health. We reviewed literature from four scientific databases and analyzed gray literature identified in consultation with 17 international experts.

Findings – The findings of this literature review are presented in three subsections. The first two subsections describe key stakeholders for development of national and sub-national EHR and health information architecture which includes status of ehealth foundations, EHR, and sub-systems in the country. The third subsection presents and discusses key challenges related to sustainability of national and sub-national EHRs. The findings in these three subsections are further explored through examples of health information flow in Uganda, and electronic medical record/EHR implementation in Sierra Leone and Malawi. These examples briefly describe stakeholders, information architecture, and sustainability challenges.

Originality/value – This paper fills an important research gap and clearly explains the urgent research need to build context-specific EHR development models to enable use of data for better health.

Keywords Information systems, Developing countries, Generation and dissemination of information, Electronic health records, Health system, Global health

Paper type Literature review

Background

The newly released World Health Organization's (WHO) draft four-year global strategy on digital health aims to "improve health for everyone, everywhere by accelerating the adoption of appropriate digital health" (WHO, 2019a) and clearly underscores the value of electronic health records (EHR) for achieving this (Syzdykova *et al.*, 2017) (Jawhari *et al.*, 2016). Development of national and sub-national EHR in the health care system of the low- and middle-income countries (LMICs) is also vital for achieving the United Nations Sustainable Development Goal of ensuring healthy lives and promoting well-being for everyone at all ages.

The uptake of EHRs has been minimal given the fact that the WHO published its EHR manual for developing countries more than a decade ago (WHO, 2006). While national EHRs are a high priority in the developed countries and there is broad adoption of EHRs across different levels of health care delivery, development and use of modern EHR systems in LMICs is still in a nascent stage or even non-existent (WHO, 2016). As a result, LMICs are struggling to deal with critical health care challenges, particularly fragmentation of information, difficulty in tracking services, and consequent gaps in safety and quality of health care. The fact that the spare and minimal use of EHR systems, where they are deployed, do not adhere to data quality, and assessment metric standards make the latter challenges even more intractable. The development of digital infrastructure such as national EHRs to support all the health system building blocks[1] of the health care system is a multi-dimensional challenge requiring a significant investment of time and money (Aminpour et al., 2014) and involves diverse stakeholders with varying, often competing, health information needs.

In order to develop a common understanding and clearly explain the problem statement and the purpose of this paper, working definitions of relevant key terms are described in Table I. These terms were identified and defined based on the author's understanding of the problem and the questions this literature review aimed to answer.

Problem statement and scope
Globally, there is a general consensus that digital technologies such as EHRs can enable capture, analysis, and use of data for both population and patient-centered health care delivery (Syzdykova et al., 2017), (Jawhari et al., 2016). The potential benefits of digital health are evident from the recent draft digital health strategy of the WHO and also from the fact that the Digital Regional East African Community Health (REACH) initiative, launched in 2017, aims to create an enabling environment for digital health across the East African Community (EAC) region that includes the partner states of the Republic of Burundi, the Republic of Kenya, the Republic of Rwanda, the Republic of South Sudan, the United Republic of Tanzania, and the Republic of Uganda (EAHRC, 2017). The Digital REACH initiative is a regional commitment to improve health outcomes through digital technologies such as EHRs. All these strategies and initiatives underline three key dimensions – stakeholders, health information architecture, and sustainability – driving the development of EHRs (Figure 1). The health information needs of diverse stakeholders – providers, payors, policy makers and managers, health information technologists, and community health workers at the facility and community, district, regional, national, and global levels are intertwined with the complex national health care systems that are embedded in the larger political and administrative structure of the country. The health care administration in the LMICs is either

	Electronic health record (EHR): It refers to patient-level data collected, managed, and used across the enterprise National/sub-national: Country and its constituent administrative structures. For example, India is a country consisting of states, districts, and sub-district level administrative structures Integration: This term refers to integration of primary, secondary, and tertiary healthcare services delivered by a country's health care system Strategy: In this review, this term refers to methods and approaches chosen to develop national EHRs in the healthcare system of the LMICs Stakeholders: Providers, community health workers, payors, policy makers/managers, health technologist Health information architecture: A blueprint that guides investment in digital health technologies, facilitate improved system interoperability, reduce duplication of development efforts, enable data exchange and data use, and maximizes value of digital health investment Sustainability: ability of a national and sub-national health care system to design, implement, use, maintain, and continuously improve a health intervention and/or digital system

Table I.
Key terms used in the paper

centralized, decentralized, or federated (differential administrative/legal authorities at national and sub-national levels) and influences the health information architecture. Most of these countries rely on external financial and technical assistance to meet financial and workforce capacity development needs. EHR development is both affected by and influences stakeholders and their information needs, health information architecture, and sustainability factors such as finance, workforce capacity, and technology infrastructure. Also, stakeholders, health information architecture, and sustainability factors interact with one another. For instance, stakeholder group composition determines the health information needs that influence the health information architecture, technology infrastructure, workforce capacity, funding requirements.

Despite the fact that understanding of stakeholders, health information architecture, and sustainability factors are essential to develop national EHRs (Kumar *et al.*, 2017), there is limited research evidence about how to develop national and sub-national EHRs in the health care systems of the LMICs that facilitates health care service delivery at the patient and population levels (Kumar and Mostafa, 2019). A quick screening of abstracts of 226 her-related review papers (https://ehrlmic.unc.edu/), especially systematic reviews, from PubMed and Web of Science databases yielded only two relevant review papers from the LMIC perspective. Moreover, these papers were focused on EHR implementation challenges in the context of LMICs.

Therefore, a landscape study comprised reviewing of available scientific literature and country-specific policy/program/strategy documents were proposed to analyze available information in order to answer the following specific questions:

(1) How have the LMICs approached the development of national and sub-national EHRs?

(2) What are the challenges to sustainability of national and sub-national EHRs?

(3) What are the key future research priorities that can guide the development of national and sub-national EHRs in the health care system of LMICs?

The scope of this paper included investigating the above research questions using the following dimensions: stakeholders, health information architecture, and sustainability.

Methods
The methodology was designed to align with the scope of this landscape study while acknowledging the fact that limited scientific publications are available in scientific databases and mostly available as gray literature.

For conducting evidence-driven review, a comprehensive survey of literature was conducted using scientific electronic databases – PubMed, SCOPUS, Web of Science, Global Health, and curated lists of publications shared by two international digital health experts at the InterAmerican Development Bank and the Asian Development Bank respectively.
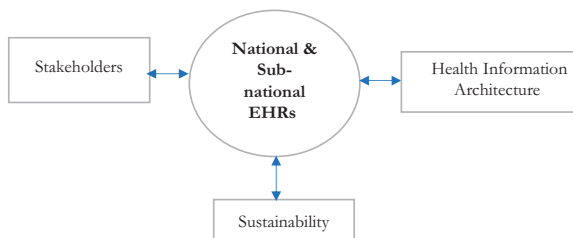

Figure 1.
Interlinkages between stakeholders, health information architecture, sustainability, and development of national and sub-national EHRs

The country-focused gray literature search included electronic repositories and consultation with international and country-based experts.

Comprehensive literature search and review

Evidence-driven literature search and review. A two-pronged strategy was adopted to conduct a comprehensive, yet focused search of peer-reviewed literature. The key terms mentioned in Table I helped to define the search terms and consult international experts to identify relevant peer-reviewed publications. These peer-reviewed publications laid the foundation for evidence-driven analysis.

First, the author conducted an electronic search across four scientific databases on May 15, 2019: PubMed, Web of Science, SCOPUS, and Global Health. PubMed is the world's largest freely available clinical and biomedical citation database. SCOPUS is updated daily and is the largest curated abstract and citation database of peer-reviewed literature. It includes more than 23,700 peer-reviewed journals in the fields of science, technology, medicine, social sciences, and arts and humanities. Web of Science is also a curated collection of over 20,000 peer-reviewed, high-quality scholarly journals published worldwide (including open-access journals). It has strong coverage of the natural sciences, health sciences, engineering, computer science, and material science disciplines. Conference proceedings (e.g. American Medical Informatics Association Annual Symposium) and books are also included. Global Health database extensively indexes journals from developing countries. Search terms used for each database are provided in Table II.

These search terms were finalized based on inputs from scholars participating in the meeting of the Laboratory of Applied Informatics Research and after consultations with an EHR expert and a health informatics librarian from the University of North Carolina at Chapel Hill. The electronic search did not use publication period or geography to limit search results in order to obtain a broad sample of literature but it did limit the focus to English-language publications.

Second, to identify any other relevant peer-review publications that the electronic search of scientific databases might have missed, the author consulted international experts from the Inter-American Development Bank in Washington, D.C. and the Asian Development Bank. The expert as the Asian Development Bank had extensive digital health experience in United States, Africa, and Asia.

Country-focused literature search and review. The country-focused gray literature search included electronic health repositories of the WHO headquarter and its regional offices in Africa and Americas, the United States Agency for International Development (USAID)-MEASURE Evaluation project, and the South Africa-based non-profit organization HealthEnabled. The literature search also included communicating with 17 international and country-based experts from 16 different organizations working in the digital health and health information systems domain (Table III).

Data management

The Mendeley reference management system was used to organize and remove duplicate publications identified through the search strategies for electronic databases and also to organize the strategy, policy, and guidance documents.

Inclusion and exclusion criteria

The peer-review publications that focused on strategies for developing national EHR in healthcare systems in LMICs were included for title and abstract screening. All non-

#	Database	Search terms	# Results
1	SCOPUS	TITLE-ABS-KEY ("delivery of health care" OR "Healthcare Delivery" OR "Health care Delivery" OR "healthcare system" OR "health care system") AND TITLE-ABS-KEY (hospitals OR hospital) AND TITLE-ABS-KEY ("Electronic Health Records" OR "Medical Records Systems" OR "Medical Informatics" OR "Personal health records" OR "Health Information Systems" OR "Hospital Information Systems" OR EHR OR EHRs OR EMR OR EMRs OR PHR OR PHRs OR "Electronic Medical Records" OR "Electronic Medical Record" OR "Computerized Medical Records") AND TITLE-ABS-KEY ("developing country" OR "Developing Countries" OR "low resource" OR "limited resource" OR "low resources")	116
2	Web of Science Core Collection	TS = ("delivery of health care" OR "Healthcare Delivery" OR "Health care Delivery" OR "healthcare system" OR "health care system") AND TS = ("hospital*") AND TS = ("Electronic Health Record*" OR "Medical Records System*" OR Medical Informatics OR Personal health record* OR Health Information System* OR Hospital Information System* OR EHR OR EHRs OR EMR OR EMRs OR PHR OR PHRs OR "Electronic Medical Record*" OR "Computerized Medical Record*") AND TS = ("developing countr*" OR "low resource*" OR "limited resource*")	72
3	PubMed	("delivery of health care" [MeSH] OR "healthcare delivery" OR "health care delivery" OR "healthcare system" OR "health care system" OR "delivery of health care") AND ("hospitals" [MeSH] OR hospitals OR hospital) AND ("Electronic Health Records" [Mesh] OR "Medical Records Systems, Computerized" [Mesh] OR Medical Informatics [MeSH] OR "Health Records, Personal"[MeSH] OR "Health Information Systems"[MeSH] OR "Hospital Information Systems"[Mesh] OR EHR OR EHRs OR EMR OR EMRs OR PHR OR PHRs OR "Electronic Medical Records" OR "Electronic Medical Record" OR "Computerized Medical Records") AND ("Developing Countries" [Mesh] OR "low resource" OR "limited resource" OR "low resources")	153
4	Global Health	TX ("delivery of health care" OR "Healthcare Delivery" OR "Health care Delivery" OR "healthcare system" OR "health care system") AND TX (hospital*) AND TX ("Electronic Health Records" OR "Medical Records Systems" OR "Medical Informatics" OR "Personal health records" OR "Health Information Systems" OR "Hospital Information Systems" OR EHR* OR EMR* OR PHR* OR "Electronic Medical Record*" OR "Computerized Medical Records") AND TX ("developing country" OR "Developing Countries" OR "low resource" OR "limited resource" OR "low resources")	61

English-language papers and those describing the developed country context were excluded from the review. The same screening criteria were used for the full text review. The country strategy, policy, and guidance documents describing EHRs (and/or related terms) were included in the review if available in the public domain and published in English language.

Data analysis
Data analysis was primarily qualitative, and findings were organized to highlight stakeholder, health information architecture, and sustainability related results.

#	Organization name	Country
1	World Health Organization (WHO) Headquarters	Switzerland
2	Africa Regional Office of the WHO	Brazeville, Congo
3	Inter-American Development Bank headquarter	United States
4	Asian Development Bank	Philippines
5	United States Centers for Disease Control and Prevention	United States
6	United States Agency for International Development	United States
7	Ministry of Health, Republic of Uganda	Uganda
8	Ministry of Health, Republic of Rwanda	Rwanda
9	Health Information Systems Program	Tanzania
10	PATH Africa Region	Tanzania
11	Baobab Trust	Malawi
12	JEMBI Health Systems	South Africa
13	HealthEnabled	South Africa
14	Intellisoft, Inc.	Kenya
15	University of Lausanne	Switzerland
16	PATH	United States
17	Asian ehealth Information Network	Philippines

Table III.
List of experts consulted to collect gray literature

#	Database	Result
1	SCOPUS	116
2	Web of Science Core Collection	72
3	PubMed	153
4	Global Health	61

Table IV.
Scientific database search results

Table IV provides a quantitative summary of the electronic database search results. A total of 116, 72, 153, and 61 publications were downloaded from the SCOPUS, Web of Science, PubMed, and Global Health databases, respectively. The database search resulted in a total of 402 publications and a list of 14 publications was recommended by two international experts. The title and abstract screening included a total of 358 publications after removing 58 duplicates. Most of the publications were excluded, as they focused on the benefits of EHR use in different healthcare settings. Many publications described broader issues related to ehealth and health information technology in developing countries. The title and abstract review resulted in the selection of 72 publications for full-text review. Upon the full-text review, publications describing general implementation challenges were excluded, as they described post-implementation experiences without explaining the strategies used to integrate EHRs in national healthcare systems. A total of 25 publications were ultimately selected for data extraction, review, and analysis (Figure 2).

For the country-focused analysis, 49 publications focused on global ehealth, country ehealth profile, national EHR/EMR guidance, HIS policy, and digital health documents were selected. The analysis was focused on development of EHRs or EMRs and other related digital systems at the national and sub-national levels as described in the selected gray literature.

Results and discussion
The findings of this literature review are presented in three subsections. The first two sections describe key stakeholders for development of national and sub-national EHR and
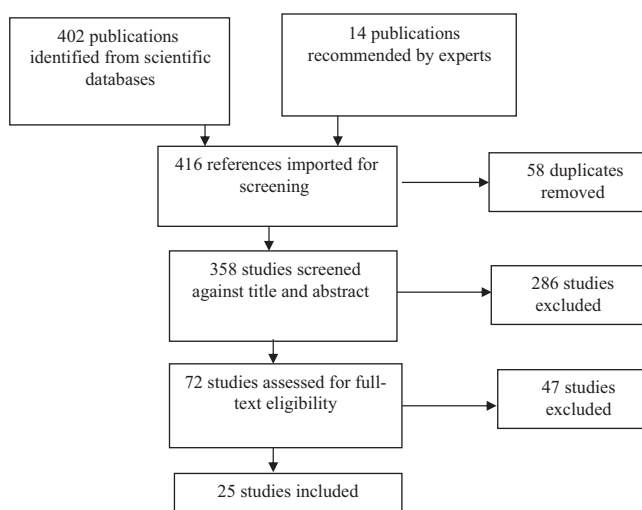
health information architecture which includes status of country ehealth foundations, EHR and sub-systems. The third subsection presents and discusses key challenges related to sustainability of national and sub-national EHRs. The findings in these three subsections are further explored through examples of health information flow in Uganda (Box 1), and electronic medical record (EMR/EHR) implementation in Sierra Leone (Box 2) and Malawi (Box 3). These examples briefly describe stakeholders, information architecture, and sustainability challenges.

Key stakeholders for the development of national and sub-national EHR
The stakeholder engagement is key to development of EHRs in the LMICs. In most instances, the national ministry of health offered leadership and support to the EMR/EHR implementation. However, EHR implementation was influenced by international funding agencies and implementing partners. For example, the United States (US) President's Emergency Plan for AIDS Relief (PEPFAR), the USAID, and the US Centers for Disease Control and Prevention (CDC) are among the largest donors funding the implementation of

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Box 1. Health Information Flow in Uganda

In the case of Uganda, District Health Information Software version 2 (DHIS 2) service delivery data provide aggregate information about the services provided to patients by facility and/or district, while the human resource information system provides information about health care providers. The patient-level data is captured in EMRs at the facilities. However, aggregate or individual data sharing is a challenge. The logistics management information system (LMIS) at the regional and national level can provide information about stocks.

At the facility level, institution-based data sources such as service delivery data and health data regarding patients, availability of equipment and medicines, and availability of provider type, provider skill mix, salary, and training information are collected. Data collected at this level are usually managed by facility-based data clerks who aggregate the data each month, and then send monthly reports to the facility's district management team. The district management then takes the monthly reports from various facilities, enters these data into the DHIS 2 system, which aggregates the data further, as needed, for use by managers at the regional and national levels.

EHRs at the sub-national level with a primary focus to address HIV health care service (USAID, 2018). These government agencies have made investments in EMRs in more than 50 countries which shows the scale of their influence in the LMICs. A recent study showed that the patient monitoring systems are funded by multi-lateral and bi-lateral donors (Suthar *et al.*, 2019) The national governments and in-country private and non-government organizations were also important stakeholders but with limited influence in terms of defining the requirements, technical capacity, financial resources, and access to state-of-the-art training resources for the national EHR development. Even though health care consumers were one of the key stakeholder groups, in general, their involvement in development of EHRs to deliver patient-centered health care services was negligible. Their role was limited to sharing health information with the health care providers. The health information needs of various stakeholders for decision-making varies depending on whether they are engaged in clinical care, program management of policy maker decision-making (Kumar *et al.*, 2017). Most of the strategic decision-making, implementation and review of policies, and resource allocation across the health sectors occurs at the national level (Abouzahr *et al.*, 2007).

Health information architecture overview
The health information architecture, in general, involved collection of patient-level data, mostly in paper forms, at the point of service and aggregated data was collected, shared and used at facility, district, and national level for clinical administrative, program management, and strategic decision-making (Latifov and Sahay, 2013) (Wilkins *et al.*, 2008). The aggregate data reporting used both paper and electronic health information systems and most of the countries had electronic national health information systems for collecting and using aggregate health care service data (WHO, 2016)' (Silvestre and Wood, 2019). Review of gray literature showed that many of the countries had pharmacy, logistics and human resources information systems. The health information flow and case from Uganda offers an example of how data is collected and shared across different levels of the health care system involving diverse stakeholders (Box 1). However, information sharing among these systems and with the national aggregate HIS is non-existent (Nabyonga-Orem, 2017) or at the most in the pilot mode. These fragmented HIS aggravate challenges associated with multiple silo systems.

Status of country-level EHR system and sub-systems
The country-focused literature review showed that countries are at different stages of national and sub-national EHR development in terms of creating ehealth foundational systems, developing EHRs and other electronic systems such as pharmacy information system, laboratory information system, and pathology information system. Most of the countries have HIS strategies or policies while some had ehealth policies. Since the WHO, international organizations and donors prioritized and invested in HIS during the last 20 years, most of the countries were able to develop HIS strategies or policies (Silvestre and Wood, 2019)' (WHO, 2016). ehealth and digital health efforts are relatively new though HIS is considered as an integral part of the ehealth and digital health efforts. Many countries have initiated preparing the digital health strategies with support from WHO-Africa and the International Telecommunications Union (WHO, 2017). Also, the 71st World Health Assembly, the highest decision-making body, of the WHO adopted the resolution on digital health which urges WHO member states to prioritize adoption and use of digital health technologies to achieve national and SDGs (WHO, 2018).

Many of the countries also have pharmacy, logistics, and laboratory information systems (WHO, 2016). Global investments by PEPFAR, CDC, USAID, UNAIDS, Global Fund, United Kingdom Department for International Development, and the Gates Foundation among

others in HIV testing, treatment, and improved health outcomes drove development of these systems in the LMICs and a number of global digital health goods such as the Open Logistics Management Information System have become available for further investment and use in the LMICs (Digital Square, 2019). While these sub-systems together with EMRs have contributed to control the HIV epidemic (Matheson *et al.*, 2012), the development of EHRs for broader health care services continued to lag behind. However, globally, there is a renewed focus on development of EHRs in the LMICs to deliver patient-level health care services and address data quality and data use challenges resulting from collection and use of aggregated data (USAID, 2018). Furthermore, health information exchange and data integration across different health sub-domains (services, workforce, logistics, laboratory, health finance, etc.) and other social determinants of health is hard to achieve in the absence of granular data in the EHRs (WHO, 2019b).

Sustainability of national and sub-national EHRs

Health program specific and/or disease focused EMR implementation is common in all the countries receiving funding for HIV programs from the United States government. While the sustainability of national and sub-national EHRs in the developed countries is driven by policy incentives and revenue generation for service delivery, the LMICs continue to rely on external finding to develop disease specific EMRs. For example, EMR implementation aimed at improving treatment and care for HIV patients is used in many countries though it is largely funded by the PEPFAR[2].

In other words, the business model for development of EHRs in LMICs is largely aimed at public health care services with minimal or no service fee and is dependent on government funding and donor grants. Sustainability of EHRs is intertwined with the stakeholder health information needs and the health information architecture. Stakeholders have an important role in generating system requirements, development and testing of innovations, and analysis and use of data to deliver health care services and manage population and patient health. Further, findings revealed limited application of theoretical models to guide or evaluate development of national and sub-national EHRs.

Limited healthcare service provision and geographical coverage

The evidence-driven review found that terms EMR and EHR were found to be used interchangeably within the same publications. A total of eight publications had a broader focus on LMICs, developing countries, Africa, or low-resource settings. These eight papers included literature reviews (Fritz *et al.*, 2015), (Tilahun and Fritz, 2015), (Khalifa, 2016) a generic focus on ehealth benefits (Blaya *et al.*, 2010), interface technologies (Kanter and Safran, 2008), and pathology and laboratory systems (Sayed *et al.*, 2018), (Settings *et al.*, 2014; Horton *et al.*, 2018). Many of the publications focused on vertical disease programs, such as HIV (4), tuberculosis (TB) (1), TB/HIV (1), and antenatal care (1). Other publications focused on rural healthcare delivery, home-based healthcare, mental health, eye care, Ebola, predicting disease patterns, mobile service trips, and pharmacies. The peer-reviewed publications spanned a wide range of geographical locations, presenting evidence from 17 countries, namely Nigeria, South Africa, Cameroon, Uganda, Ghana, Kenya, Sierra Leone, Malawi, Ethiopia, Peru, Haiti, China, Malaysia, India, Pakistan, Sri Lanka, and Saudi Arabia. The findings confirmed that application of EHRs predominantly supports vertical disease programs, which are often donor funded. For example, EHR implementation in Nigeria, Uganda, Kenya, Malawi, Sierra Leone, Peru, Haiti, and Pakistan was funded by international donors. Except for the publication on Malaysia, all had a very narrow disease or health program focus and use of EHRs was described as limited to a few clinics or hospitals. This contrasts with the WHO recommendation for countries to develop national

EHRs to achieve the Sustainable Development Goals on health and universal health coverage.

Influence of disease programs

The full-text review of the peer-reviewed publications showed that none of the publications approached EHR development with an aim to cater to the health information needs of diverse stakeholders, to align with the national HIA and facilitate sustainability over a period of time. Instead, the focus was primarily on vertical disease programs and HIS subsystems, such as pharmacy (Oqua *et al.*, 2013) or pathology and laboratory medicine systems (Sayed *et al.*, 2018), (Horton *et al.*, 2018), (Wilson *et al.*, 2018). For example, one of the publications described a study on EMR use by mobile medical service trips in remote settings (Dainton and Chu, 2017), while another described the development, implementation, and use of iSanté, Haiti's national HIV care and treatment EMR system (Matheson *et al.*, 2012). Another study focused on the development and deployment of Open Medical Record System (OpenMRS) in the context of Ebola and highlighted the challenges of developing an entire system during an emergency rather than being able to rapidly adapt an existing one (Oza *et al.*, 2017).

Application of theoretical and conceptual models

The reviewed identified application and testing of several theoretical frameworks and technology adoption models. One of the studies provided empirical data about the relevance of DeLone and MacLean (D&M) information system success model in the context of EMR implementation in low-resource settings (Tilahun and Fritz, 2015). The constructs and relationships from the updated D&M model were found applicable for assessing the success of EMRs in low-resource settings. Additionally, computer literacy was found to be a mediating factor in EMR use and user satisfaction of health professionals. The study suggested that EMR implementers and managers in those settings should give priority to improving service quality of the hospitals, including technical support and infrastructure; providing continuous basic computer trainings to health professionals; and giving attention to the information quality of the systems they want to implement. While the study demonstrated relevance of the D&M model for EMR implementation, the publication did not describe what strategies, if any, were used to integrate EHR in the healthcare system.

Another study focused on the adequacy of the unified theory of acceptance and use of technology (UTAUT) (Bawack and Kala Kamdjoug, 2018). The UTAUT is a widely used technology acceptance model for investigating the behavioral intentions of users to accept technology. The study found that the original UTAUT was not adequate for identifying factors that influence the adoption of HIS by clinicians in developing countries. Simplifying the model by using age as the only moderating factor significantly increases the model's ability to predict HIS adoption in this context. Thus, younger clinicians are more likely and ready to adopt HIS than older ones. This paper made an important contribution to the knowledge base concerning UTAUT but did not discuss strategies driving the integration of EHRs in healthcare systems in low-resource settings.

Similarly, another study focused on evaluation of a scalable model for implementing EHRs in resource-limited settings (Were *et al.*, 2010). This study described an implementation model that relied on shared responsibility among local sites and an external, three-pronged support infrastructure consisting of (1) a national technical expertise center, (2) an implementer's community, and (3) a developer's community. The findings of this evaluation showed that providers were highly satisfied with the EHR system and its support infrastructure. This study focused on three HIV clinics and primarily targeted infrastructural support. Findings of the evaluation contradicted several other reviews and

studies that evaluated technical, financial, ethical, political, and leadership factors as critical for the success of EHR implementation (Fritz *et al.*, 2015), (Jawhari *et al.*, 2016; Syzdykova *et al.*, 2017).

Strategies for EHR implementation
Most of the LMIC countries have either HIS or ehealth policies but only few of them have developed an EHR-related guidance document. For example, Kenya has developed national guidance documents for EMR (Ministry of Medical Services, 2011), pharmacy (Ministry of Medical Services, 2014), and laboratory information systems (Ministry of Health Kenya, 2014a) while India has published a revised national EHR standards document in 2016 that emphasizes use of international standards such as ICD (Ministry of Health and Family Welfare, 2016). Tanzania has published guidance for development of integrated electronic facility management systems (The United Republic of Tanzania, Ministry of Health, Community Development, Gender, 2016). These policy and guidance documents showed that each country had approached EHR development from their country perspective and are at the different stages of national EHR development. Each of these countries were using instances of OpenMRS as well as proprietary EHRs but none of these countries had developed national EHRs. With the growing emphasis on achieving the UHC and the push to adopt digital health technologies, the LMICs were making efforts to develop digital health policies as evident from the Digital REACH initiative in Africa, the draft EMR implementation guidance for the Americas, and the draft National Health Stack consultation paper published by Government of India (NITI Aayog (National Institute for Transforming India), 2018).

The slow uptake of EHRs is intriguing given that the WHO–Western Pacific Region published *Electronic Health Records: A Manual for Developing Countries* in 2006 (WHO, 2006). This manual provides basic definitions of EHR, EMR, and other related terms; offers guidance for developing an EHR implementation plan; describes issues and challenges associated with implementation; explains planning for EHR introduction via policies and strategies; outlines factors for consideration in the implementation plan; and treats implementation of EHRs. The manual calls for strategies to include the identification of critical factors for success, which could include patient identification, data exchange standards, education and trainings, storing EHRs, risk management, quality assurance, and

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Box 2. Implementation of the Open Medical Record System (MRS) – Ebola in Sierra Leone

The OpenMRS-Ebola, an EHR system, was developed and deployed in the Ebola Treatment Center (ETC) of Kerry Town in Sierra Leone. The purpose was to demonstrate how to rapidly develop and deploy an EHR with limited scope in an emergency situation. This EHR system was expected to improve quality, quantity, and confidentiality of patient data in an emergency situation. Implementation of the EHR system followed a phased approach with an initial focus on patient tracking, drug ordering, and monitoring, and allowing clinicians to review relevant patient information in both infectious and non-infectious zones. This customized EHR was used to register 112 patients, 569 prescription orders, and 971 medication administration records.

However, this EHR had limited relevance, as it was used solely for the Ebola epidemic. Once new Ebola cases began to decline, the ETC closed and the EHR modules capturing patients' vital signs, lab results, clinical notes, and patient summaries were rarely used. Furthermore, the dynamic nature of clinical workflow, together with a lack of familiarity with treatment protocols and workforce turnover, hindered implementation. While OpenMRS-Ebola EHR served its limited purpose in an emergency situation, it was not guided by a national EHR vision for the country.

Box 3. Electronic medical records system for TB/HIV co-infected patients in Malawi

Using an iterative process, the Lighthouse clinic and Baobab Health Trust developed and implemented a point-of-care electronic medical records (EMR) system in an integrated public clinic in Malawi. This clinic serves clients infected with HIV. The components of the EMR were related to patient demographics, anthropometric measurements, laboratory samples and results, HIV testing, WHO clinical staging, TB diagnosis, family planning, clinical review, and drug dispensing.

Experiences in the public clinic suggested that the EMR system led to improved provider decision making and patient management. However, several challenges were encountered during implementation, including expansion of EMR components, changes in national antiretroviral treatment guidelines, and low health worker capacity to use the EMR system. Implementation was delayed for more than a year. Continuous stakeholder engagement with providers, in particular, a functional back-up system, and on-site technical support helped overcome some of the implementation challenges. Yet, EMR implementation focused on HIV/TB co-infected patients and was dependent on donor funding. In addition, how the system could contribute to the development and sustainability of a national EHR system in Malawi was not considered.

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personal health records, among others. These success factors focus on functions and features of EHR, workforce training, system quality, and integrity. The manual offers guidance and information relevant to strengthening EHR implementation while assuming prior integration in the country's healthcare system.

Scope and focus of national EHR guidance

Even though countries are using EHRs or other sub-systems, at least in the HIV domain, country-focused literature review found only three countries – India (Ministry of Health and Family Welfare, 2016), Kenya (Ministry of Health Kenya, 2014b), and Tanzania (The United Republic of Tanzania, Ministry of Health, Community Development, Gender, 2016) that had published standards guideline for EHRs. It is important to note that almost all the countries that had HIS or ehealth policy/strategy had a reference to patient level HIS and clearly describe the importance of collecting, sharing and using patient level for achieving improved health outcomes. Since the global and national focus had been primarily on population health issues (emanating from the Millennium Development Goals and, now, Sustainable Development Goals of the United Nations) and regional and global health reporting, the LMICs prioritized development of national HIS for collecting, sharing, and using aggregated health services data even though most of these data were aggregated from patient-level data captured in paper-registers at the point-of-care. The LMICs had made significant progress in the development of national HIS though these countries have multiple HIS linked with vertical disease programs such as HIV, TB, and malaria. These fragmented and siloed approach had led to duplication of financial, technological and human resources and fragmentation of individual health care data. Development of EHR has the potential to enable data exchange among diverse systems and address data quality issues associated with aggregated health care data. Further, it can reduce duplication of data collection and maximize use of limited resources through creation of shared technology infrastructure and delivery of integrated health care services through the life-cycle.

Assessment and evaluation methods

The evidence-driven literature review showed use of quantitative, qualitative and mixed methods for evaluating EHR system functionalities, generate system requirements, assess user acceptance, evaluated data collection and data use efficiency, and assess impact of EHRs on health outcomes. Further, the International Training and Education Center for Health at

the University of Washington had prepared a draft "Practical Toolkit for Health Information System Evaluation". This toolkit is a systematic, comprehensive, structured, and practical knowledge base for conducting HIS evaluations in global, resource-limited settings. Even though the toolkit is primarily focused on HIV care use cases, the evaluation design and methods are applicable to other health care settings also. The review did not find any evidence that described evaluation of national and sub-national EHR development in the LMICs though such evaluation exists in the context of developed countries (Price *et al.*, 2019) and guidance for evaluating digital health interventions is also available (Pan American Health Organization and Brazilian Network Information Center, 2018), (World Health Organization, 2016).

Future research directions

The literature review findings clearly highlight lack of evidence required to develop national and sub-national EHRs and understand how EHRs impact population and patient-level health outcomes in the context of LMICs. The review findings showed that HIS/EMRs were primarily designed to support monitoring and evaluation of health programs through vertical disease programs. Given that national governments and international donors (e.g. PEPFAR) are now paying attention to EHRs for improving patient care, there is need for further research that explains how a country can develop national/sub-national EHR to improve efficiency and quality of patient care while supporting the monitoring and evaluation functions of the national health care enterprise.

While there is growing emphasis on user-centered design in digital health, the findings showed that patient engagement in development of EHRs is minimal or non-existent. Further, the role and authority of health care providers to determine the national EHR requirements is adversely influenced by the dominance of external financial and technical assistance. For example, an important research priority could be what contexts are appropriate for conducting recommended research (at the provider level, at the government level, at the consumer level), and what methods (surveys, qualitative interviews, mixed methods, limited prototype deployment and testing) should be used to conduct such research. Further, research can focus on identifying appropriate business models for development of national and sub-national EHRs in the health care system of LMICs. Given the lack of clearly defined national health information architecture there is need for research to suggest appropriate health information architecture that accommodates federal or centralized administrative structure, diverse health information needs and supports health care services at all the levels of the health care system.

As country matures the way in which they develop national/sub-national EHR, a common way to mature could be from secondary use to primary care delivery for improving efficiency and quality of patient care which will depend on how EHRs are understood, designed, governed, and scaled. The pathway to maturity would demand in-depth research that offers "how to guidance", and "identifies and describes developmental stages and metrices" associated with the purpose and scope of the system (primary and secondary use of clinical data), health information architecture, leadership and governance, organizational resources (finance, workforce, information and communication technology infrastructure), interoperability and data standards, data quality, and data use.

Study limitations

This comprehensive review examined empirical peer-reviewed publications written in English and indexed in scientific databases and the gray literature published by international organizations such as the WHO and the national governments. In general,

researchers from LMICs have limited access to high-impact and/or subscription-based journals, and only a few can publish in these journals. In addition, many of the journals published in African countries are not indexed in the scientific databases included in this review; therefore, it is possible that some relevant peer-reviewed papers were not included. Despite efforts to include all published papers in this area, some may have also been missed due to publication after the electronic search was completed. Furthermore, a wide range of terms are used in LMICs to refer to EHR systems but are difficult to capture in an electronic search strategy, as their meanings vary based on the country context. The gray literature search was conducted in the digital repositories of the WHO, the USAID-MEASURE Evaluation project and the South Africa-based non-profit organization HealthEnabled. However, these digital repositories did not include national EHR policy and strategy document and most of the national governments did not have those documents on their public website. To overcome the limitations resulting from unavailability of policy and strategy documents in the public websites, a wide group of national and international level experts from funding organizations, governments, non-profit organizations, and technology vendors were consulted to identify relevant gray literature.

Conclusions

The EHR infrastructure is vital for facilitating population and individual healthcare service delivery, guiding resource allocation and utilization, enabling data sharing and use, and aligning health sector goals and ehealth strategies. There is growing evidence that adoption of national EHR systems is on the rise, but not in LMICs. The review findings show that most EHR/EMR adoption and implementation is limited to disease programs such as HIV and TB in a small geographical location of a country. Available evidence explains successful EHR implementation but fails to articulate strategies for integrating EHR in the healthcare system as the foundational digital health infrastructure. In the absence of evidence strategies that could drive integration of national EHR infrastructure in the healthcare system, fragmentation of the healthcare data system will continue to pose challenges to healthcare systems. When determining strategies in preparation for the introduction of an EHR system, it must be kept in mind that healthcare organizations in the country have diverse change management capacity and access to resources at national and subnational levels. There is a need for further research to generate evidence-based strategies to enable EHR integration in the national healthcare systems of LMICs.

Notes

1. Health workforce, service delivery, health information, financing, medical technologies, and leadership and governance.

2. Information about the adoption of EMRs for HIV case management was shared by an expert from United States Centers for Disease Control and Prevention, Atlanta during a phone conversation that discussed about national EHR policy and strategy in African countries.

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