

Contextual Barriers to Implementing Open-Source Electronic Health Record Systems for Low and Lower-Middle Income Countries: Scoping Review

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Abstract

Background: Open-source electronic health records (EHRs) can enhance healthcare delivery in low and lower-middle income countries (LMICs) by improving the collection, management and analysis of health data needed to inform healthcare delivery, policy, and planning. While open-source EHR systems are cost-effective and adaptable, they have not proliferated rapidly in LMICs. Implementation barriers slow adoption, with existing research focusing predominantly on technical issues preventing successful implementation.

Objective: This interdisciplinary scoping review aims to provide an overview of contextual barriers affecting the adaptation and implementation of open-source EHR systems in LMIC settings, and identifies areas for future research.

Methods: We conducted a scoping literature review following a systematic methodological framework based on Arksey and O'Malley. Seven databases were selected from three disciplines: medicine and health sciences, computing, and social sciences. The findings were reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR). The Mixed Methods Appraisal Tool (MMAT) and the Critical Appraisal Skills Programme (CASP) checklists were utilized to assess the quality of relevant studies. Data was collated and summarised, and results were reported qualitatively, adopting a narrative synthesis approach.

Results: The 13 studies included in this review examined open-source EHR implementation in LMICs from three perspectives: socio-environmental, technological, and organizational barriers. Key issues identified include limited funding (n=13), sustainability (n=13), organizational and management (n=11), infrastructure (n=10), data privacy and protection (n=10), and ownership (n=5). Data protection, confidentiality, ownership, and ethics emerged as important issues, often overshadowed by technical processes (n=11).

Conclusions: While open-source EHRs have the potential to enhance healthcare delivery in LMIC settings, implementation is fraught with difficulty. This scoping review shows that depending on the adopted perspective to implementation, different implementation barriers come into view. A dominant focus on technology distracts from socio-environmental and organizational barriers impacting the proliferation of open-source EHRs. The role of local implementing organizations in addressing implementation barriers in LMIC settings remains unclear. A holistic understanding of implementers' experiences of implementation processes could help characterize and solve implementation problems, including those related to ethics and the management of data protection. We hope that the review results will inform areas for future research and enhance implementation.

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Original Manuscript

Contextual Barriers to Implementing Open Source Electronic Health Record Systems for Low and Lower-Middle Income Countries: Scoping Review

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Abstract

Background: Open source Electronic Health Records (EHRs) can improve healthcare delivery in low and lower-middle income countries (LMICs). There is demand for open source EHR systems in LMICs as they are cost-effective and provide the flexibility to customise systems to meet context-specific needs. However, open source EHRs have not proliferated rapidly. Implementation barriers prevent successful adoption. Little is known about the roles of implementers in addressing these barriers. Existing research focuses predominantly on technical perspectives for open source EHR project implementation. In contrast, this scoping review identifies contextual barriers impacting the implementation of open source EHR systems for LMICs.

Objective: This scoping review aims to provide an overview of the key contextual barriers impacting the implementation of open source EHR systems for LMIC settings, and identifies areas for future research.

Methods: An interdisciplinary scoping literature review was undertaken, guided by a systematic methodological framework based on Arksey and O'Malley. Seven databases were selected from three disciplines: Medicine and health sciences, computing, and social sciences. The Mixed Methods Appraisal Tool (MMAT) and the Critical Appraisal Skills Programme (CASP) checklists were utilised

to assess the quality of relevant studies. Data was collated, summarised, results were reported qualitatively adopting a narrative synthesis approach.

Results: The 13 studies included in this review examined open source EHR implementation in LMICs from three distinct perspectives: socio-environmental barriers, technological barriers, and organisational barriers. Key issues that influenced the implementation were identified in the literature as: limited funding (n=13), sustainability (n=13), organisational and management (n=11), infrastructure (n=10), data privacy and protection (n=10), and ownership (n=5). Data protection and confidentiality, ownership and ethics emerged as important issues, often overshadowed by technical processes (n=11).

Conclusions: While open source EHRs have the potential to facilitate enhanced healthcare and encourage sustainable development in LMICs, it is vital to take into consideration the specific context in which such technologies are to be implemented within. This study revealed the key perceived barriers that impact open source EHR implementation success. Research is required to better understand the implementation process and how socio-environmental, technical, and organisational barriers can be addressed, particularly in relation to ethics and management of data protection. We hope that the review results will inform areas for future research and enhance implementation.

KEYWORDS: implementation; open source; electronic health records; electronic medical records; digital health; software; barriers; ethics; data protection; global healthcare; review

Introduction

Background

This scoping review provides an overview of barriers impacting the implementation of open source Electronic Health Record (EHR) systems in low and lower-middle income countries (LMICs), identifies gaps in the existing literature, and points to opportunities for future research. Open source is broadly defined as a free software which includes a flexible source code [1-3] that can be adapted for various settings without incurring any license fees [4]. An EHR system is a computerised version of a patient's (longitudinal) medical records, which is maintained by the given healthcare provider [5-7]. Open source EHRs can aid the provision of healthcare delivery for LMICs, inform research and policy.

For this review, we used the World Bank's definition and list of LMICs from 2021 [8]. In most LMICs there is limited access to healthcare [9, 10], particularly for vulnerable individuals [11-13]. The resource-scarce settings of LMICs account for a higher percentage of global epidemic and chronic diseases [14, 15]. In a similar vein, there is limited access to information about vulnerable individuals health – which makes it difficult to improve healthcare systems. This persistent problem of limited access to healthcare exacerbates inequalities in LMICs [16].

Open source EHRs are implemented by local implementers and software developers to enhance the delivery of healthcare for local health facilities [17-20]. An implementer can be identified as a member of a local implementing organisation who understands the technology, context and the end-users. An implementing organisation can be defined as a social enterprise, profit driven firms and non-profit organisations (NPOs) or non-government organisations (NGOs). There is demand for open source EHR systems in LMICs because they provide implementers with flexibility to customise the system to meet context-specific needs [21]. However, open source EHRs have not proliferated rapidly. Implementation barriers prevent successful adoption. Little is known about the roles of implementers in addressing these barriers. Therefore we need to understand these barriers in order to enhance implementation. This scoping review identifies contextual barriers impacting the implementation of open source EHR systems for LMICs, and identifies areas for future research. The remainder of this section briefly reviews the digital transformation of global healthcare, evolution of open source EHR systems, and open source software vs propriety software. The section concludes with a summary of context-specific barriers.

Digital Transformation of Global Healthcare

The transformation and innovation of technology over the last few decades has shaped the way in which the global healthcare industry operates [22]. The demand for universal access to quality healthcare is rising, putting pressure on governments to develop sustainable solutions for the effective delivery of healthcare [23]. While digital technologies have the potential to enable more equal delivery of better healthcare [24], they also raise important questions around ethics and data protection [14, 25-27], particularly in settings characterised by stark power imbalances. A focus on the development of better technical solutions can distract from the underlying values and ethical concerns associated with healthcare technologies.

The United Nations Sustainable Development Goals (UNSDGs), ‘Goal 3: Good Health and Wellbeing’ highlights the importance of improving access to quality healthcare and managing global health risks [28]. The World Health Organisation (WHO) advocates the use of electronic health tools [29] to enhance monitoring of patient care [30, 31]. An electronic health record (EHR) can be defined as “a computer based patient records system designed mainly for the use of doctors [or other clinicians that have direct contact with the patient]” [6, p.576]. EHR systems can help ease the burden of existing paper record processes and provide better management of patient care electronically [19]. The sustainable development and implementation of EHR systems is a challenge in the contemporary environment [21, 32], specifically from political, economic, social, technological and ethical perspectives [6, 33]. Data ownership, informed consent, data protection and confidentiality are concerns which influence the implementation of many health technologies including EHR systems [27, 34].

Evans [35] and Manders-Huits [36] assert the importance of acknowledging and integrating human values responsibly in healthcare technology. Therefore, if the context of implementing EHR systems is better understood it could help address key challenges and barriers from a comprehensive perspective.

Evolution of Open Source EHR Systems

There has been a rapid growth of open source software, notably in the healthcare sector [5, 37]. The phrase ‘open source software’ was coined in 1998 [4]. Open source software includes a flexible source code, when the source code is made publicly accessible under a free licence [38] it can be adapted by healthcare providers to meet context-specific requirements [1, 2, 39, 40]. There are various types of open source software solutions used for distinct purposes in LMIC settings [41, 42] such as the Open Enterprise-level Laboratory Information System (OpenELIS) a laboratory information system, District Health Information Software 2 (DHIS2) a web-based platform communicating health data across several levels of a given healthcare system, and GNU Health a hospital information system [19, 43-45].

An open source EHR system provides an adaptable and digitalised version of a patient’s medical history; a record that comprises identifiable and personal health information such as: demographics, allergies, medication, medical episodes, and health facility visits [5-7]. Open source EHR systems can enhance healthcare delivery, inform the development and delivery of healthcare at the policy level, and lower costs for LMIC settings [17, 18, 21, 46, 47]. A good example of an open source EHR system, adopted primarily for LMIC settings, is the Open Medical Record System (OpenMRS) platform [48-51]. The OpenMRS platform is perceived as a collaborative project [20, 52-54] aiming to serve a moral purpose in “bringing people together to write code and save lives” [55].

Two early examples of open source EHRs were the Computer Stored Ambulatory Record (COSTAR) and the Veterans Health Information Systems and Technology Architecture (VistaA), both developed nearly five decades ago in a developed country (the United States) [7, 37, 56, 57]. Since then there has been increasing interest in developing and using EHR solutions that are open source [4, 5, 19]. Today, open source EHR systems are used in many countries but predominantly in LMICs where they are seen as helping to address the high cost and inflexibility associated with proprietary EHR systems [9, 18, 58-61]. Open source EHR systems can however introduce different tensions when being implemented in LMIC settings [2, 5]. Despite the promises of open source EHR systems, they are not proliferating as expected. It remains unclear what barriers inhibit their implementation, whether these barriers vary according to different contexts, and how these can be addressed.

Open Source Software vs Proprietary Software

Open source software offers a publicly available source code that can be customised and distributed without incurring licensing fees [1, 38, 62]. In contrast, proprietary software has copyright restrictions

on source code – it is not publicly available [3]. Proprietary software such as Microsoft Windows or Office can be perceived as an out of the box solution and any adaptations required must be completed by the proprietor of the software - resulting in additional fees [4]. Open source software can be adapted to the specifics of a given context, but this often requires technical expertise and adequate funding for implementation [25, 63-65]. Moreover, Reynolds and Wyatt [2] contend that opening the source code compels developers to carefully examine and craft the quality of their code, making bug patching easier, which strengthens the security aspect of open source systems [37, 39]. Proprietary software can be more costly to develop in comparison to open source software [47] - where the source code can be adapted and shared, particularly if there is a need to customize certain system aspects or adding additional system features [40, 66].

Open source software does not miraculously address the inadequacies of existing healthcare systems [4, 62, 64, 67-69]. It still requires a level of expertise and human competence for software design and developing effective systems for end-users [70]. Nevertheless, open source software offers the potential for communities to collaborate effectively, build stronger networks, develop new skills, and transform policy and practice where required [71, 72]. There are therefore a number of benefits to using open source software for healthcare in LMIC settings [17, 47, 73].

Open source EHR systems include an adaptable open source code which provides implementers with greater flexibility in building customised systems for a given context, and can ease suffering from vendor lock-in often found with proprietary EHR systems [3, 40, 61, 65, 73]. For example, vendors for proprietary EHR systems are often restrictive in what they share with users, adopt surveillance measures, and impose upgrades [1, 2], hence to some extent inhibiting freedom and flexibility for end-users [5, 57]. Conversely, a perceived challenge with open source EHR systems is that it requires specialised skill for implementation and maintenance support [4, 9]. Nevertheless, open source EHR systems allow implementers to adapt a given system to meet context-specific needs [47, 66, 74].

Context-Specific Barriers

The notion of a ‘one size fits all’ solution may work for some contexts, however for LMICs, adopting open source EHR systems without adaptation can result in poor outcomes [9]. Context can be defined as “the place where an intervention is delivered...or unique factors surrounding an implementation effort.” [75, p.106]. LMIC settings have unique requirements. There are different user realities to consider, and specific issues seem to determine the success or failure of open source EHR implementations [76]. These contextual barriers have been found to include political, economic, social and technological issues [27, 77]. To better understand these barriers to implementing open source

EHRs in LMICs, one has to first acknowledge the given setting, understand end-user realities, and the availability of resources [78].

There is emerging literature on EHR implementations [9], yet little is known about the context-specific issues of implementing open source EHRs in LMIC settings. Existing research has focussed on technical perspectives [26, 27, 36] and factors such as technology infrastructure, power supply and backups, as well as a lack of financial resources [17, 61, 66, 79, 80]. However, local and regional context-specific barriers inhibiting the implementation of open source EHRs, and issues inhibiting implementing organisations from adopting such technology in LMICs, has not yet been researched.

Information technology (IT) implementation requires diverse stakeholders “taking a design and translating it into a working system” [6, p.580]. The process of implementing an open source EHR system involves different stakeholders conducting an initial analysis, adapting the software to local requirements, software development, configuration and installation, as well as providing user training and support [17, 81, 82]. Open source EHR implementation requires stakeholder engagement and participation to co-create a solution that results in a change that generates true value for a given context [75, 83]. Consequently, there is a need for various stakeholders such as local software developers, implementers, IT providers and healthcare practitioners to work collaboratively when designing and adopting open source EHR systems for LMIC settings [21, 35, 84].

Therefore, this review provides an overview of the context-specific barriers and facilitators impacting the implementation of open source EHR systems in LMICs. No previous scoping review has explored the perceived contextual barriers impacting the implementation of open source EHRs for LMICs.

Methods

Overview

This scoping review aims to provide an overview of the contextual barriers impacting the implementation of open source EHR systems in LMIC settings, and outlines opportunities for future research. A scoping review methodology was chosen because it provides an understanding of the potential breadth of literature available, lends itself to the identification of relevant concepts and research gaps, and enables the researcher to assess whether a full systematic review is needed or indeed possible [85, 86]. This interdisciplinary research draws literature from medicine and health sciences, computing, and social sciences.

Stage 1: Identifying the Research Question

To address the interdisciplinary nature and scope of the gap in our understanding, a broad review question was chosen to map the breadth of literature available, and identify key concepts and related themes for further exploration. The following research question was formulated:

What are the perceived key contextual barriers impacting the adaptation and implementation of open source EHRs in LMICs?

This review follows the five stages of the systematic methodological framework for conducting scoping studies in Arksey and O'Malley [87], and following relevant guidance from Joanna Briggs Institute [88], Levac et al. [89], and Davis et al. [90]. The following terms were used in the search of relevant material: LMIC, open source, EHR, adaptation and implementation. These were defined prior to the search to ensure consistency across the range of databases. The definitions of these key terms can vary, however, for this review the following definitions were adopted:

- We used the World Bank's definition of *LMICs* [8].
- An *EHR* system is a computerised version of a patient's (longitudinal) medical records, specifically designed for clinicians who have direct contact with patients [6, 7].
- *Open source* software includes a publicly available source code that can be adapted to meet context-specific requirements without incurring any license fees [1-4, 38, 39].
- *Implementation* is a complex process, which requires organised and deliberated effort to put a given innovation or intervention into practice in such a way that results in better outcomes for an identified context [75, 83]. *Adaptation* is an element of the implementation process, it is the construction of different processes: analysis, customisation, installation and configuration, training and support, that support the use of a given innovation or intervention [91].

Stage 2: Identifying Relevant Studies

The seven most relevant electronic databases were searched using the date range January 1960 – September 2021 (**Table 1**); as EHR developments initially started in the early 1960s [7]. The first reviewer performed a comprehensive search, which was supported by using a Population, Intervention and Outcome (PIO) framework [92] which identified four key terms: (1) LMIC, (2) open source, (3) EHR, (4) adaptation and implementation. The key terms and synonyms are detailed in **Multimedia Appendix 1**. The selection of databases covered literature from medicine and health sciences,

computing, and social sciences. In addition, Open Grey was used to identify relevant grey literature using the key terms which retrieved nil results. A backwards and forwards citation search was performed using Google Scholar from reference lists of selected papers to ensure potentially relevant articles were not overlooked [92]. The searches concluded on 27 September 2021. The searches for Medline and Medline In Process, CINAHL, and Web of Science are included in **Multimedia Appendix 2**.

Table 1. Literature search.

Electronic Databases	
1	Medline and Medline In Process
2	Embase
3	CINAHL
4	EBSCO Business Source Premier
5	Web of Science
6	Cochrane Library
7	IEEE Xplore

Stage 3: Study Selection

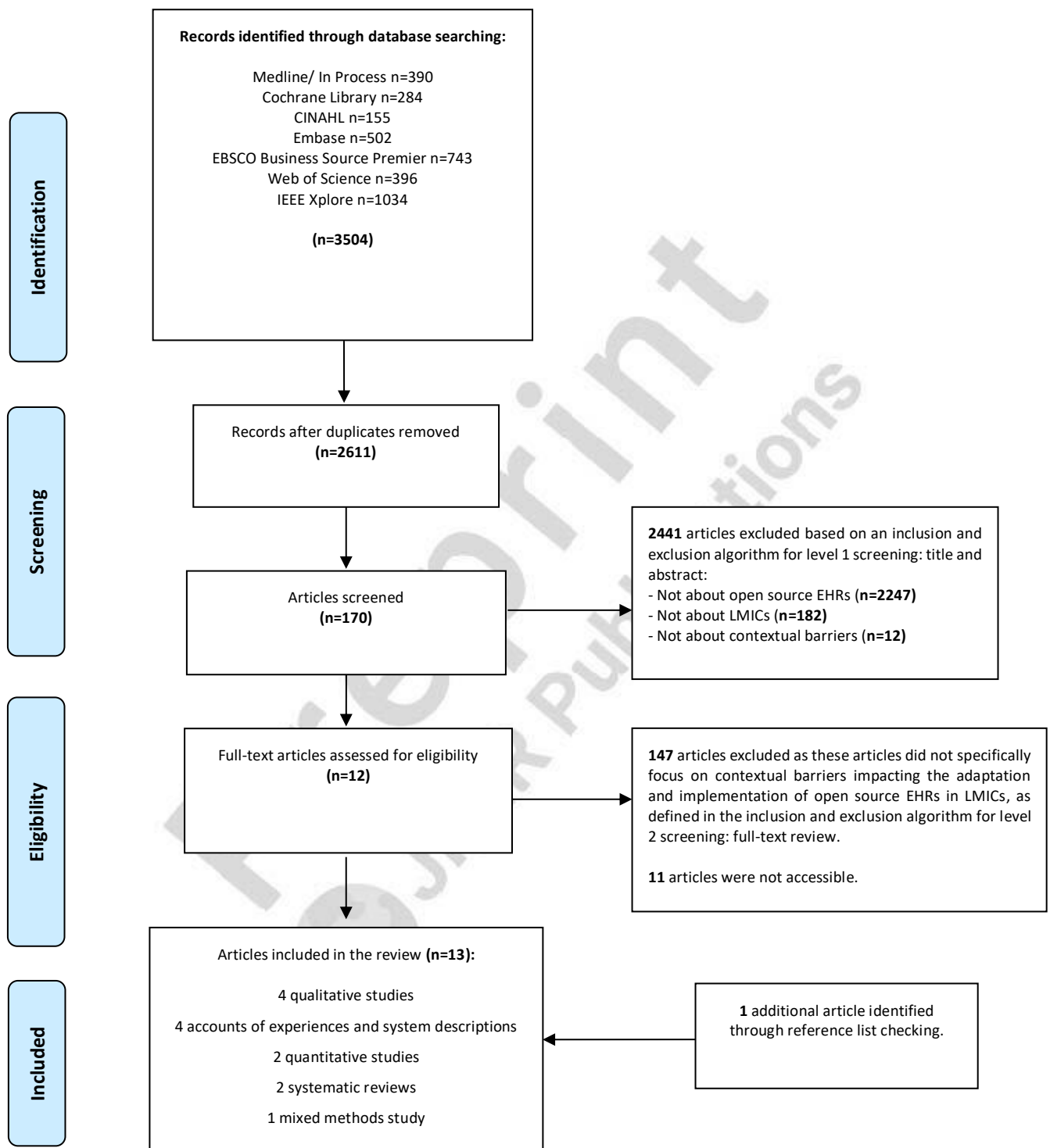
Studies were included in the review if they were published in English, presented empirical data (including systematic reviews) or non-empirical accounts of experiences and system descriptions on the adaptation and implementation of open source EHRs in all variations (associated synonyms and phrases) in LMICs. No restrictions were placed on the study design or the format of the publication and both published and unpublished (grey) literature were included. Papers were reviewed at title, abstract and full-text review in order to exclude articles that did not address the adaptation and implementation of open source EHRs or were not concerned with LMICs. No other criteria were applied; this was to maximise the search results for an initial enquiry. **Multimedia Appendix 3** shows the list of LMICs [8] used for the inclusion criteria.

Overall, the search yielded 3504 articles which were exported into EndNote X9 reference software. After removing 893 duplicates, the first reviewer (SB) screened articles via a two-level process: 2611 titles and abstracts were screened for relevance resulting in 170 full-text articles reviewed. In addition, a team of three reviewers (RR, LJ and OJ) independently quality checked (10%) the articles, using the inclusion and exclusion algorithm for screening titles and abstracts, and then full-text reviews (see **Multimedia Appendix 4**). Any disagreements were discussed and resolved among the reviewers. Finally, 12 studies met all criteria of the inclusion and exclusion algorithm. An additional article was discovered through the forward and backward reference list check. In total 13 studies were found to satisfy the inclusion and exclusion criteria and included in the review. The Preferred Reporting Items

for Systematic Reviews and Meta-Analyses extension for Scoping Reviews [93] flow diagram was used to report the results of the study selection process (see **Figure 1**).



Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) flow diagram - detailing study selection process.



Stage 4: Charting the Data

A standard data extraction form was used to obtain an overview of the 13 selected studies. For each study the following categories were included: author(s), publication year, country of origin - where the study was conducted or published, aims or purpose, type of research, study population and sample size (if applicable), methods, intervention type (open source EHRs), and key findings - outcomes that relate to the scoping review question. Any inconsistencies were discussed and resolved among the reviewers.

Stage 5: Collating, Summarizing, and Reporting the Results

After charting the key data from the 13 studies, a qualitative thematic analysis [94, 95] and synthesis approach was adopted [89]. The first reviewer coded, categorised and grouped results into key themes to address the scoping review question, and identified the implications for future research. The thematic analysis was inspired by existing frameworks presented by Jawhari et al. [84] and Muinga et al. [21], who synthesised key findings using relevant categories to illustrate the advantages and barriers to implementing electronic medical record (EMR) systems in a given geographical bounded space. However, this scoping review focused at the global level – examining contextual barriers impacting the implementation of open source EHR systems for LMIC settings (local and regional). Therefore, the categories and key themes identified in this review were generated from the analysis of the 13 studies.

Quality Assessment

The Mixed Methods Appraisal Tool (MMAT) and the Critical Appraisal Skills Programme (CASP) checklists were adopted to assess the quality (where relevant) of the included studies as the review comprises a broad range of study designs and methodologies [96-98].

Results

Characteristics of Studies

Table 2 briefly summarises the characteristics of included studies. All studies were published between 2002 and 2021. Of the 13 studies included in this review, geographically, the majority of the studies report research conducted in Sub-Saharan Africa, Uganda, Ethiopia, Kenya, Ghana, and Sierra Leone [14, 19, 21, 24, 40, 84, 99-101]. Two studies were conducted in Southern Asia: India and Nepal [102, 103]. The type of research varied across the spectrum, with the most common following a qualitative design, with the use of interviews, surveys including qualitative questions, participatory techniques and observations used to address the design, barriers and facilitators with implementing open source EHRs [14, 21, 84, 100]. Two studies adopted a quantitative design with controlled observations, a survey using statistical measures to address issues and recommending a potential model for an open source EHR implementation in LMICs [24, 101]. One study adopted a mixed method design inclusive of

quantitative and qualitative aspects [82]. The systematic reviews looked at various open source EHRs in LMICs and the challenges inhibiting implementation [19, 40]. Other studies were more accounts of experiences and system descriptions [64, 99, 102, 103]. A majority of the studies addressed rural areas [14, 19, 21, 24, 40, 64, 82, 99, 102, 103] and other studies addressed urban settings [84, 100, 101]. **Multimedia Appendix 5** illustrates the detailed characteristics of each included study.

Table 2. Brief summary of characteristics of included studies.

Authors	Year of Publication	Country - Research Setting	Study Design	Urban/Rural
Mohammed-Rajput et al. [14]	2011	Kenya, Rwanda, Lesotho, Tanzania, Uganda, and Malawi	Qualitative	Rural
Syzdykova et al. [19]	2017	Ethiopia	Systematic Review	Rural
Muinga et al. [21]	2018	Kenya	Qualitative	Rural
Oza et al. [24]	2017	Sierra Leone	Quantitative	Rural
Akanbi et al. [40]	2012	Sub-Saharan Africa	Systematic Review	Rural
Fish and Guha [64]	2020	Haiti	Descriptive	Rural
Verma et al. [82]	2021	United States ^a	Mixed Methods	Rural
Jawhari et al. [84]	2016	Kenya	Qualitative	Urban
Gainer et al. [99]	2012	Ethiopia	Descriptive	Rural
Gyamfi et al. [100]	2017	Ghana	Qualitative	Urban
Were et al. [101]	2010	Uganda	Quantitative	Urban
Anantraman et al. [102]	2002	India	Descriptive	Rural
Raut et al. [103]	2017	Nepal	Descriptive	Rural

^areporting on implementation projects delivered in LMICs.

Quality Assessment

The MMAT checklist was used for seven studies [14, 21, 24, 82, 84, 100, 101], and the CASP Systematic Review checklist was used for two systematic reviews [19, 40]. Four studies [64, 99, 102, 103] were non-empirical accounts of experiences and system descriptions of open source EHR implementations which provide interesting insights, but were not suitable for quality assessment. Two qualitative studies in this review were of moderate quality as it is unclear what data was included in the analysis [14], and there was no information about the analysis [21]. Five studies were assessed as good quality; two qualitative [84, 100], two quantitative studies [24, 101], and the mixed methods study [82]. Two systematic reviews were assessed as moderate quality [19, 40] with less scientific rigour, as there was no information about the quality of the included studies. The data table reporting the quality assessments is included in **Multimedia Appendix 6**.

Contextual Barriers Impacting Open Source EHR Implementations

The 13 included studies provide a broad overview of the perceived key contextual barriers impacting the adaptation and implementation of open source EHRs in LMICs. Three distinct but interrelated barriers emerged from the thematic review: the (1) socio-environmental barriers draw attention to issues surrounding the relationship between humans in a given society and their external environment such as: environment, social capital, social cohesion, infrastructure (local and regional), culture, values, language(s), institutions and stakeholders. The (2) technological barriers emphasise the issues surrounding the software and hardware used in open source EHR implementations. The (3) organisational barriers draw attention to the operational practices in organisational structures of open source EHR implementations.

Our findings indicate that implementation of open source EHRs is influenced by the three contextual barriers in a given context, as summarised in **Table 3**. Some perceived issues (sub-categories) are addressed within more than one barrier where they are interpreted through different lenses. For example, issues such as infrastructure, ethical practices or finance, are not only of importance from a socio-environmental perspective, but are also raised (albeit in different ways) by researchers who adopt a technological or an organisational perspective. Notably, organisational and management, limited funding, infrastructure (local and regional), data privacy and protection, ownership, and sustainability appear to be key barriers that influence the implementation of open source EHRs in LMICs. The three thematic barriers are explored in the following section.

Table 3. Thematic analysis illustrating perceived contextual barriers impacting the implementation of open source EHRs in LMICs.

Contextual Barriers	Sub-Categories (subsumed issues)
1. Socio-Environmental Barriers	▪ Lack of social cohesion: voice and trust^[14, 19, 21, 24, 40, 84, 99, 101, 102, 103] ▪ Require stakeholder engagement and participation, political support^[14, 19, 21, 24, 40, 64, 82, 84, 99, 100, 101, 102, 103] ▪ Sustainability: co-design and collaboration^[14, 19, 21, 24, 40, 64, 82, 84, 99, 100, 101, 102, 103] ▪ Social capital and lack of funding^[14, 19, 21, 24, 40, 64, 82, 84, 99, 100, 101, 102, 103] ▪ Language barriers: reliance on the local language^[40, 64] ▪ Epidemic diseases (health emergencies)^[14, 21, 24, 40, 64, 84, 99, 102, 103] ▪ Environment - lack of resources (poverty)^[14, 19, 21, 24, 40, 64, 82, 84, 99, 100, 101, 102, 103] ▪ Infrastructure: access to electricity, local network coverage, medical facilities, rural and urban health^[14, 19, 21, 24, 40, 64, 82, 84, 99, 100, 101, 102, 103]
2. Technological Barriers	▪ Infrastructure (power, network and technology)^[14, 19, 21, 24, 40, 64, 82, 84, 99, 100, 103] ▪ Data security, privacy and confidentiality, storage, quality and ethics^[14, 19, 21, 24, 40, 64, 82, 84, 99, 100, 101, 103] ▪ Software and hardware suitability (context-specific)^[14, 21, 24, 40, 64, 84, 99, 100, 101, 103] ▪ Interoperability^[19, 21, 24, 64, 84, 99] ▪ Sustainability of systems^[14, 21, 24, 40, 64, 82, 84, 99, 100, 101, 103] ▪ User interface: not supporting different clinical roles^[14, 19, 21, 24, 40, 64, 82, 84, 99, 100] ▪ Patient centered design (lack of end-user (clinicians, health facility administrators, patients) involvement)^[14, 21, 24, 64, 82, 84, 99, 102, 103]
3. Organisational Barriers	▪ Finance and benefactors (costs for context-specific implementations and maintenance)^[14, 19, 21, 24, 40, 64, 82, 84, 99, 100, 102, 103] ▪ Human resource development (training, IT skills/ expertise, support, staff shortage)^[14, 19, 21, 24, 40, 64, 82, 84, 99, 100, 101, 103] ▪ Resistance to change^[21, 24, 40, 64, 82, 84, 99, 100] ▪ Organisational culture and change management^[14, 19, 21, 24, 40, 64, 82, 84, 99, 100] ▪ Strategic, agile planning (context-specific)^[14, 19, 21, 24, 64, 84, 99, 100, 103] ▪ Lack of leadership^[19, 21, 24, 40, 64, 82, 84, 100, 103] ▪ Documentation and resources^[14, 19, 24, 64, 82, 84, 99, 100, 103] ▪ Self-sufficiency^[14, 21, 64, 84, 100] ▪ Communication, transparency^[14, 19, 21, 24, 82, 84, 99, 100, 102] ▪ Trust, social cohesion, ownership^[14, 21, 64, 82, 84, 100, 103] ▪ Workflow pressure, staff morale, ethical practices^[14, 19, 21, 24, 40, 84, 99, 100, 101, 103] ▪ More reactive than proactive^[14, 21, 24, 40, 64, 84, 100, 102] ▪ Deep-rooted habits (relative to culture/ specific context)^[24, 40, 64, 82, 84, 99, 100]

Papers identified from scoping review:

Mohammed-Rajput et al. [14]; Syzdykova et al. [19]; Muinga et al. [21]; Oza et al. [24]; Akanbi et al. [40]; Fish and Guha [64]; Verma et al. [82]; Jawhari et al. [84]; Gainer et al. [99]; Gyamfi et al. [100]; Were et al. [101]; Anantraman et al. [102]; Raut et al. [103]

1. Socio-Environmental Barriers Impacting Open Source EHR Implementations

The socio-environmental barriers include diverse issues: resource scarcity, limited political support and socio-economic difficulties. These issues impact open source EHR implementation in LMICs. Nearly all studies [14, 19, 21, 24, 40, 64, 82, 84, 99, 101-103] have shown that a lack of resources (technical expertise, power and connectivity, investment, workstations, human resource) and support (stakeholder engagement and participation) available in LMIC settings impede successful implementations.

The lack of effective stakeholder engagement and participation appears to impact long-term sustainability and healthcare delivery in LMICs [101]. Anantraman et al. [102] state that the implementation of open source EHRs are best supported through effective involvement of various stakeholders such as end-users, IT providers, clinicians and developers [21]. Moreover, Akanbi et al. [40], Syzdykova et al. [19] and Muinga et al. [21] highlighted the importance of government intervention in supporting open source EHR project (pre- and post-) implementations. This is confirmed by Raut et al. [103] who describe the success of two open source EHR implementations in rural Nepal, primarily because of commitment, cohesion and support provided by the government of Nepal (at local and regional level) as a key stakeholder.

Jawhari et al. [84] reported on the importance of addressing social challenges and health inequalities within marginalised communities in urban-poor contexts as a key issue, but one that is often overlooked in implementations. Moreover, little is known about how implementers enact the implementation process and how they respond to the perceived challenges in local settings. An important finding by Jawhari et al. [84] illustrates that socially constructed stigmas associated culturally with certain diseases can impact the acceptance and effective use of open source EHRs in slums and other urban-poor settings; where some patients use multiple identities or show resistance in their data being recorded electronically. Resistance from patients may be related to “general mistrust of systems that might track identities” [84, p.250] as often these individuals reside in insecure tenures, lack rights and legal status. These issues are perceived to be influenced simultaneously by the *technological barriers*: poor patient centred design, data privacy and confidentiality issues, and *organisational barriers*: lack of trust, communication issues, limited funds for context-specific implementations and maintenance support [64].

2. Technological Barriers Impacting Open Source EHR Implementations

Our review suggests that technological barriers include power outages, network failure, interoperability, hardware suitability, data privacy and system sustainability [14, 64, 82, 99]. Data security, privacy and confidentiality issues emerged as a critical need in terms of addressing adequate security features prior to implementation, with concerns that patient data is too broadly accessible to healthcare professionals not directly involved in a patient's care [21, 84, 100].

A number of studies [14, 19, 21, 24, 40, 84, 99, 100, 102, 103] reported on limited interoperability of their open source EHRs with legacy health systems, and how that can hinder successful implementations. These are additionally influenced by socio-environmental (lack of resources and stakeholder intervention) and organisational (lack of expertise and finance) barriers [64]. Unreliable infrastructure at local and regional level is perceived to be a major challenge encountered in urban and rural settings often because of limited funding, poor stakeholder intervention and limitation of key resources [82, 100]; issues that are perceived to be influenced by socio-environmental and organisational barriers. Moreover, there is little information on how implementers address the identified challenges responsively.

3. Organisational Barriers Impacting Open Source EHR Implementations

There are broad issues particularly relating to management of organisation and human resources which are categorised within the organisational barriers theme. For example, finance, human resource development, strategic planning, change management, data ownership, social cohesion, trust and ethical practices, appear to influence open source EHR (pre- and post-) implementation in LMICs. The ethical issues intersect across multiple perspectives. From an organisational perspective, ethical issues comprise: ownership, trust, management and organisational culture [14, 21, 100]. From a technological perspective, ethical issues raise concerns for: data privacy and confidentiality, protection and infrastructure [19, 99]. From a socio-environmental perspective the ethical issues emphasise: sustainability and context, stakeholder intervention, and socio-economic factors [64, 84].

Several studies identified hybrid interventions where open source EHR systems were used alongside paper processes and described how this approach appeared to impede successful implementations [24, 40, 84, 99]. This may be interpreted in terms of inadequate stakeholder intervention, unreliable infrastructure (local and regional), lack of proficiency and training, and inherent habits impeding open source EHR implementation [64, 84, 103]. The practice of such hybrid interventions appears to lower the true value of open source EHR success and constructs a dysfunctional organisational environment in LMIC settings; over-burdening staff, increase in workload pressure, hindering morale and influencing resistance to change [24, 82, 99]. Furthermore, there is limited information on how exactly

open source EHRs are implemented in LMICs and the roles of implementers in the implementation process.

From a socio-environmental and technological perspective, finance can be seen as an important factor for resources and sustainability. However, from an organisational perspective finance is perceived to be a major challenge that impacts the implementation of open source EHRs in LMICs. This can be observed in terms of the inability to source proficient software-developers and IT providers, inadequate staff training and support, limited funding from potential stakeholders and over-reliance on funders [14, 40, 100]. The lack of adequate training and support from stakeholders such as implementers, developers, IT providers, funders and government, appears to have adversely influenced open source EHR ownership [21, 82]. This can be understood in terms of inefficient organisational responsibility of system management, quality data, and conflicting stakeholder relations: the lack of leadership, inability of taking responsibility, risking patient data - raising confidentiality concerns, poor communication, and trust leading to an insecure organisational environment [24, 64, 84, 99]. End-users report lack of leadership, motivation, communication, and suggest the need for a reliable organisational culture and human resources that provides adequate support and training [100].

Discussion

Principal Findings

This scoping review revealed sets of socio-environmental, technological, and organisational barriers to the implementation of open source EHRs for LMICs. Specific issues, which were mentioned often, include organisational and management, limited funding, infrastructure (local and regional), data privacy, confidentiality and protection, ownership, sustainability, and appear to influence the implementation of open source EHRs in LMICs [14, 21, 82, 100]. From an organisational and management perspective, data protection and confidentiality, ownership and ethics emerge as important issues that are context dependent. Data protection and ethics is a key topic to explore because it appears to be an issue often overshadowed by technical processes with less emphasis on the social perspective [26, 27, 36, 64], which requires the application of a relational lens to gain an in-depth understanding [104]. It appears that there is a need to better understand how implementing organisations in LMICs address socio-environmental, technical, and organisational barriers in particular with a view to growing concerns around ethics and management of data protection.

The literature identified in this scoping review suggests that lack of funding, leadership, organisational and human resources issues also raise potential questions about the provision of patient-level data protection and confidentiality [40, 64, 84, 100]. Open source EHR implementation requires supportive processes through collaborative actions: ensuring implementation sites are sufficiently equipped with

access to power, consideration of data protection and confidentiality, network and workstations are integrated efficiently and alternative measures are considered in case of emergency situations [21, 24, 84]. It has been argued that there is a need for implementing organisations to develop self-sufficiency and take responsibility for data protection and ownership, establish local support and training initiatives, and build relations with key stakeholders for long-term sustainability [101, 103]. This notion suggests that organisations could better engage with key stakeholders, develop better ethical practices in terms of taking responsibility, managing organisational culture and change responsibly. Nevertheless, strategic and agile organisational planning are also perceived essential for successful implementations in LMICs.

There is a need to examine the given context, encourage meaningful change, involve end-users such as clinicians, health facility administrators, patients in implementation design, and collaborate with a diverse range of stakeholders cohesively for successful implementations [21, 64, 84, 100]. Key stakeholders, particularly government, need to collaborate, support and develop sustainable context-specific open source EHR implementations that offer a robust functionality, as unreliable technical infrastructure at local and regional level can have negative implications for open source EHR implementations in LMICs. Open source EHR systems can enable better healthcare access, can have a positive impact on medical record quality, and enhance the potential for patient care [18, 73]. However, the challenge with implementing open source EHR systems is finding local expertise (IT skills) and sophisticated support for implementation and maintenance, which are key ingredients needed to make it work meaningfully in LMIC settings [2, 4, 9, 82]. Therefore, there is a disconnect between the understanding of the context-specific barriers, the implementation process, and stakeholder relations.

Context-specific barriers and issues in open source EHR implementations can be better understood through the voices of key stakeholders (implementers and end-users) on the ground [21, 64, 77, 82, 100]. There are challenges that need to be addressed systematically such as taking the socio-environment and organisational perspectives into consideration, understanding change from a reflexive perspective, conducting responsible operations, integrating values and including stakeholders into design before implementing open source EHRs in LMICs [84, 102]. For example, Oza et al. [24] highlight that implementing an open source EHR system during a health emergency (Ebola outbreak) was a major problem as the outbreak (fortunately) started to decline which limited the usefulness of the system (post-implementation) in a resource-scarce environment. Furthermore, designing open source EHR systems whilst epidemic cases are increasing is not a sustainable action, intervention needs to be planned earlier and in retrospect to address the true value of what open source EHRs can offer in health emergency situations [24]. This perception suggests that, depending upon the situation different socio-environmental barriers to implementation can arise. The findings indicate that understanding and addressing, collectively, the perceived key contextual barriers in LMICs prior to an implementation is

of paramount importance. There is a gap in our understanding of how open source EHRs are implemented and the roles implementers enact in the implementation process.

Literature which was not included in the study selection, but considered useful, provided supplementary information. For example, it indicates the presence of a wider discourse on how stakeholders need to reflect on ownership, data confidentiality and protection of information - patient dignity, and address unethical operations [2, 26, 33, 35, 59]. Were and Meslin [27] contend that many ethical frameworks exist (relating to issues on research ethics); however, there are no such frameworks that evaluate how well open source EHR implementations address ethical issues for LMIC settings. While the level of discussions in developed countries focus on “privacy, confidentiality, data security, informed consent, data ownership, and secondary use of data” [27, p.1499], little research has been conducted to address similar ethical issues existing with open source EHR implementations in LMICs. Therefore, if the open source EHR implementation process is better understood it could help implementers address issues effectively and improve implementation success for LMICs.

It is currently unclear who is accountable for protecting data: the healthcare provider, the government, the implementing organisation or the end-user? What level of influence do implementers or end-users exert in protecting data? How is responsibility for data negotiated during implementation? Such questions point to the broader issue of whether responsibility is socially assumed or co-constructed. Manders-Huits [36, p. 274] highlights that “[health] technologies can promote or undermine specific human values...technology shapes our practices and institutions in important ways”. This suggests that developers and implementers as key stakeholders have a level of responsibility (acting purposefully in a role) to embed human values and ethical considerations within open source EHR implementations. There is potential for research to explore the roles of local implementing organisations who play a fundamental role in adopting open source EHRs on the ground. Little is known about the roles of the implementers of open source EHR systems in LMIC settings. It is key to better understand the roles of implementers and what influence they have on addressing the key ethical challenges with concerns to data privacy and practices (in a responsive manner), that impact the implementation of open source EHRs in LMICs.

Strengths and Limitations

The results in this review may be limited and literature may be missing to some extent because only studies published in English were included, and hence subject to potential selection bias. Nevertheless, no other restrictions were placed on the study design or the format of the publication as this was to maximise the search results. The identified key search terms (LMIC, open source, EHR, adaptation and

implementation) were defined prior to the search to ensure consistency across the range of databases. In addition, by utilising an inclusion and exclusion algorithm to screen titles and abstracts, and full-text reviews, made this a simpler process to identify relevant articles for the review. This scoping review identified a small number of helpful studies exploring the contextual barriers impacting open source EHR implementations in LMICs. However, the reviewed studies do not explore the roles of implementers and how, if at all, they respond responsibly to barriers in a given context. Therefore, the gap in the literature highlights a need to conduct further research in this area.

Conclusion

This scoping review provides an overview of the key perceived contextual barriers impacting the implementation of open source EHRs in LMICs. Limited funding and sustainability were reported by all papers. This scoping review identifies that it is vital to take into consideration the specific context in which open source EHRs are to be adopted within, and to address the needs for successful implementation through collaboration with key stakeholders. Open source EHRs have the potential to facilitate enhanced healthcare, encourage sustainable development in LMICs where designed effectively and responsibly within the country specific requirements. A lack of empirical evidence limits our understanding of how exactly open source EHRs are implemented. Research is required to better understand the implementation process and how socio-environmental, technical, and organisational issues can be addressed, particularly in relation to ethics and management of data protection. We hope that the review results will inform areas for future research and enhance implementation.

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Conflicts of Interest: None declared.

Multimedia Appendix 1

Identification of key terms and synonyms using PIO framework.

Multimedia Appendix 2

Search terms and search strategy for Scoping Review.

Multimedia Appendix 3

List of LMIC countries.

Multimedia Appendix 4

Inclusion and exclusion algorithm for screening articles.

Multimedia Appendix 5

Characteristics of included studies.

Multimedia Appendix 6

Quality Assessment Tools Table.

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Abbreviations

- CASP:** Critical Appraisal Skills Programme
- DHIS2:** District Health Information Software 2
- EHR:** Electronic Health Records
- EMR:** Electronic Medical Records
- GNI:** Gross National Income
- IT:** information technology
- LMIC:** low and lower-middle income countries
- MMAT:** Mixed Methods Appraisal Tool
- NGO:** non-governmental organisation
- NPO:** non-profit organisation
- OpenMRS:** Open Medical Record System
- OpenELIS:** Open Enterprise-level Laboratory Information System
- PIO:** Population, Intervention, and Outcome
- PRISMA-ScR:** Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews
- UN:** United Nations
- UN SDG:** United Nations Sustainable Development Goals
- WHO:** World Health Organisation