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Review

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Barriers and facilitators to health information exchange in low- and middle-income country settings: a systematic review

Ather Akhlaq,[1,*] Brian McKinstry,[1] Khalid Bin Muhammad[2] and Aziz Sheikh[1]

[1]Centre for Medical Informatics, Usher Institute of Population Health Sciences and Informatics, the Medical School, University of Edinburgh, Teviot Place, Edinburgh, EH8 9AG, UK and [2]College of Computer Science and Information Systems, Institute of Business Management, Korangi Creek, Karachi, Pakistan

*Corresponding author. Centre for Medical Informatics, Usher Institute of Population Health Sciences and Informatics, the Medical School, University of Edinburgh, Room 112, Doorway 1, Teviot Place, Edinburgh EH8 9AG, UK. E-mail: ather.akhlaq@ed.ac.uk

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Abstract

The exchange and use of health information can help healthcare professionals and policymakers make informed decisions on ways of improving patient and population health. Many low- and middle-income countries (LMICs) have however failed to embrace the approaches and technologies to facilitate health information exchange (HIE). We sought to understand the barriers and facilitators to the implementation and adoption of HIE in LMICs. Two reviewers independently searched 11 academic databases for published and on-going qualitative, quantitative and mixed-method studies and searched for unpublished work through the Google search engine. The searches covered the period from January 1990 to July 2014 and were not restricted by language. Eligible studies were independently, critically appraised and then thematically analysed. The searches yielded 5461 citations after de-duplication of results. Of these, 56 articles, three conference abstracts and four technical reports met the inclusion criteria. The lack of importance given to data in decision making, corruption and insecurity, lack of training and poor infrastructure were considered to be major challenges to implementing HIE, but strong leadership and clear policy direction coupled with the financial support to acquire essential technology, improve the communication network, and provide training for staff all helped to promote implementation. The body of work also highlighted how implementers of HIE needed to take into account local needs to ensure that stakeholders saw HIE as relevant and advantageous. HIE interventions implemented through leapfrog technologies such as telehealth/telemedicine and mHealth in Brazil, Kenya, and South Africa, provided successful examples of exchanging health information in LMICs despite limited resources and capability. It is important that implementation of HIE is aligned with national priorities and local needs.

Key words: Barriers, facilitators, health information exchange, low- and middle-income countries

Key Messages

- Effective health information exchange (HIE) is essential to the provision of high quality care and the efficient running of health systems.
- There is currently limited capacity to undertake HIE in many low- and middle-income country (LMICs) settings.
- This systematic review has found that structural, political and financial considerations are important barriers to promoting HIE in LMICs.
- These barriers can however be overcome through the combination of leadership, vision, use of low cost technologies, and alignment with national and local initiatives that are dependant of data sharing.

Introduction

Information can be defined as the data and knowledge that humans and intelligent systems need to support their decisions (Wyatt and Sullivan 2005). Reliable health information exchange (HIE) can help clinicians and policymakers make evidence-based decisions. (Ndabarora *et al.*, 2014, Wyatt and Sullivan 2005). HIE can be defined as:

> Health information exchange (HIE) is the electronic mobilisation of clinical and administrative information within or across organisations in a region or community and, potentially, internationally between various systems according to locally and/or nationally recognised standards while maintaining the authenticity and accuracy of the information being exchanged, enabling stakeholders to make informed decisions to enhance healthcare quality of a patient and population. HIEs are multi-stakeholder organisations that oversee the business, operational and legal issues involved in the exchange of information.' (Adapted from Finn 2011).

Policymakers, healthcare professionals, industry groups and researchers recognize HIE as a vital component of the solution to the problems posed by disparate and fragmented health systems and non-interoperable technologies (Brailer 2005; Hripcsak *et al.* 2007). The use of information and communication technology (ICT) has seen significant progress in some high-income countries (HICs) such as Australia, Canada, the UK and the USA, e.g. by creating electronic health records (EHRs) and electronic prescribing systems (Sheikh *et al.* 2011; Charles *et al.* 2013; WHO 2011b; Cresswell *et al.* 2014). The Health Information Technology for Economic and Clinical Health (HITECH) Act is the most recent example of support for HIE in the USA. Under HITECH's 'Meaningful Use' Stages 2 and 3, EHRs need to be connected in a manner that can provide electronic exchange of health information between providers thereby supporting efforts to improve the quality of healthcare and achieve improved patient health outcomes. Another example is the Emergency Care Summary (ECS), part of National Health Service Scotland's eHealth strategy (Greenhalgh *et al.* 2013a). The ECS provides a summary of demographic information, current medications and allergies for Scottish patients, which can be securely accessed by any healthcare professionals treating patients in an emergency; these include emergency out-of-hours clinicians, paramedics in Emergency Ambulances, Accidents and Emergency Departments and Acute Receiving Units (Greenhalgh *et al.* 2013b). The Summary Care Record (SCR) in England provides similar information (Greenhalgh *et al.* 2013b; England 2014). In Denmark, the national healthcare system and a high-level implementation of information technology have facilitated robust exchange of patient data through the national network (Protti and Johansen 2010).

Many barriers and facilitators have been identified in implementing and using HIE in HICs. First and perhaps foremost, cost has been found to be a consistent substantial barrier in the US (Kruse *et al.* 2014). The HITEC Act provided initial stimulus funds and the US federal government asked states to contribute to the establishment of HIE infrastructure throughout the USA; a recent analysis has however suggested that many state HIEs have found it difficult to establish effective business models and are therefore likely to close down their activities soon after the federal funding has been consumed (Kruse *et al.* 2014). Second, several barriers have been identified as being responsible for the incomplete patient information—these include patients reluctance to participate because of privacy concerns and/or they received care in the area where HIE was unavailable and hospitals reluctant to exchange information with competitors because of concerns about losing patience and business (Eden *et al.* 2016). Third, usability and organizational and workflow barriers have been highlighted in for example Austria, Finland, Denmark and the USA; these included the need for separate logins, the perceived excessive clicks needed to retrieve information and the difficulty faced by providers in getting privileged access to shared data (Kruse *et al.* 2014; Eden *et al.* 2016). Fourth, technical barriers in Europe and the USA included the lack of data standards, and concerns about timeliness of information (better to go directly to the hospital information portals than to rely on HIE) (Eden *et al.* 2016). Also, lack of awareness and the difficulties in demonstrating value of HIE (e.g. the cost of participating in HIE which may result in a reduction in repeat laboratory tests may be greater than the cost of just repeating tests) impeded HIE process (Kruse *et al.* 2014). Finally, it was perceived that HIE participation may hamper competition (inequity between providers of information/those who pay to participate in HIE and those who benefit from the availability of information such as disparate organizations and patients) especially in the US due to the competitive nature of the healthcare sector (Kruse *et al.* 2014).

To overcome financial barriers, Kruse et al. (2014) concluded that the USA may need to additionally incentivize providers or that more health plans (e.g. Obama Care/Affordable Act Care) were required to contribute HIE process (Kruse *et al.* 2014). Second, in order to address privacy concerns of patients and providers, it was considered essential to construct transparent policies and promote awareness of data sharing and privacy among all healthcare stakeholders (Eden *et al.* 2016). Third, technical facilitation such as simplified single login, sufficient technical assistance and training to support the new workflow, the availability of champion users to encourage the required culture change to help clinicians see HIE as an essential part of managing care, and the use of non-physician proxies (such as of admitting staff and nurses entering most of the data) will allow greater use of HIE by addressing organization and workflow barriers (Eden *et al.* 2016). An example of how this can be done is the HITECH Act which established Regional Extension Centres to provide technical assistance to the organizations

interested in participating in HIE or transitioning to EHRs. Fourth, to address user and technology needs, it is essential to acquire the ability to send/read summarized medical reports first instead of full patient's history, share contextual notes to set patient-related information, automate integration with existing provider systems, and to seek advice from providers and proxy users when designing interfaces (Eden *et al.* 2016; Kruse *et al.* 2014). Finally, Kruse et al. (2014) concluded that efforts from senior leadership (once they realize the value of HIE) to help curb the competitive environment might enable nations to participate more and increase inter-organizational trust towards HIE (Kruse *et al.* 2014).

Countries with a national health system such as the UK do not face the same barriers related to competition. HIE in the UK has been achieved through robust infrastructure and policies (such as privacy protection) which in turn built strong financial and clinical incentives to nurtured an ecosystem of applications (such as SCR and repositories) essential for HIE (Payne *et al.* 2011). Despite these advances and although the GP2GP service has allowed electronic transfer of health records directly and securely between GP practices in England (HSCIC 2015), complete health records could not be transferred between different cities of the UK at a time of emergency (Payne *et al.* 2011).

The '2015 World Health Organization (WHO) Global Survey on eHealth' in the WHO European Region revealed that around 30–31 Member States (70% of the total survey) had a national eHealth policy and financial resources earmarked for implementation. Moreover, technical colleges and universities provided students and professionals with training opportunities in eHealth and ICT (Europe 2016). Funding was found to be the main barrier to implement national EHR systems in 22 Member States. Political commitment, dedicated eHealth strategies and adoption of standards were the key recommendations among others (such as guidance on telehealth and regulations in mHealth) to implement eHealth interventions in the European region (Europe 2016).

Unfortunately, the picture is less encouraging in many LMIC as eHealth systems typically have scarce resources, and limited capability and capacity (WHO 2011b). Lack of information obstructs the delivery of healthcare that results in many preventable deaths in LMICs (Chatterjee *et al.* 2012). This lack of information prevents adequate planning of services and targeting in areas of greatest need and also affects the ability to attract funding because it is not clear if key indicators such as Millennium Development Goals (MDGs) have been met and/or Sustainable Development Goals (SDGs) will be met (Guardian 2013; Pande and Elgin-Cossart 2013). Although data reporting and recording systems in most of the LMICs produce poor quality data (Ali and Horikoshi 2002; Lal *et al.* 2002; Kimaro and Twaakyondo 2006; Rumisha *et al.* 2007; Consulting 2009; Qazi and Ali 2009; Meankaew *et al.* 2010; Ranck 2011; WHO 2011a; Nutley *et al.* 2013) inappropriate for transferring, processing and making analysis, there has been increasing evidence from regional and local studies that careful system design and innovation through ICTs can provide feasible solutions to data related problems and thereby enhance the process of HIE (WHO 2011b). A process of health system reforms has been initiated in several LMICs, e.g. Belize, China, Ethiopia, India, Pakistan and Thailand, through the introduction of ICTs and open source technologies such as EHR, district health information system (DHIS) and DHIS 2, integrated human resource information system, mobile phones and geographical information systems (GIS) to promote recording, reporting, sharing, quality control and analysis of data at various levels of the system (WHO 2011b) but on a small scale and for specific health problems (Scott *et al.* 2002; Garrib *et al.* 2008; Fontaine *et al.* 2010; Vest and Gamm 2010; Bakar *et al.* 2012; Manya *et al.* 2012; Chaiyachati *et al.* 2013). Nevertheless, these interventions allowed stakeholders to respond effectively to a rapidly changing epidemiological environment; decrease healthcare costs reduce duplicate treatments and medical errors; and enhance healthcare quality by monitoring health of individuals and segments of populations (Scott *et al.* 2002; Garrib *et al.* 2008; Fontaine *et al.* 2010; Vest and Gamm 2010; Bakar *et al.* 2012; Manya *et al.* 2012; Chaiyachati *et al.* 2013).

However, despite strong initiatives by national and international organizations such as the Global Observatory on eHealth by the WHO (to inform eHealth policy and practice) (WHO 2008), implementation and adoption of HIE interventions have been slow, typically fragmented and uncoordinated, providing low quality and incomplete healthcare data unsuitable for health policy making and planning (Ali and Horikoshi 2002; Lal *et al.* 2002; Kimaro and Twaakyondo 2006; Rumisha *et al.* 2007; Qazi and Ali 2009; Consulting 2009; Meankaew *et al.* 2010; Samb *et al.* 2010; Ranck 2011; WHO 2011a; Nutley *et al.* 2013). This then begs the questions of what are the reasons behind the slow diffusion of HIE in LMICs and what factors impede and/or support the implementation of HIE in LMICs? In this review, we sought to identify, appraise and synthesize evidence on the barriers and facilitators to HIE in LMICs.

Methods

Study registration and protocol publication

This review was registered with the PROSPERO International Prospective Register of Systematic Reviews (CRD42014009826) (Akhlaq et al. 2014). We provide below an overview of the methods employed; a fuller description is available in the published protocol (Akhlaq et al. 2015).

Eligibility criteria

Eligible participants and care settings

Eligible participants included were healthcare and medical professionals, patients, carers, facility managers and national authorities responsible for exchange of health information. All healthcare settings in LMICs (as defined by the World Bank) were considered (Bank 2012).

Eligible interventions

A study was eligible for inclusion if it was related to health information that was transmitted, shared or needed to be exchanged electronically within and across organizations (e.g. hospitals and clinics), located within the same or different regions (e.g. within city or intercity transfer) or at a national level. Relevant health information included patients' clinical information and data, demographics, health records, claims and administrative data.

The eligible studies included components of HIE that facilitate sharing and exchanging data, for example, EHR, health information systems (HIS), hospital information systems, hospital information management systems, health management information system (HMIS), synonyms of HIE (clinical information exchange, healthcare information exchange, electronic document exchange, medical data exchange), health information infrastructure and e-mail. We were also interested in legacy electronic means of exchanging health information—e.g. telephone and fax.

Outcome measures

We sought to identify and understand the financial, cultural, organizational or technical barriers and facilitators to HIE in LMICs

irrespective of whether these were operating at the individual, organizational, community, regional or national levels.

Eligible studies

We considered published, unpublished and on-going qualitative, quantitative and mixed-method studies investigating the barriers and/or facilitators to the development, adoption or use of electronic systems for exchanging patient or administrative data within or across parts of a healthcare delivery system.

Search methods

The searches were not restricted by language, data or publication status. Where relevant, papers were translated into English. We searched the literature from January 1990 to July 2014 for research investigating problems and challenges in exchanging health information. This start date was chosen because it was the time when policymakers and researchers became interested in problems associated to HIS, a component of HIE, in LMICs (Sandiford *et al.* 1992; Okuonzi and Macrae 1995; Jayasuriya 1999). Experts were contacted for unpublished/in progress research by sharing the list of eligible studies. See Appendix 1 for details.

Electronic searches

A.A. and K.B.M. independently searched for published, unpublished and on-going studies in the following electronic databases:

a. MEDLINE
b. EMBASE
c. ISI Web of Science: Science Citation Index Expanded (SCI-EXPANDED)
d. CINHAL Plus
e. PakMediNet
f. IndMED
g. Global Health
h. Global Health Library (Regional Indexes and WHOLIS)
i. African Index Medics
j. KoreaMed
k. Google Scholar

We searched for technical reports through the Google search engine (first 200 results). See Appendix 2 for search strategy.

Quality assessment tool

The Mixed Method Appraisal Tool (MMAT) version 2011, a quality assessment tool (see Appendix 3) (Pluye *et al.* 2011), was used to appraise the quality of studies. This instrument has previously been used in many other mixed-methods systematic reviews (Humphries *et al.* 2014; Kannisto *et al.* 2014; Blondell *et al.* 2015). A.A. and K.B.M. independently assessed the quality of included studies. Any disagreements with respect to the quality of studies were resolved through discussion or arbitration by a third reviewer, if necessary.

For each retained study, an overall quality score was calculated using the MMAT. The overall score was represented using the following descriptors: *, **, ***, ****. For qualitative and quantitative studies, all four criteria needed to be met to get the highest score. The score can also be expressed as the number of criteria met divided by 4 to obtain a percentage score (scores varying from 25% (*) i.e. one criterion met to 100% (****) indicating that all criteria were met). For mixed method studies, the overall quality score is the lowest score of the study components—qualitative and quantitative, i.e. it cannot surpass the quality of its weakest component.

Data extraction

A.A. and K.B.M. independently abstracted the data onto customized data extraction sheets (Appendices 4 and 5). The variables extracted were: author and year of publication; country of origin; language; healthcare setting; participants and sample size; technology used; intervention; methodology and design of study; data collection tool(s); barriers; and facilitators.

Data analysis

The results were analysed descriptively due to heterogeneity of study designs, systems, types of barriers and facilitators and study population and context. Barriers and facilitators were thematically analysed and placed under different emerging themes as represented in the included studies and past reviews (van Panhuis *et al.* 2014).

Results

Study selection and study characteristics

The searches yielded a total of 6091 citations; after de-duplication 5461 citations remained. After screening the titles and abstracts, a total of 326 articles were scrutinized in detail. Of these, 56 articles, three conference abstracts and four technical reports satisfied our inclusion criteria. The study selection process is summarized in the PRISMA flow diagram (Figure 1) .

The included studies were from 1997 to 2014 and were all in English except for one Chinese article (Cao *et al.* 2009). The included research papers and abstracts were from 27 LMICs (Table 1). One research report was based on case studies of three countries: Brazil, India and Zambia (Consulting 2009). The report also briefly discussed HIS of 19 LMICs (see Appendix 4) from Asia, the Caribbean, Latin America and Sub-Saharan Africa (Consulting 2009). Another report discussed HIS and the critical factors responsible for the success and failure of ICT in the Pacific region (including countries such as Fiji, Papa New Guinea and Vanuatu) (Lewis *et al.* 2012).

The studies encompassed various healthcare settings where HIE was used to manage different types of patients and diseases (Table 2). The care of HIV/AIDS patients was however a particularly strong driving force to the development of HIE.

A wide spectrum of participants was found in the retained studies including patients with malaria, HIV, and trauma; clinical staff (doctors, nurses, midwives and laboratory personnel); medical students; managers, secretaries, administrators; medical directors; information officers and field workers, computer operators and other ICT personnel; state, provincial, district and community-level officials; parliamentarians; government agencies; non-governmental agencies; system and tool users; and citizens.

The types of ICT covered in selected studies are represented in Table 3. Three studies which were based on the information needs of stakeholders did not mention any specific technology (Kapadia-Kundu *et al.* 2012; Lemay and Bocock 2012a; Sylla *et al.* 2012).

A quantitative approach (mainly surveys and secondary sources) was employed in 17 published studies and two conference abstracts, whereas, a qualitative approach was employed in 19 published studies and 1 conference abstract. Mixed methods were employed in 24 published studies (see Table 4).

Most of the selected studies described interventions in the context of assessment or evaluation of current or newly implemented technologies and processes, for example to: assess infectious disease surveillance systems (Mghamba *et al.* 2008); evaluate an existing information system at the district level (Odhiambo-Otieno 2005); and to assess the strengths and weaknesses of a data management and

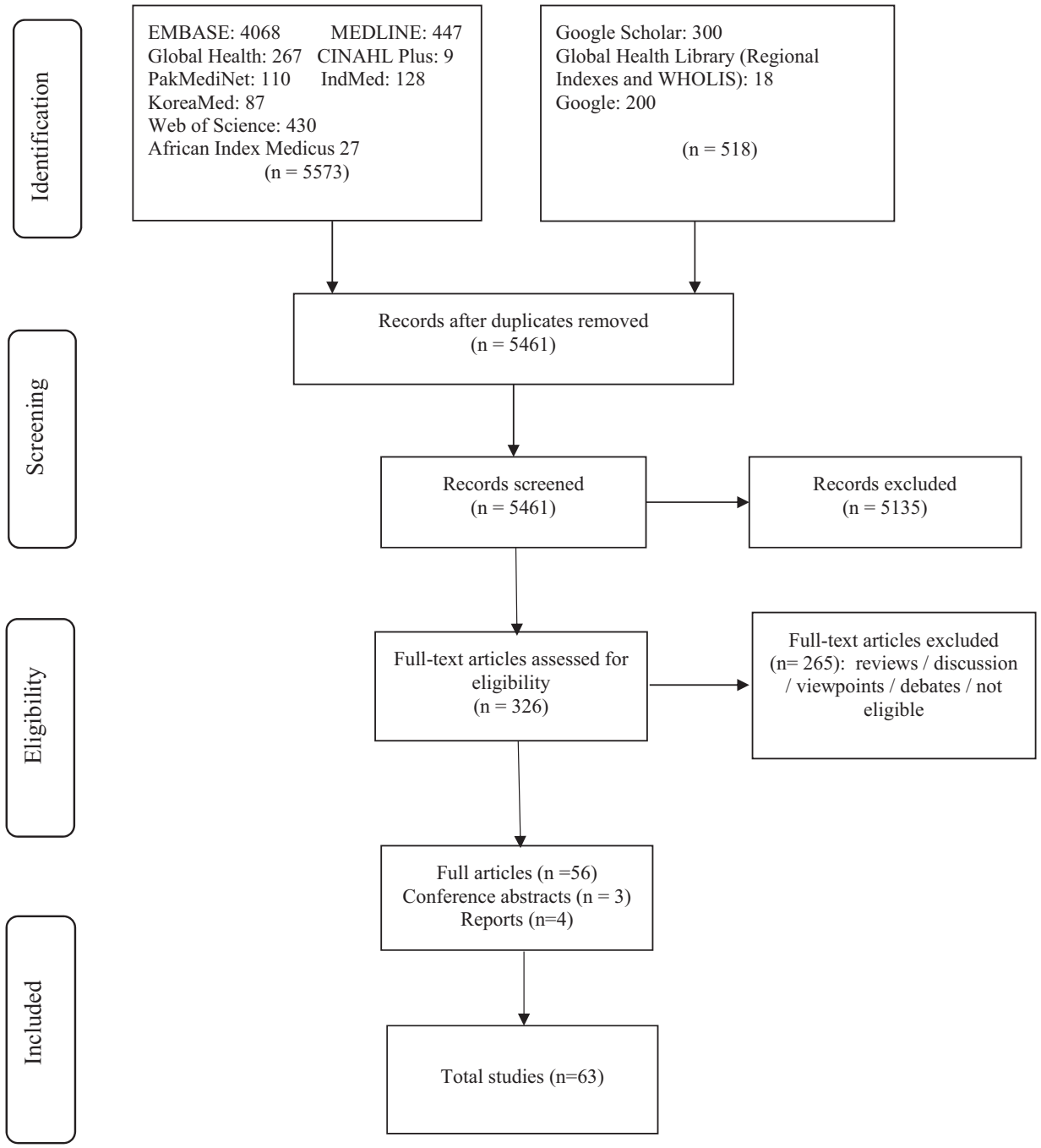

Figure 1. PRISMA diagram.

Table 1. Number of studies from specific LMICs

Name of countries	Number of studies from each country (total)
Botswana, Cameroon, Colombia, Malawi, Mexico, Nepal, Nigeria Senegal, Somalia and Turkey	1 (10)
Brazil, China, Peru/Nicaragua, Sri Lanka and Thailand/Cambodian	2 (10)
Ethiopia, Ghana, Iran and Rwanda	3 (12)
Tanzania and Uganda	4 (8)
India, Pakistan and South Africa	5 (15)
Kenya	6 (6)

reporting system (Ledikwe *et al.* 2014). Other interventions described were on the basis of implementation and introduction of a specific ICT, for instance, implementation of EHRs into a health organization (Li *et al.* 2013); use of telephone/mobile to connect mid-level healthcare workers (HCWs) with general practitioners (Morrison *et al.* 2013); adoption of telemedicine (Nchise *et al.* 2012); and use of mHealth in strengthening DHIS 2 (Asangansi *et al.* 2013) See Table 5 for full details.

Quality appraisal

Overall, the included studies were of high quality. Out of 56 full research papers appraised, 34 had a quality score equal to or >75%.

Table 2. Number of studies according to the healthcare settings

Health care settings	Number of studies from each setting (total)
Emergency medicine, Hansen's disease (leprosy), FP, infectious disease, midwifery, paediatric, pandemic influenza A H1N1, reproductive and child care, maternal mortality, reproductive tract infections, road traffic injuries, TB	1 (13)
Cancer, mother and child health	2 (4)
Hospitals, malaria	3 (6)
HIV/AIDS	9 (9)
No health settings given	31 (31)

Table 3. Types of ICT in selected studies

Type of ICT	Number of studies
GIS	3
Hospital Information System, DHIS, DHIS2, National Health Information System (NHIS)	5
Surveillance systems	5
Electronic medical/health/patient records	4
Others: e.g. Telephone, web-based, internet and computers, database, District Health Profile (DHP) tool	8
Telehealth and Telemedicine	10
mHealth	9
HIS, HMIS, IS, patient safety information system (PSIS)	16

Table 4. Study designs and methods used in data collection

Study design	Number of studies and methods used to collect data	
Quantitative	19	Questionnaire or surveys, medical records, reports, databases, registers, pharmacy files and systems' data
Qualitative	20	Interviews, document analysis, program auditing, focus groups, direct observation, group discussion, workshops, trainings, evaluating implementations, meetings and case study
Mixed Methods	24	Case studies, interviews, discussions, meetings, focus groups, registers, documentary review, call data, observations, summary reports, databases, text queries, usability testing and close-ended/structured questionnaire surveys, consultative meetings, site visits and literature reviews.

The quality score of quantitative studies was the highest among all types of methods, followed by mixed methods studies and qualitative studies (see Table 6).

Synthesis of results

The seven themes for factors influencing the adoption of HIE which arose were, 'socio-political', 'financial', 'infrastructure', 'organizational', 'technical', individual' and 'data management'. Barriers and facilitators identified under each theme are presented in Appendix 6. In addition, barriers and facilitators are also grouped according to the types of ICT as presented in Appendix 7.

Socio-political

This theme comprised of cultural, environmental and political factors.

Cultural. Research from India, Kenya, South Africa and Tanzania on managing and using different types of HIS, found that the healthcare stakeholders gave low importance and priority to data and therefore did not use available health information when making clinical decisions (Lal *et al.* 2002; Kimaro and Twaakyondo 2006; Garrib *et al.* 2008; Mate *et al.* 2009; Nutley *et al.* 2013). A quantitative study in Sri Lanka (Ranasinghe *et al.* 2012) emphasized the need to promote evidenced-based decision making among health managers (HMs) by enabling HIS to transform information into valid evidence. Healthcare stakeholders needed to perceive data as intrinsically valuable in the management of patients and their own performance by simplifying data collection and reporting process (Mate *et al.* 2009).

In a qualitative study on HIV and family planning (FP) conducted in Malawi, it was found that HCWs preferred face-to-face interactions, such as meetings, to seek immediate feedback on health issues, but due to the high cost required to regularly gather large number of HCWs, took up mobile phones for information sharing (LeMay and Bocock 2012b). In a study involving interviews and focus groups in rural Uganda on the usage of mobile phones in delivering emergency medical services for maternal and child health, it was found that gender inequality in the possession of phones was the biggest challenge in adopting mHealth (Williams 2013). Another example of cultural influence was that discussions on sex-related topics with HCWs and professionals were considered taboo by the local population of Colombia, but a teleconsultation service facilitated the discussion and encouraged individuals to ask open questions from healthcare professionals (Valenzuela *et al.* 2007).

Environmental. Insecurity to HCWs and professionals was a major drawback for HIE in a few LMICs (Lewis *et al.* 2012; Zachariah *et al.* 2012; Asangansi *et al.* 2013; Chang *et al.* 2013). For example, in a war-torn Somalia, where doctors work in one of the most insecure environments in the world, a teleconsultation service gave professionals a feeling of proximity and unity with senior associates (Zachariah *et al.* 2012). In a study to improve HIV care, researchers in Uganda conducted interviews and focus groups with a variety of healthcare stakeholders, and found that community HCWs felt insecure in field work carrying a smartphone for fear of theft of the phones (Chang *et al.* 2013).

Political. Lack of leadership and coordination to ensure collection and exchange of information between community and national levels make decision-making difficult, especially in times of disasters and emergency (Seyedin and Jamali 2011; WHO 2011a; Cohn and Xiong 2012; Razzak *et al.* 2012). Corruption and unpredictable change in policies and regulations were other important barriers here. For example, a questionnaire study from Pakistan revealed that some employees failed to comply with HMIS reporting as they knew that no action could be taken against them due to their corrupt association with politicians (Kumar *et al.* 2012). Similarly, in a qualitative study from Pakistan, HMs raised concerns about the corruption of HMIS staff and management citing the misuse of HMIS

Table 5. Objectives of selected studies

S. No.	References	Objective
1.	Abeysekera et al. (1997)	To optimize the malaria data recording system in malaria endemic region.
2.	Adjorlolo and Ellingsen (2013)	To examine the readiness of University of Ghana hospital towards the implementation of the Electronic Patient Record.
3.	Ali and Horikoshi (2002)	1. To do a situational analysis of HMIS in Pakistan observing strengths and weakness. 2. To review the present role of GIS in the HIS in Pakistan.
4.	Alkmim *et al.* (2012)	To improve patient access to specialized healthcare through implementing and maintaining Telehealth.
5.	Amoroso *et al.* (2010)	To document the process of identifying areas within the electronic medical record (EMR) programme requiring and implementing interventions using multiple strategies to improve EMR data quality and use of the data to improve patient care.
6.	Asangansi *et al.* (2013)	To describe the operation of a mobile-based community data collection system designed and implemented to provide quality for the national HMIS software, DHIS2. To give details of the organizational mechanisms that reduced the problems of data collections and strengthened DHIS2.
7.	Cao *et al.* (2009)	To evaluate the coverage of childhood immunization information management system
8.	Chaiyachati *et al.* (2013)	1. To assess the acceptability and feasibility of mobile phone application (Mobilize) to record and submit adverse events forms weekly during multidrug-resistant tuberculosis therapy. 2. To evaluate mobile HCW perceptions throughout the pilot study period.
9.	Chang *et al.* (2011)	To evaluate the impact of mHealth (mobile phone) on AIDS care in rural Uganda.
10.	Chang *et al.* (2013)	A formative study to guide the development and implementation of task-shifting mHealth HIV/AIDS care interventions to be used by Community health workers (CHW).
11.	Darkwa, (2000)	To assess the infrastructure for telemedicine and barriers to healthcare providers in applying telemedicine.
12.	Galvao *et al.* (2008)	The aim of this paper to evaluate the national notifiable disease information system, quality of data input, the exchange of data from the municipality to state levels, human resources and other aspects related with HIS infrastructure.
13.	Garrib *et al.* (2008)	To evaluate the DHIS in rural settings.
14.	Ghia *et al.* (2013)	To estimate the benefits of telemedicine in healthcare system in rural India.
15.	Hernandez-Avila *et al.* (2013)	Evaluating the design and implementation of an EHR in the public health system of Colimo, its perceived benefit and limitations and recommendations for improving the implementation process.
16.	Kapadia-Kundu *et al.* (2012)	A need assessment to better understand health information needs and barriers across all levels of healthcare system.
17.	Karari *et al.* (2011)	To evaluate the acceptability and impact of a telephone consultation service, Uliza! clinicians' HIV hotline.
18.	Kimaro and Twaakyondo (2006)	To investigate the barriers to the use of ICT for improving healthcare delivery system.
19.	Kumar *et al.* (2012)	The study examines the role of HMIS in disease reporting.
20.	Lal *et al.* (2002)	To determine the process of recording and reporting of health information.
21.	Ledikwe *et al.* (2014)	The study assess strengths and weaknesses of the data management and reporting systems form the point of generation to the point of incorporation.
22.	LeMay and Bocock (2012)	1. The study aimed to identify priority health information needs among managers and providers working in HIV/AIDS and FP/reproductive health (FP/RH). 2. To explore the opportunities and challenges for improving information flows. 3. To design an intervention to improve access health information in Malawi.
23.	Li *et al.* (2013)	A case study at a healthcare organization to test its applicability and assess the preparedness for eHealth system.
24.	Martinez *et al.* (2004)	To assess the effects of the Enlace Hispano Americano de Salud (Hispanic American Health Link) system on the working environments of rural HCWs.
25.	Martinez *et al.* (2005)	The empirical analysis of the consultation, information and training needs of health staff in rural areas that can be approved by accessible communication networks.
26.	Mate *et al.* (2009)	To assess the completeness and accuracy of key PMTCT of HIV data elements collected and reported routinely through DHIS of all clinics and hospitals.
27.	Meankaew *et al.* (2010)	To assesses the effectiveness of integrating the use of cell phones into a routine malaria prevention and control programme, and to improve the management of malaria cases in under-served population.
28.	Mengiste (2010)	The study discovers the challenges of introducing computer-based HIS in the Ethiopian public healthcare systems.
29.	Mghamba *et al.* (2008)	To assess the infectious disease surveillance system in relation data management tools and identify barriers and facilitators in its implementation.
30.	Morrison *et al.* (2013)	A pilot study to increase referral and connectivity between district centre and peripheral health facilities.
31.	Nchise *et al.* (2012)	A case study on the adoption of telemedicine in Rwanda.
32.	Ndira *et al.* (2008)	1. To assess and compare the electronic eHMIS with the paper based HMIS for accuracy, availability and timeliness of routine health reports

(continued)

Table 5. Continued

S. No.	References	Objective
		2. To assess the staff satisfaction with the new eHMIS.
33.	Ngwakongnwi et al. (2014)	To assess the implementation of the NHIS by knowing the experiences of stakeholders.
34.	Nsanzimana *et al*. (2012)	The article describes a national electronic cell-phone based and web-based monitoring and evaluation system, TRACnet, for both pre-ART HIV car and ART services.
35.	Nutley *et al*. (2013)	The study provides an example of the development and application of a decision-support tool, DHP and its effect on data-informed decision making at the district level.
36.	Nwagwu *et al*. (2013)	The study inspects how ICTs are used to facilitate communication and information sharing among stakeholders in terminal cancer cases for the purpose of managing patients.
37.	Odhiambo-Otieno (2005)	To evaluate the existing information systems that have supported the operational management of health services at the district level.
38.	Otwombe *et al*. (2007)	An exercise was created out to determine the barriers to the flow data in voluntary counselling and testing centres.
39.	Qazi and Ali (2009)	The study explores the perceptions of HMs of HMIS within their organizations in the context of decentralization process in Pakistan.
40.	Ranasinghe *et al*. (2012)	To investigate the availability of information support for public sector healthcare management by knowing the perceptions of HMs.
41.	Rangraz Jeddi *et al*. (2013)	To determine the ability of HIS to establish evidence-based medicine.
42.	Razzak *et al*. (2012)	The article describes a setting up an urban Road Traffic Injuries surveillance programme in the emergency departments of five major hospital in Karachi.
43.	Rumisha *et al*. (2007)	To assess the Integrated Disease Surveillance and Response in selected districts.
44.	Scott *et al*. (2002)	The study evaluates the potential of GIS in the creation of a HIS for cancer. It also illustrates the shortage of data in developing country.
45.	Seyedin and Jamali (2011)	The article investigates the information and communication system of Iranian health organizations for emergency management in response to disasters.
46.	Sheikhtaheri *et al*. (2013)	The study developed a framework of a PSIS.
47.	Shiferaw and Zolfo (2012)	The article provides an overview of an Ethiopian telemedicine case study, highlighting its challenge, success and failures.
48.	Srivastava *et al*. (2009)	To evaluate the performance of newly implemented surveillance system, Integrated Disease Surveillance Project, in terms of completeness and timeliness of information reporting weekly.
49.	Sylla *et al*. (2012)	A study of health information needs, flow and use.
50.	Thomas et al. (2012)	The article describes a mobile phone-based HIS, K-Shree Health Information Dashboard (KHID) that is developed to facilitate the reporting of RH issues among the women.
51.	Usmani (2006)	To assess the practice of Diseases Early Warning System in Azad Kashmir and suggest ways to improve it.
52.	Valenzuela *et al*. (2007)	A case study on web-based asynchronous teleconsulting service in Spanish, Doctor Chat, for consumers.
53.	Vanessa et al. (2012)	To allow health care workers to use a tablet PC to access patients' health records through an application, Family Folder Collection.
54.	Velez *et al*. (2014)	A usability study presents midwives working in rural Ghana with a mHealth application, mClinic.
55.	Wong and Bradley (2009)	To evaluate the impact of an inexpensive business process re-engineering on the accessibility and completeness of patient information by implementing a hospital-wide patient registration and medical records.
56.	Zachariah *et al*. (2012)	Introducing telemedicine and perceptions of local clinicians.
57.	Al-Mafazy *et al*. (2012)	To analyse malaria epidemic early detection system (MEEDS) data and to see trends related to outbreak detection in numerous MEEDS attributes.
58.	Cohn and Xiong (2012)	A pilot study at a public HIV clinic to support clinical decision making by providing mobile telephone system to community health workers.
59.	Williams (2013)	To explore and examine the role of mobile phones in emergency medical services in rural Uganda.
60.	Consulting (2009)	To review health care systems facing threats and challenges in developing countries, To survey efforts for creating successful HIS at national levels and To examine three in-depth case studies to review the significant challenges and opportunities in building up effective HIS.
61.	WHO (2011)	To assess country HISs of LMICs.
62.	Ranck (2011)	To examine the role of mobile technology and information technologies to improve access to quality health information, To examine health information flows from patients to healthcare organizations and to identify information gaps technology can address and To identify barriers and recommendation for using information technologies to provide efficient information flows.
63.	Lewis *et al*. (2012)	To categorize and discuss HIS in developing countries, To summarize the potential benefits and opportunities presented by the use of ICT and To discuss barriers and facilitators of ICT.

Table 6. Study designs and methodological scores (excludes conference abstracts and reports)

	Number of studies and methodological appraisal scores			
Study design	25% (*)	50% (**)	75% (***)	100% (****)
Quantitative			2	15
Mixed methods	3	5	7	5
Qualitative	6	8	5	

office resources, such as typing of unofficial letters, the appropriation of computers by senior management and data manipulation to hide the causes of epidemic diseases (Qazi and Ali 2009). A perceived lack of interest of the ruling elite of Mexico (Hernandez-Avila *et al.* 2013) and the unpredictable uncertain environment of the public healthcare system (new policies, strategies and regulations) in Ethiopia (Mengiste 2010) were considered to have deterred development of HIS and HIE.

Authors from Ethiopia, Mexico, Nigeria, Pakistan, Sri Lanka and Senegal, concluded that political and administrative will, which led to reformed and flexible policies, the establishment of innovative partnerships and role models, and the documenting of practices and guidelines may help to facilitate the implementation and adoption of HIE in their countries (Qazi and Ali 2009; Mengiste 2010; Ranck 2011; WHO 2011a; Nchise *et al.* 2012; Ranasinghe *et al.* 2012; Razzak *et al.* 2012; Shiferaw and Zolfo 2012; Sylla *et al.* 2012; Asangansi *et al.* 2013; Hernandez-Avila *et al.* 2013).

Financial

Financial constraints were identified as the main barrier to HIE implementation and adoption in LMICs (Darkwa 2000; Martinez *et al.* 2005; Kimaro and Twaakyondo 2006; Rumisha *et al.* 2007; Cao *et al.* 2009; Consulting 2009; Qazi and Ali 2009; Mengiste 2010; WHO 2011a; Lewis *et al.* 2012; Nchise *et al.* 2012; Razzak *et al.* 2012; Adjorlolo and Ellingsen 2013; Ghia *et al.* 2013; Hernandez-Avila *et al.* 2013). Maintenance costs (Martinez *et al.* 2005; Qazi and Ali 2009; Chang *et al.* 2011; Lewis *et al.* 2012; Hernandez-Avila *et al.* 2013), management costs (Ndira *et al.* 2008; Cao *et al.* 2009; Qazi and Ali 2009; Lewis *et al.* 2012) and high air time costs (mobile minutes) (LeMay and Bocock 2012b; Sylla *et al.* 2012) were additional cost-related barriers post implementation of HIE technologies.

Research from Botswana, China, Mexico and Pakistan gave high importance to invest more in building and operating electronic medical systems and training of human resource due to lack of medical systems and insufficient training (Cao *et al.* 2009; WHO, 2011a; Razzak *et al.* 2012; Hernandez-Avila *et al.* 2013; Ledikwe *et al.* 2014). Studies from Ethiopia and Ghana on implementing telemedicine emphasized the need to establish alliances with other sectors to raise capital and investment and to develop a business model for telemedicine (Darkwa 2000; Shiferaw and Zolfo 2012). Cost-effective technologies for HIE included the use of email and voice communication, e.g. in telehealth/telemedicine and DHIS 2 (Martinez *et al.* 2004; Alkmim *et al.* 2012; Lewis *et al.* 2012; Asangansi *et al.* 2013), usage of hotline/toll numbers to reduce communication costs between health workers and clinical staff (Chang *et al.* 2011; Karari *et al.* 2011) and the use of freely available open source software, e.g. OpenMRS and DHIS (Consulting 2009; Amoroso *et al.* 2010; Asangansi *et al.* 2013).

Infrastructure

Lack of infrastructure (office space, supplies, equipment, computers, printers, alternate power) (Abeysekera *et al.* 1997; Odhiambo-Otieno 2005; Kimaro and Twaakyondo 2006; Galvao *et al.* 2008; Ndira *et al.* 2008; Cao *et al.* 2009; Consulting 2009; Mengiste 2010; Ranck 2011; Kumar *et al.* 2012; Razzak *et al.* 2012; Sylla *et al.* 2012; Ghia *et al.* 2013) and shortage of electricity (Martinez *et al.* 2005; Ndira *et al.* 2008; Wong and Bradley 2009; Sylla *et al.* 2012; Ranck, 2011; LeMay and Bocock 2012b; Lewis *et al.* 2012; Adjorlolo and Ellingsen 2013; Morrison *et al.* 2013) were the two most prominent infrastructure barriers in LMICs. Communications challenges were due to limited internet services (Cao *et al.* 2009; Lewis *et al.* 2012; Nchise *et al.* 2012; Sylla *et al.* 2012; Adjorlolo and Ellingsen 2013; Ghia *et al.* 2013; Li *et al.* 2013), poor telecommunication network (Martinez *et al.* 2005; Ndira *et al.* 2008; Karari *et al.* 2011; LeMay and Bocock 2012b; Lewis *et al.* 2012; Asangansi *et al.* 2013; Morrison *et al.* 2013) and limited access to phones (Chang *et al.* 2011, 2013). In several studies it was demonstrated that lack of working HIS in facilities contributed to the fragmented healthcare delivery (Ranck 2011; Seyedin and Jamali 2011; Razzak *et al.* 2012; Sheikhtaheri *et al.* 2013).

Usage of mobile phones (Chang *et al.* 2011; LeMay and Bocock 2012b; Lewis *et al.* 2012; Nsanzimana *et al.* 2012; Sylla *et al.* 2012; Nwagwu *et al.* 2013) and very high frequency radios (Martinez *et al.* 2004, 2005; LeMay and Bocock 2012b) were found to facilitate rapid communication among HCWs and providers. Alternate sources of electricity (such as generators, solar rechargers) were suggested to overcome power shortages to meet the requirements of electronic systems (Ndira *et al.* 2008; Lewis *et al.* 2012; Adjorlolo and Ellingsen 2013; Asangansi *et al.* 2013).

Organizational

Lack of training (Ali and Horikoshi 2002; Kimaro and Twaakyondo 2006; Usmani 2006; Garrib *et al.* 2008; Mghamba *et al.* 2008; Qazi and Ali 2009; Srivastava *et al.* 2009; WHO 2011a; Nchise *et al.* 2012; Sylla *et al.* 2012; Asangansi *et al.* 2013; Chang *et al.* 2013; Ghia *et al.* 2013; Hernandez-Avila *et al.* 2013; Nutley *et al.* 2013; Mengiste 2010) was cited as the main barrier under this theme followed by lack of trained human resource (Martinez *et al.* 2005; Kimaro and Twaakyondo 2006; Otwombe *et al.* 2007; Galvao *et al.* 2008; Garrib *et al.* 2008; Ndira *et al.* 2008; Kumar *et al.* 2012; LeMay and Bocock 2012b; Sylla *et al.* 2012; Consulting 2009; Ranck 2011; WHO 2011a; Lewis *et al.* 2012). For these reasons, staff often felt overburdened and unable to fulfil their tasks efficiently (Lal *et al.* 2002; Rumisha *et al.* 2007; Mghamba *et al.* 2008; Morrison *et al.* 2013; Ledikwe *et al.* 2014). Absence of effective coordination, management and supervision among organizational departments and professional hierarchies created communication gaps and management issues (Ali and Horikoshi 2002; Kimaro and Twaakyondo 2006; Galvao *et al.* 2008; Mghamba *et al.* 2008; Ndira *et al.* 2008; Qazi and Ali 2009; Kumar *et al.* 2012; Nchise *et al.* 2012; LeMay and Bocock 2012b; Asangansi *et al.* 2013; Chang *et al.* 2013). Finally, the tropical climate of the Pacific region was found to be damaging to equipment, therefore controlled and dust-free environments were needed for the safety of equipment (Lewis *et al.* 2012).

Training of staff and healthcare professionals was found to be the most essential facilitator (Darkwa 2000; Ali and Horikoshi 2002; Lal *et al.* 2002; Martinez *et al.* 2005; Usmani 2006; Rumisha *et al.* 2007; Garrib *et al.* 2008; Mghamba *et al.* 2008; Ndira *et al.* 2008; Consulting 2009; Qazi and Ali 2009; Karari *et al.* 2011; Seyedin and Jamali 2011; WHO 2011a; Kumar *et al.* 2012; Shiferaw and Zolfo 2012; Adjorlolo and Ellingsen 2013; Asangansi *et al.* 2013; Chaiyachati *et al.* 2013; Chang *et al.* 2013; Rangraz

Jeddi *et al.* 2013; Li *et al.* 2013; Nwagwu *et al.* 2013; Ledikwe *et al.* 2014) under this theme. The second most important facilitator was to motivate staff by offering incentives for using information in decision making (Odhiambo-Otieno 2005; Rumisha *et al.* 2007; Ndira *et al.* 2008; Qazi and Ali 2009; Kumar and Aldrich 2010; WHO 2011a; Morrison *et al.* 2013). Hiring more staff (Ali and Horikoshi 2002; Ndira *et al.* 2008; Consulting 2009), involving key health personnel for new policies (Darkwa 2000; Rumisha *et al.* 2007), and defining new roles and careers structures for managing HMIS (Qazi and Ali, 2009; Kumar *et al.* 2012) were suggested to facilitate health information management and sharing.

Technical

Incomplete, faulty, rigid, fragmented and limited functionality of electronic health systems (Abeysekera *et al.* 1997; Darkwa 2000; Odhiambo-Otieno 2005; Galvao *et al.* 2008; Cao *et al.* 2009; Qazi and Ali 2009; Ranck 2011; Adjorlolo and Ellingsen 2013; Chaiyachati *et al.* 2013; Ghia *et al.* 2013; Hernandez-Avila *et al.* 2013; Rangraz Jeddi *et al.* 2013; Ledikwe *et al.* 2014) were the main technical barriers in LMICs. Additionally, overuse of technical language (LeMay and Bocock 2012b; Sylla *et al.* 2012) and HIS not meeting the expectations of HMs (Ranasinghe *et al.* 2012; Li *et al.* 2013) were presented as examples of neglecting users' requirements when designing systems (Odhiambo-Otieno 2005) which in turn had negative consequences on HIE. Another key technical challenge was that individual patients were often not uniquely identified within the national HIS because data were usually statistical and lacked patient identification (Ranck 2011). Moreover, limited software have been developed in languages other than English which has been a barrier for low-populated countries, especially in Pacific regions, where the locals speak a number of different dialects (Lewis *et al.* 2012).

The most notable technical facilitators found were usage of simple and user friendly technology, for example, the use of pocket digital camera and desktop for telemedicine, fax, internet and email (Martinez *et al.* 2005; Amoroso *et al.* 2010; Alkmim *et al.* 2012; Shiferaw and Zolfo 2012; Sylla *et al.* 2012; Kapadia-Kundu *et al.* 2012; Nsanzimana *et al.* 2012; Chaiyachati *et al.* 2013), computerize the existing manual systems for data collection and sharing e.g. DHIS (Martinez *et al.* 2005; Odhiambo-Otieno 2005; Kapadia-Kundu *et al.* 2012; Asangansi *et al.* 2013; Nwagwu *et al.* 2013) and use of open source technologies e.g. OpenMRS (Martinez *et al.* 2005; Amoroso *et al.* 2010). Finally, software must be developed in local languages to make the technology more meaningful (Lewis *et al.* 2012).

Individual

Unawareness of technology, applications or processes (Darkwa 2000; Mghamba *et al.* 2008; Karari *et al.* 2011; Kumar *et al.* 2012; Razzak *et al.* 2012; Rangraz Jeddi *et al.* 2013) were the most frequent individual barrier to adopt HIE. Privacy concerns of individuals for their health information being revealed (Odhiambo-Otieno 2005; Chang *et al.* 2011, 2013; Ghia *et al.* 2013) and resistance to new work processes (Ali and Horikoshi 2002; Wong and Bradley 2009; Alkmim *et al.* 2012; Hernandez-Avila *et al.* 2013; Asangansi *et al.* 2013) were found as other important challenges for HIE under this theme. Furthermore, inadequate English language skills (Qazi and Ali 2009; Kapadia-Kundu *et al.* 2012; LeMay and Bocock 2012a) deterred the HIE process.

It was seen to be important to assess the needs of users when adopting or improving technology or interventions (Qazi and Ali 2009; Alkmim *et al.* 2012; Al-mafazy *et al.* 2012; Kapadia-Kundu *et al.* 2012; Chaiyachati *et al.* 2013; Asangansi *et al.* 2013; Li *et al.* 2013; Velez *et al.* 2014). In particular, perceived usefulness was found to be the important facilitator for individuals to adopt HIE (Valenzuela *et al.* 2007; Ndira *et al.* 2008; Chaiyachati *et al.* 2013; Nutley *et al.* 2013; Velez *et al.* 2014).

Data management

Lack of timely reporting of health data and feedback from supervisors were found to be important barriers to health data management in LMICs (Ali and Horikoshi 2002; Martinez *et al.* 2005; Kimaro and Twaakyondo 2006; Otwombe *et al.* 2007; Rumisha *et al.* 2007; Galvao *et al.* 2008; Garrib *et al.* 2008; Mghamba *et al.* 2008; Qazi and Ali 2009; Meankaew *et al.* 2010; Kapadia-Kundu *et al.* 2012; Nsanzimana *et al.* 2012; Razzak *et al.* 2012; Sylla *et al.* 2012; Nutley *et al.* 2013). The delivery of too much/irrelevant/incomplete/redundant information (Lal *et al.* 2002; Scott *et al.* 2002; Martinez *et al.* 2005; Otwombe *et al.* 2007; Garrib *et al.* 2008; Consulting 2009; Meankaew *et al.* 2010; WHO 2011a; Kapadia-Kundu *et al.* 2012; LeMay and Bocock 2012b; Nsanzimana *et al.* 2012; Sylla *et al.* 2012; Li *et al.* 2013; Nutley *et al.* 2013) was another barrier which in turn may have exacerbated perceived data quality issues (Ali and Horikoshi 2002; Lal *et al.* 2002; Kimaro and Twaakyondo 2006; Rumisha *et al.* 2007; Qazi and Ali 2009; Consulting 2009; Meankaew *et al.* 2010; Ranck 2011; WHO 2011a; Nutley *et al.* 2013). Other significant issues were the lack of data analysis tools (Odhiambo-Otieno 2005; Kimaro and Twaakyondo 2006; Usmani 2006; Mghamba *et al.* 2008; WHO 2011a; LeMay and Bocock 2012b; Li *et al.* 2013), no data capture or exchange from the private sector (Abeysekera *et al.* 1997; Consulting 2009) and lack of data standards for reporting data and interoperability (Rumisha *et al.* 2007; Ranck 2011; WHO 2011a).

Availability of standardized data sets and forms for reporting (Usmani 2006; Garrib *et al.* 2008; Consulting 2009; Ranck 2011; Seyedin and Jamali 2011; WHO 2011a; Sheikhtaheri *et al.* 2013), regular feedbacks (Otwombe *et al.* 2007; Galvao *et al.* 2008; Consulting 2009; Qazi and Ali 2009; Sheikhtaheri *et al.* 2013), supportive supervision (Galvao *et al.* 2008; Mghamba *et al.* 2008; Mate *et al.* 2009; LeMay and Bocock 2012b; Ledikwe *et al.* 2014), and regularly evaluating and monitoring systems at health facilities (Galvao *et al.* 2008; Mghamba *et al.* 2008; Ndira *et al.* 2008; Srivastava *et al.* 2009) were the most promising facilitators to HIE under this theme.

Discussion

Statement of principal findings

Socio-political factors such as a stable and transparent political system, promotion of an evidence-based decision making culture and a secure environment are very important factors to facilitate the implementation and adoption of HIE in LMICs. Although finance, too, is an important factor to develop infrastructure, purchase technology and pay for training and human resource, it can only be used efficiently and effectively when there is strong political leadership and the system is relatively free of corruption. Moreover, there needs to be a focus on capacity building such as the provision of qualified supervisors, follow-up of training, and coaching to gradually change attitudes towards the use of ICTs. Other issues comprised unawareness of technology, resistance to new processes, lack of timely reporting and feedback and poor data quality. In order to address these issues, it is essential to assess users' needs when implementing

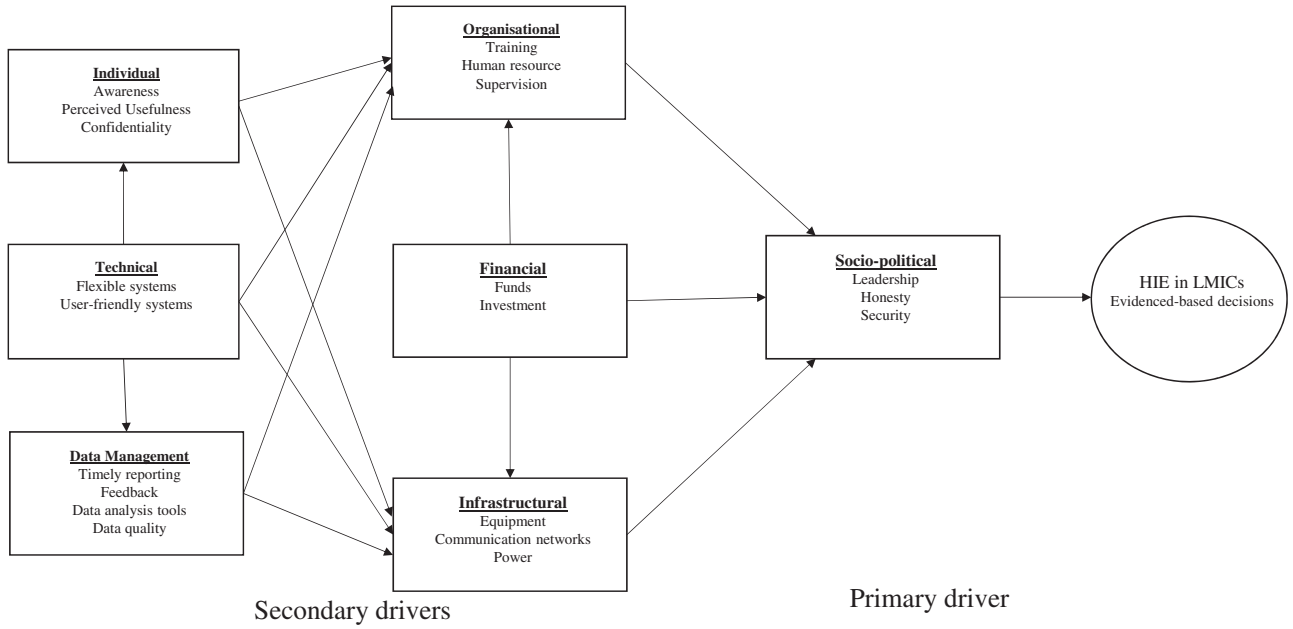

Figure 2. Relationship between the main themes in achieving HIE in LMICs.

HIE, provide timely feedback and develop data standards to improve data quality and interoperability. Figure 2 represents the primary and secondary drivers to implement and adopt HIE in LMICs.

Despite these challenges, some LMICs have been able to implement HIE interventions. Examples included the introduction of disease and treatment of malaria module using mobile technology in Thai-Cambodian region (Meankaew *et al.* 2010), the use of mHealth application for treating TB in South Africa (Chaiyachati *et al.* 2013), a telephone consultation service for HIV care in Kenya (Karari *et al.* 2011), the implementation of road traffic injury surveillance in Pakistan (Razzak *et al.* 2012), the use of DHIS2 and mobile technology to improve community data collection in Nigeria (Asanganси *et al.* 2013) and the use of telehealth in connecting clinics with hospitals in Brazil (Alkmim *et al.* 2012). The concern here is that all these interventions were pilot-based that have never been scaled up because they often require a high amount of financial resources, therefore, LMICs should plan HIE interventions with a view to a large scale that can also be sustained in the long term.

Strengths and limitations

This review made use of an exhaustive search strategy including 11 national and international databases for search queries; applied no language restrictions; included all types of ICT and interventions; a wide spectrum of stakeholders ranging from healthcare professionals to HMs, bureaucrats and patients; and included all types of study designs. We applied methodological appraisal scores to assess the quality of individual studies.

Studies merely detailing software and/or system development (Malamateniou and Vassilacopoulos 2003; Guo *et al.* 2005; Delrobaee *et al.* 2006), were discarded. The MMAT is an efficient quality appraisal tool; however, its reliability requires further improvements particularly for the two items in the qualitative section including the sentences 'appropriate consideration' (Souto *et al.* 2015) (see Appendix 3 Sections 1.3 and 1.4). Generally, few qualitative articles correspond to the detailed features of these items, whereas, in some qualitative research either these features do not exist or only provide very less details (Souto *et al.* 2015). Similarly in this review, the appraisal scores of qualitative studies were lower than quantitative and mixed methods studies because details corresponding to these two items were rarely present. We did not exclude any study on the basis of low quality scores as the purpose of the review was exploratory. Also, we may have found other relevant literature by including other national academic databases and search engines but we restricted our searches due to time constraints. It is also possible that some key developments may not have been written up and some findings might be dated. Finally, we have found HIE processes in different contexts (such as HIV/AIDS, FP, malaria) using different technologies (such as mHealth, telehealth, DHIS, Global Positioning System), it was difficult to make inferences from one context to another.

Interpreting the findings in the context of wider published literature

Socio-political system

The structure of a social system can impede or facilitate the diffusion of innovations and HIE (Rogers 2003). Unfortunately, political, environmental and cultural barriers pose major challenges, even if the financial barriers can be overcome. Data exchange is successful when a perceived need is addressed and the social context is taken into account (Sane 2015). For example, the difficulty of coordination between federal, provincial and district level can throw up barriers to HIE at macro and lower levels of public health system. Similarly, lower and higher ranking officers in organizations may give low importance to use available health information (Garrib *et al.* 2008; Nutley *et al.* 2013), possibly because there is no internal or external political pressure to make decisions based on available evidence. Also, in some LMICs the unstable public healthcare system with rapid modification of policies challenged the implementation of information systems (Mengiste 2010). Similarly, insecure environment compromising lives of HCWs/professionals created difficulties in collecting patient data, thus making the HIE process more complex in few LMICs. Socio-political barriers to HIE can be

addressed through strong political commitment and effective policies that may promote mandatory evidenced-based decision making and health planning (Rumisha *et al.* 2007; Qazi and Ali 2009; Sylla *et al.* 2012; Hernandez-Avila *et al.* 2013). Therefore, governments should actively manage diffusion of HIE through leadership and stewardship and provide funds to purchase or implement health technologies (Nandakumar *et al.* 2009).

Role of investment

A political directive at the initial stages of implementation of an innovation can enhance its chances of adoption, probably most significantly when simultaneously a dedicated finance channel is provided (Greenhalgh *et al.* 2004). Technology diffusion in LMICs has been found to be positively correlated with national per capita spending (Desiraju *et al.* 2004). According to the WHO, national and international goals such as the MDGs and SDGs are impossible to accomplish unless and until there is greater and effective investment in health systems and services (WHO 2007b; Espey 2015). For example, availability of funds is necessary to train individuals in order to help them: adopt certain skills; implement technology and provide equipment; develop capacity in key organizations, hire more human resource to facilitate overburdened staff; and to improve infrastructure. Financing, therefore, underpins the health system building blocks among service delivery, workforce, information, commodities and governance, of the WHO Health System Framework (WHO 2007a). However, while LMICs lack financial resources, their health budgets have in some countries increased from national and international donors such as global funds to fight HIV/AIDS, TB and malaria. However, the increase in international funding for health has also accelerated the demand for more reliable health data and information that are required to track performance and ensure accountability (Boerma and Stansfield 2007). This is again only possible through strong administration and supervision. Donors that particularly contribute to strengthening HIS include; the WHO, the Japan International Co-operation Agency (such as the DHIS project for Pakistan), the UK Department for International Development, the US Agency for International Development (MEASURE Evaluation project) and Global Alliance for Vaccines and Immunization. Increasingly, donors are only disbursing funds to countries that provide reliable and updated information on how the funds are utilized and outcomes achieved (Uganda's 2005). This then begs the question as to why so many countries are ill-equipped to provide health information data in spite of available funds from national and international organizations. Again, the evidence suggests, it is because of weak political systems (Consulting 2009; Kumar *et al.* 2012).

Infrastructure and technology

An innovation that integrates well with the organization's supporting technologies is more likely to be assimilated (Greenhalgh *et al.* 2004). Similarly, if a technology is customized and there is appropriate training and support, it will be more readily adopted (Greenhalgh *et al.* 2004). Infrastructure and technical limitations in LMICs need not prevent the diffusion of HIE. One example of a successful leapfrog approach is the diffusion of mobile phones in LMICs skipping some of the intermediate phases of development—in particular, wired phone systems—found in HICs (Wyber *et al.* 2015). The opportunities for HIE and improvement in healthcare delivery offered through mobile phones has generated considerable enthusiasm for mHealth projects in LMICs. Likewise, alternate power resources such as generators and uninterruptible power supply may enable HIE implementation and adoption in LMICs (Sylla *et al.* 2012; Adjorlolo and Ellingsen 2013) by providing necessary electricity required for electronic medical systems. It is also important to use simple and user friendly technology because simple to use innovations are more likely to be adopted by individuals (Rogers 1995).

Human aspects

It is essential to give importance to the needs of individuals when developing and implementing electronic health systems because perceived usefulness and advantages offered by the innovation are important facilitators to HIE. This resonates well with the Innovation Diffusion Theory (Rogers 1995), Theory of Planned Behaviour (Ajzen 1991) and Technology Acceptance Model (Davis 1986). For instance, instead of perceiving the usefulness of EHR such as enhanced availability and sharing of data (Sheikh *et al.* 2011), physicians in Mexico resisted adopting it because they perceived it to be monitoring their work challenging their trustworthiness (Hernandez-Avila *et al.* 2013). The perceived complexity of the innovation can be reduced by demonstration and practical experience whereas perceived risk can be minimized by balancing between the benefits and risks of HIE (Greenhalgh *et al.* 2004) in the management of patients and improving performance (Mate *et al.* 2009). Similarly, training of individuals (staff and healthcare professionals) may facilitate using data analysis skills and tools in order to manage, analyse and improve quality of data for decision making. Moreover, team-based training is more effective than individual training when learning complex technology or innovation provided with high-quality training material, essential for the successful and sustainable implementation of an innovation (Greenhalgh *et al.* 2004).

Implications for policy, practice and research

Identifying and classifying barriers to HIE has provided a landscape of data-exchange challenges in LMICs that must be addressed to ensure successful implementation comprehensively utilizing the range of recognized facilitators. This review will help inform national healthcare stakeholders as well as international donor agencies and thereby enable them to plan effective strategies to implement HIE in LMICs.

Governments must take the lead and emphasize the need for accurate information on which to base decisions that in turn will be attractive to external funders. Governments must provide the groundwork to address infrastructure, organizational, technical, individual and data management barriers to HIE with the support of international organizations.

However, although the available resources to tackle barriers (e.g. infrastructure organizational, technical, data management) vary in each of the LMICs there is benefit in LMICs sharing their resources (experts, workforce, technology, interventions) and learning to develop HIE. Collaborative governance and technical partnerships, e.g. Population Health Implementation and Training partnerships, to enhance district health systems in five sub-Saharan African countries, namely Ghana, Mozambique, Rwanda, Tanzania and Zambia (Mutale *et al.* 2013), may facilitate successful implementation and adoption of HIE.

Those LMICs that still haven't adopted HIE and are planning to do so, may learn from these examples and avoid unnecessary failures. Similarly, international organizations that support LMICs financially, technically and providing infrastructure may make use of these classified facilitators to improve outcomes. A summarized conceptual map of barriers and facilitators is given in Figure 3.

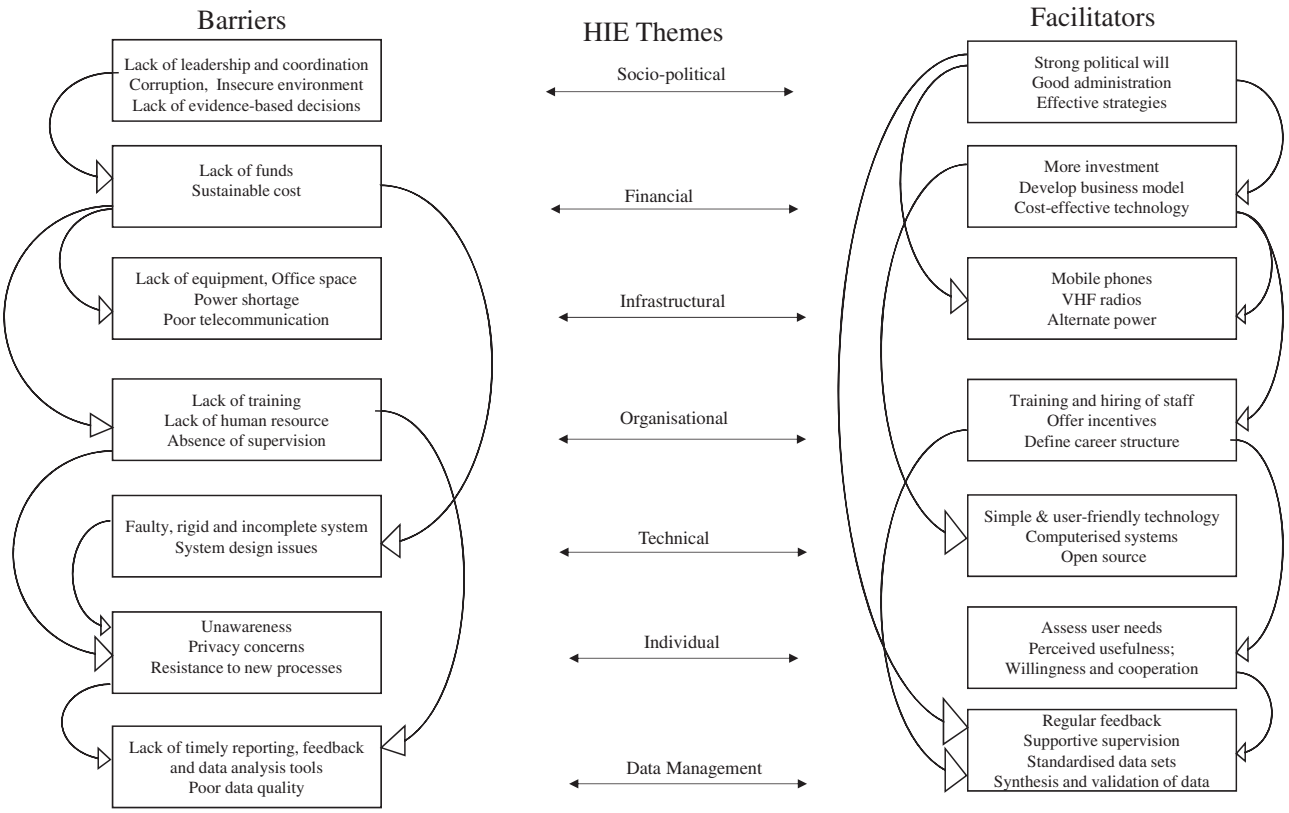

Figure 3. Conceptual map of barriers and facilitators to HIE in LMICs.

Conclusions

Although finance is essential to build infrastructure, organizational capacity and provide training and technology, implementations will fail unless government and administrators in LMICs promote an evidence-based decision-making culture through effective policies and demonstrate strong political will to push these forward to make effective and efficient use of investment from international and national channels. It is important that any implementation of HIE clearly meets national priorities for the countries and the needs of key stakeholders. It is also important to promote and develop a culture amidst healthcare managers and providers of using ICTs for HIE because they have not been exposed to the use of ICTs in everyday life as it is the case in HICs possibly due to the poor ICT infrastructure in many LMICs. We have identified several examples of successful HIE processes in LMICs, this being achieved through leapfrog technologies facilitating poor infrastructure and weak organizational capacities.

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