

Assessing Clinical Information Quality in Digital Health Technologies

Kayode Philip Fadahunsi

Global Digital Health Unit
Department of Primary Care and Public Health
School of Public Health
Imperial College London

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Declaration

I declare that this thesis is entirely my own work completed under the guidance of my PhD supervisors, Profs. Josip Car, Azeem Majeed, Petra A. Wark and Joseph Gallagher.

Chapters 2 and 3 have been published, both as protocols and as research papers in academic journals. Chapters 4 and 5, have also been submitted for publication. I am the first author of all the published papers with contributions from my supervisors and collaborators.

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Abstract

Introduction

Digital health is a critical driver of quality, safety, and efficiency in healthcare. However, poor quality of clinical information in Digital Health Technologies (DHTs) can compromise the quality and safety of care. This study aims to develop a framework that can be used to assess the quality of clinical information in DHTs.

Methods

A systematic review of information quality frameworks was conducted to identify, define, and integrate information quality dimensions that are relevant to assessing clinical information in DHTs. Qualitative synthesis of 10 existing information quality frameworks resulted in the Clinical Information Quality (CLIQ) framework. The CLIQ framework was revised in an international eDelphi study among 35 clinicians with varying digital health expertise. The framework was then validated based on pilot assessment of clinical information in SystmOne Electronic Health Records (EHRs) by 109 healthcare professionals in the UK.

Results

The CLIQ framework integrates 3 categories of information quality dimensions: informativeness (accuracy, completeness, interpretability, plausibility, relevance, and trustworthiness); availability (accessibility, portability, searchability, security, and timeliness); and usability (conformance, consistency of presentation, and maintainability). The CLIQ framework reached a high expert consensus and demonstrated a high reliability with a modest construct validity.

Conclusion

This thesis highlights the importance of information quality and its relevance to the quality and safety of care. The CLIQ framework offers a pragmatic approach to assessing the quality of clinical information in DHTs and can be used as part of the information quality assurance systems to maintain information quality of DHTs. Informatics training for health care professionals, automated error detection systems and integration of digital health systems can improve the quality of clinical information in DHTs. The thesis further identifies a need to match information quality research with rapid innovations in digital health. Policies, guidelines, and regulatory standards are needed to drive the translation of information quality research into clinical practice.

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Abbreviations

BeHeMoTh:	Behaviour of phenomenon of interest, Health context, Model/Theory
CASP:	Critical Appraisal Skill Programme
CDSSs:	Clinical Decision Support Systems
CIHI:	Canadian Institute for Health Information
CINAHL:	Cumulative Index to Nursing and Allied Health Literature.
CLIQ:	Clinical Information Quality
DHTs:	Digital Health Technologies
ECG:	Electrocardiogram
eDelphi:	Electronic Delphi
EHRs:	Electronic Health Records
EPSs:	Electronic Prescribing Systems
FDA:	United States Food and Drug Administration
HMIC:	Health Management Information Consortium
IEC:	International Electrotechnical Commission
ISO:	International Organisation for Standardization
mHealth apps:	Mobile Health Applications
MHRA:	Medicines and Healthcare products Regulatory Agency
NHS:	National Health Service
PRISMA:	Preferred Reporting Items for Systematic Review and Meta-analysis
PROSPERO:	International Prospective Register of Systematic Reviews
SQuaRE:	Systems and software Quality Requirements and Evaluation
WHO:	World Health Organization

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List of Publications

Thesis-related Publications

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Other Publications

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Chapter 1

Introduction and Literature Review

1.1 Introduction

Digital health is a critical driver of quality, safety, and efficiency in healthcare (Institute of Medicine, 2003). The World Health Organization defines digital health as “the field of knowledge and practice associated with the development and use of digital technologies to improve health” (WHO, 2021, p.39). Digital technologies are electronic devices, systems and resources that generate, process and store information (Gharbi, Daoud and Kammoun, 2021). This thesis describes the development and validation of a novel approach to assessing the quality of clinical information in digital health technologies (DHTs). The first chapter presents background literature on DHTs and information quality, as well as the objectives, rationale, and overview of the thesis.

1.2 Digital Health Technologies

DHTs, such as Clinical Decision Support Systems (CDSSs), Electronic Health Records (EHRs), Electronic Prescribing Systems (EPSs), and Mobile Health applications (mHealth apps), can enhance the quality and safety of care (Gomes, Murray and Raftery, 2022). CDSSs generate valuable patient-specific recommendations to clinicians (Sutton *et al.*, 2020; Teufel and Binder, 2021). EHRs make patient records readily available at the point of care (Institute of Medicine, 2003). EPSs reduce incidents of medication errors (Graf *et al.*, 2023). mHealth apps offer self-management support to people living with chronic conditions (WHO, 2011). Telemedicine platforms provide access to healthcare services, especially in hard-to-reach areas (Loeb *et al.*, 2020).

Telemedicine, the remote delivery of healthcare services using information and communication technology, is the earliest documented application of digital health. In the 1860s, telegraph was used to transmit information about injured soldiers to a medical team during the American Civil War (Jagarapu and Savani, 2021). Willem Einthoven, the inventor of electrocardiogram (ECG), successfully transmitted an ECG from his laboratory to an academic centre in 1906 (Abouzid *et al.*, 2022). With the invention of the internet and mobile technologies towards the end of the last millennium, telemedicine became a popular approach of improving access to effective healthcare services in hard-to-reach areas, especially as a means of exchanging information between clinicians, such as a specialist remotely supporting a generalist (Jagarapu and Savani, 2021). However, the popularity of telemedicine soared during COVID-19 pandemic due to the need for social distancing (Loeb *et al.*, 2020; Richardson *et al.*, 2020). Telemedicine has since evolved to become a means of remote consultation directly between clinicians and patients (Loeb *et al.*, 2020). Nowadays, many internet-based remote consultation tools have been developed allowing for synchronous and asynchronous exchange of information including videos, photographs and texts (Richardson *et al.*, 2020). Telemedicine is a cost-effective, efficient, and convenient approach of improving access to healthcare services (Abouzid *et al.*, 2022). However, telemedicine may exacerbate health inequality by making healthcare services more accessible to people with internet services at the expense of those without (Richardson *et al.*, 2020). In addition, remote consultation may not be appropriate for certain medical conditions especially those requiring physical examination. There is also an increased risk to patient confidentiality if the platform used for remote consultation is not adequately secured (Richardson *et al.*, 2020).

Traditionally, patient health records were exclusively documented on paper until the 1960s and 1970s when new computer technologies led to the development of EHRs (Evans, 2016). This digital form of health records has gradually replaced paper-based health records in many parts

of the world, especially in high-income countries (Tapuria *et al.*, 2021; Akwaowo *et al.*, 2022). For example, health records in the UK are managed electronically with Egton Medical Information System (EMIS) and SystmOne EHRs in primary care. EHRs are used primarily in patient care to manage health information, laboratory results, order entry, decision support, electronic communication, patient support and administrative tasks (Institute of Medicine, 2003). EHRs are also used secondarily for education, regulation, research, public health and policy (Institute of Medicine, 2003). EHRs increase access to patients' records, improve record keeping, lower cost of care and promote evidence-based practice (Keshta and Odeh, 2021). However, concern about privacy and security of health information has been identified as a barrier to implementation of the EHRs (Keshta and Odeh, 2021). Funding could also present a significant barrier because implementation of EHRs is capital intensive.

EPSs are usually integrated with the EHRs. EPSs facilitate digital exchange of medication-related information between a prescriber and a dispenser (Aldughayfiq and Sampalli, 2021). Electronic prescriptions eliminate legibility problem, which is usually associated with paper prescription. It is more convenient and efficient to issue prescriptions electronically, especially repeat prescriptions for chronic conditions (Aldughayfiq and Sampalli, 2021). Integration with EHRs allows clinicians to access information on previous medications, drug sensitivity reactions, side effects, cautions, contraindications, and drug interactions at the point of care (Graf *et al.*, 2023). Adoption of EPSs reduces medication errors, improves efficiency of medication management and reduces costs of healthcare (Zarour, Fetni and Belagrouz, 2021). Despite these benefits, multiple safety incidents involving the EPSs have been reported such as poor user interface causing selection of a wrong dose of medication (Kim, Coiera and Magrabi, 2017).

CDSSs are software that match patient's characteristics to computerised knowledge-base to generate patient-specific clinical recommendations which could be in form of alerts, reminders,

templates, guidelines, workflow etc. (Teufel and Binder, 2021). CDSSs started as computer-based in the 1970s before becoming integrated with EHRs and EPSs (Sutton *et al.*, 2020). Nowadays, certain CDSSs are based on mobile devices, as mHealth apps, and are not linked to EHRs. Thus, CDSSs provide decision support to clinicians, patients and care-givers (Sloane and Silva, 2019). The use of CDSSs improves guidelines adherence, cost efficiency, documentation and coding, patient engagement, and workflow management (Sutton *et al.*, 2020). All CDSSs require a clinical data source. Knowledge-based CDSSs generate recommendations based on expert medical knowledge (Teufel and Binder, 2021). Non-knowledge based CDSSs, on the other hand, generate recommendations based on Artificial Intelligence (AI) or Machine Learning (ML) algorithms which mimic human decision-making process (Sloane and Silva, 2019; Teufel and Binder, 2021). However, there have been reports of healthcare professionals, out of lack of confidence in CDSSs, ignoring or overriding critical alerts (Kim, Coiera and Magrabi, 2017; Iacobucci, 2019). There are a lot of medico-legal risks relating to the use of CDSSs including a potential breach of patients' privacy and automation bias leading to clinicians accepting erroneous AI outputs without interrogation (Oliva *et al.*, 2022).

DHTs capture, store, process and transmit large volumes of health information (Black *et al.*, 2011). A systematic review of literature reported widespread incidents of delayed, missing, partial and wrong information in DHTs resulting in adverse outcomes and deaths across different countries (Kim, Coiera and Magrabi, 2017). Thus, poor quality of clinical information in DHTs can compromise the quality and safety of care (Magrabi *et al.*, 2011; Meeks *et al.*, 2014). Most documented information quality problems involving DHTs are extracted retrospectively from incident reporting systems (e.g., Kim, Coiera and Magrabi, 2017). While it is useful to learn retrospectively from documented adverse events, it is more important to

proactively prevent information quality problems. Hence, there is a need to develop an approach to assessing the quality of clinical information in DHTs.

1.3 Information Quality

Information quality is a multidimensional concept which denotes the extent to which information is fit for purpose (Lee *et al.*, 2002; CIHI, 2017). Each dimension of information quality describes a specific aspect of information (Almutiry, 2017). Information quality dimensions that are relevant to a specific system (e.g., EHRs) are integrated into an information quality framework (Lee *et al.*, 2002). For example, Almutiry (2017) developed an information quality framework for EHRs in Saudi Arabia comprising of eleven information quality dimensions which are classified into three categories as shown in Figure 1.

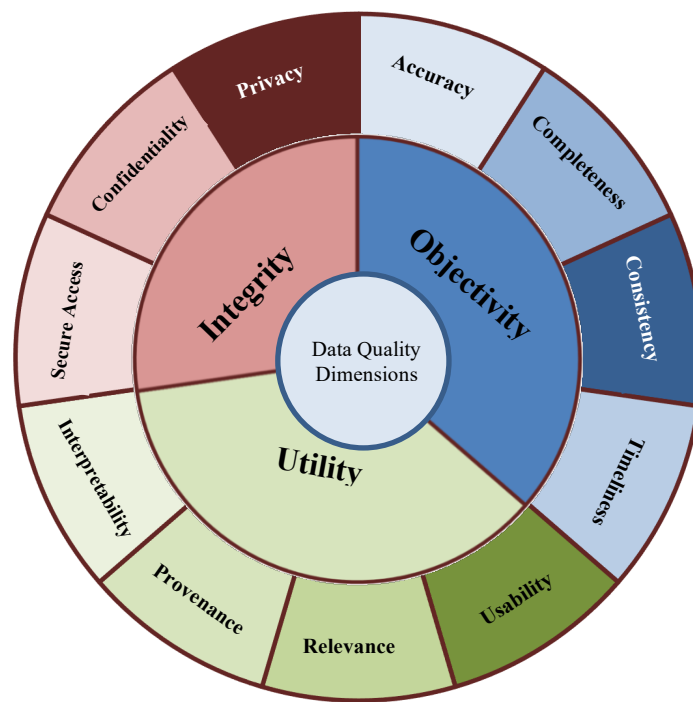


Figure 1: Information Quality Framework for Electronic Health Records¹

¹ Almutiry, O. S. (2017). *Data Quality Assessment Instrument For Electronic Health Record Systems in Saudi Arabia*. University of Southampton. Image reproduced with permission of the rights holder, University of Southampton.

An information quality framework specifies dimensions to be considered while assessing information and provides guidance on how to conduct the assessment (Eppler and Wittig, 2000). Thus, an information quality framework is a tool for information quality assessment. Each information quality dimension is either assessed quantitatively or qualitatively. Quantitative assessment of information quality involves the use of mathematical formulae and survey questionnaires (Almutiry, 2017). Qualitative assessment is based on methods such as interviews and focus group discussions (Pipino, Lee and Wang, 2002).

The relevance of information quality dimensions is influenced by the context in which the information is used (Almutiry, 2017; CIHI, 2017). A dimension which is relevant to information in one context may be irrelevant in another (Eppler and Wittig, 2000). For example, legibility is an important information quality dimension for hand-written records, but it is less relevant for electronic notes (Stetson *et al.*, 2012).

The contextual factors in this current study include:

1. **Type of information:** Clinical information in a digital form, that is, information in DHTs.
2. **Users of information:** Clinicians, that is, healthcare professionals using clinical information from DHTs as part of clinical decision making.
3. **Purpose of information:** Clinical purposes which refers to the use of information for patient care including diagnostic, therapeutic and prognostic purposes.

1.4 Aims and Objectives

The overall aim of this research is to develop a framework to assess the quality of clinical information in DHTs. The objectives include:

1. To identify, define, and integrate information quality dimensions that are relevant to assessing the quality of clinical information in DHTs.
2. To develop a novel approach to assessing the quality of clinical information in DHTs.
3. To build international consensus among clinicians on the novel approach to assessing quality of clinical information in DHTs.
4. To evaluate the novel approach to assessing quality of clinical information in DHTs.

1.5 Overview of Thesis Methodologies and Chapters

The study was conducted in four stages corresponding to the four objectives of the study. A systematic review and qualitative synthesis of existing information quality frameworks for DHTs was conducted to develop the initial Clinical Information Quality (CLIQ) framework for DHTs. An assessment questionnaire was developed based on the CLIQ framework and further evidence from literature. The CLIQ framework, with its accompanying questionnaire, was then revised in an international eDelphi study among clinicians. Finally, the framework was validated in a pilot CLIQ assessment of SystmOne EHRs in the UK.

The systematic review of information quality frameworks is presented in Chapter 2. The development of the CLIQ assessment questionnaire with its revision in the international eDelphi study is presented in Chapter 3. The pilot CLIQ assessment is presented in Chapter 4. The implications of the study findings are discussed in Chapter 5. Figure 2 shows the stages and chapters of the thesis.

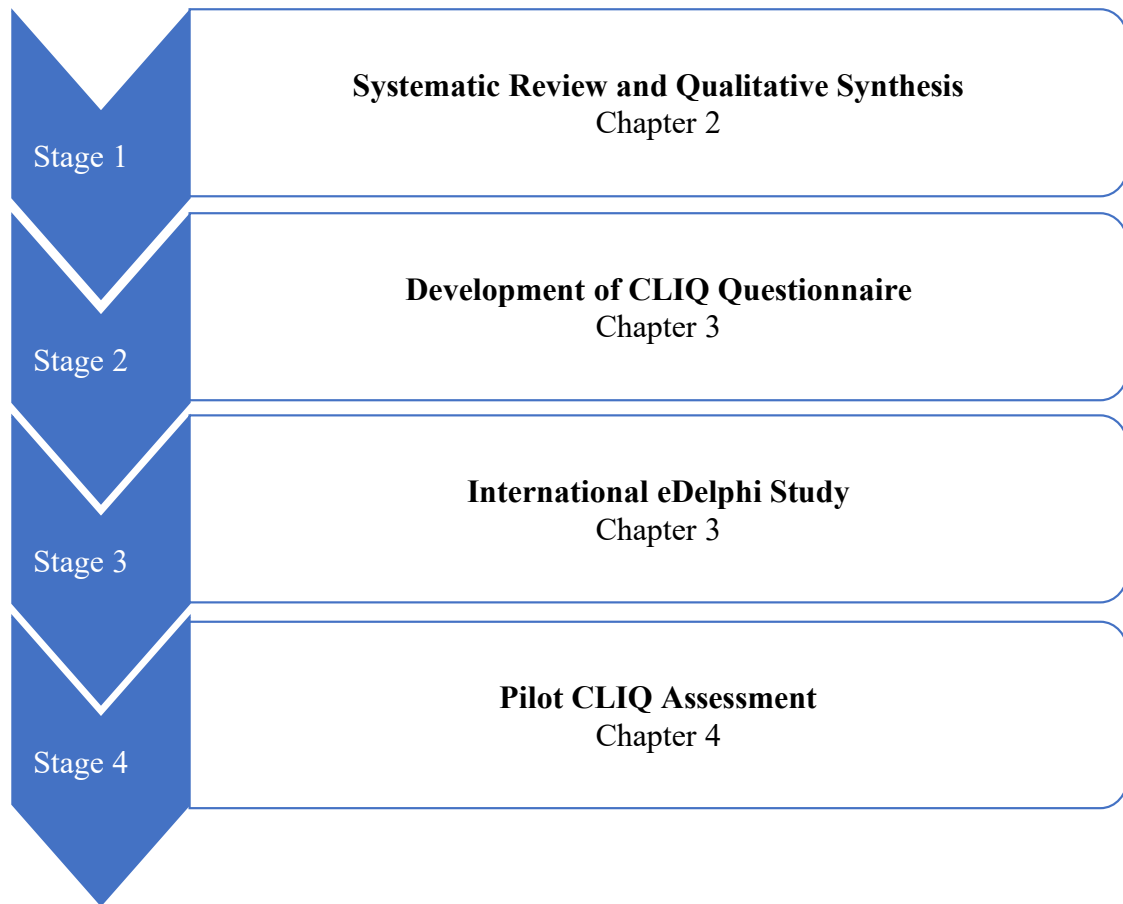


Figure 2: Study Stages

1.6 Study Rationale

There was no consensus on information quality dimensions that are relevant to assessing clinical information in DHTs. There was also a lack of consistency in the terminology and definition of information quality dimensions in existing frameworks, thus limiting a common understanding of information quality requirements for DHTs (Kahn *et al.*, 2016). This thesis employed an evidence-based approach, including systematic review of literature, eDelphi study and empirical CLIQ assessment, to integrate dimensions that are relevant to clinical information in DHTs. The thesis built consensus on the definition and measurement of the dimensions, thus promoting a common understanding among information stakeholders and ensuring an information quality framework that is contextualised to the needs of information users (Eppler and Wittig, 2000; Lee *et al.*, 2002).

The application of previous frameworks were limited to individual DHTs (e.g., CDSSs in McCormack and Ash, 2012) and geographical locations (e.g., Saudi Arabia in Almutiry, 2017). A systematic review of safety incidents relating to DHTs revealed that information quality problems are similar in different DHTs across different countries (Kim, Coiera and Magrabi, 2017). Therefore, the thesis was therefore not limited by country or type of DHTs. Although individual DHTs have different uses, there is an increasing tendency towards integration and same clinical information is often used across multiple DHTs. Hence this thesis focusses on information quality of DHTs generally rather than on individual DHTs resulting in a generic framework with wide applicability across different DHTs and geographical locations. In addition, the focus on clinical purposes aligns with the definition of information quality as ‘fit-for purpose’(Lee *et al.*, 2002).

Although there have been previous attempts to define information quality dimensions relating to DHTs, most studies focussed on administrative and research use of information from DHTs. However, this thesis focusses on clinical use of DHTs and takes cognizance of quality and safety of care. Assessing the quality of clinical information in DHTs could identify issues that may compromise the quality and safety of care (Kim, Coiera and Magrabi, 2017). This is particularly important with the increasing automation and adoption of AI in healthcare as human checks are reduced when clinical information feeds into AI tools and algorithms (Fadahunsi, 2022). For example, a dataset shift was reported in AI which caused an error in the diagnosis of sepsis throughout a health facility (Finlayson *et al.*, 2021).

Finally, safety concerns, relating to quality of information, may discourage healthcare professionals from using potentially useful DHTs (Kim, Coiera and Magrabi, 2017; Iacobucci, 2019). Thus, a framework that can be used to assess clinical information in DHTs can boost the confidence of clinicians in DHTs.

1.7 My Roles – from an Outsider to an Insider in Digital Health Research

I started the PhD programme as a public health physician with research interest in digital health. I had been working on health policies and programmes at the Nigerian Federal Ministry of Health Headquarters without prior exposure to DHTs in clinical practice. Thus, I started as an outsider trying to understand and proffer solutions to a problem I had not personally experienced. At this stage of the programme, I relied mainly on evidence from literature for insights into the research problems and methods. I developed the proposal for my PhD and the initial CLIQ framework based on evidence from literature.

My role was transformed dramatically midway into the PhD programme. Sadly, I had issues with the funding of my PhD and had to interrupt my studies for two and a half years. I switched to a part-time PhD programme and took on the role of a full-time clinician working across different clinical settings including acute care hospitals, urgent treatment centres and general practices. This turned out to be a blessing in disguise as my clinical exposure gave me a first-hand experience of using DHTs and reorientated my approach to digital health research. I became acquainted with information quality problems associated with clinical information in DHTs. I was transformed from being an outsider to an insider in digital health research. I realised that the problem was not only about non-availability of assessment frameworks but also about limited involvement of clinicians in their development.

When I thought I had seen it all, having completed the period of interruption occasioned by funding issues, COVID-19 struck. As a frontline clinician during the unprecedented COVID-19 pandemic, I had to juggle a challenging clinical work with family life and PhD. Although I had initially considered a modified Delphi approach, which combines a face-to-face meeting with eDelphi, a complete virtual approach became the most pragmatic option in the context of the pandemic. In addition, the rapid evolution of digital health also made changes in research focus and terminologies necessary. For instance, the focus of my PhD was changed from the

eHealth systems to the digital health systems to accommodate newer technologies such as AI and ML which became popular during my PhD. Thus, not only was my role transformed in this research; so also did my research focus and approach.

Despite all the challenges, the research works were accomplished with the help of a supportive team of dedicated supervisors and collaborators. Working with different teams for each study provided me an opportunity to develop my networking and leadership skills. I learnt to delegate duties and set realistic target for myself and other members of the research team. Further details about how each study was undertaken are reported in subsequent chapters starting with the systematic review of literature in Chapter 2.

Chapter 2

Systematic Review of Information Quality Frameworks

2.1 Chapter Introduction

This chapter describes the development of the initial CLIQ framework through a qualitative systematic review of literature. A multidisciplinary team with expertise in digital health, evidence synthesis and information quality conducted the systematic review to identify, define, and integrate dimensions relevant to assessing clinical information in DHTs. My roles in this study included conceptualisation of the study, literature search, data management, data analysis and report writing. The roles of all reviewers have been previously specified in published reports (Fadahunsi *et al.*, 2018, 2019, 2021). This chapter is presented based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Moher *et al.*, 2009).

2.2 Methods

2.2.1 Review Questions

This systematic review was conducted to answer the following questions:

1. What frameworks currently exist for evaluating information quality in DHTs?
2. How are dimensions within these existing information quality frameworks defined?
3. Which dimensions indicate how well information in DHTs is fit for clinical purposes?
4. How are these information quality dimensions related to one another?

2.2.2 Eligibility Criteria

The eligibility of the included studies was determined based on the following criteria:

1. The study presents an information quality framework.
2. The framework is multidimensional.
3. The information in the targeted DHTs is used for a clinical purpose, e.g., diagnostic, therapeutic and prognostic purposes.
4. The study is written in English.

The following exclusion criteria were used:

1. The framework is based on an online search for health information, eLearning, or self-management applications.
2. Information in the DHTs is solely for non-clinical or administrative purposes (e.g., incidents reporting system).
3. The study is written in a language other than English.

The review was not restricted by the date of publication or type of study. Both grey literature and published papers were included.

2.2.3 Literature Search

The search terms were based on three keywords ‘information quality’, ‘digital health’, and ‘framework’, which correspond respectively to ‘**B**ehaviour of phenomenon of interest’, ‘**H**ealth context’ and ‘**M**odel/**T**heory’ in the BeHeMoTh guidelines (Carroll *et al.*, 2013; Booth and Carroll, 2015). The BeHeMoTh guidelines is a specific procedure for systematic reviews of models and theories (Carroll *et al.*, 2013; Booth and Carroll, 2015). Terms relating to each keyword were combined with OR, and the resulting search strings were combined with AND. The search strategy, presented in Appendix 1, was developed in consultation with a librarian.

The literature search was conducted in bibliographic databases for healthcare, including Cumulative Index to Nursing and Allied Health Literature (CINAHL), EMBASE, Global Health, Maternity and Infant Care, Medline, PubMed, and PsycINFO. Scopus was also searched for information quality literature in Engineering, Computer Science, and other non-healthcare disciplines. Health Management Information Consortium (HMIC) and ProQuest Dissertations and Theses Global were searched for relevant grey literature. The database search was complemented with manual reference search and citation tracking using Scopus and Google Scholar.

2.2.4 Study Selection

The search results were imported into Endnote reference management software, version X9 (Clarivate, Philadelphia PA, USA). Duplicates were removed with Endnote. Further duplicates were removed manually. The deduplicated results were then imported into Covidence review management software (Veritas Health Innovation Ltd, Melbourne, Australia), allowing independent reviewers to work simultaneously on study selection.

The study selection was carried out in two stages: 1) title and abstract screening and 2) full-text review. Two independent reviewers screened the titles and abstracts of all studies against the eligibility criteria. The full-text review of the studies selected at the screening stage was then conducted by two independent reviewers to identify eligible studies for inclusion in the qualitative synthesis. Disagreement on the eligibility of studies at each stage was resolved by discussion between the reviewers and adjudication by a third independent reviewer when necessary.

2.2.5 Data Extraction

Two independent reviewers extracted data from the included studies using a pre-piloted data extraction form on Microsoft Excel version 16.0 (Microsoft Corporation, Redmond,

Washington DC, USA). In addition, other members of the team reviewed the extracted data for accuracy and completeness. Extracted data relating to study details included: author(s), year of publication, country, affiliation, study aim, study design and publication status. Extracted data relating to information quality framework included: method of framework development; method of framework validation (when available); type of DHTs; information quality dimensions, verbatim definition of information quality dimensions; information quality categories (when available) and metrics of measurement (when available).

2.2.6 Quality Assessment

The quality of the included studies was assessed using the Critical Appraisal Skills Programme (CASP) checklist for qualitative studies (CASP, 2018). Applying this tool was challenging because the included papers used various methods, including ethnography, literature review and mixed methods, with some papers not explicitly stating their methods. Thus, some questions in the checklist did not apply to some of the included studies. The quality assessment outcome was not used to exclude studies. It, however, provided an insight into the quality of the framework development methods, thus the strength of evidence.

2.2.7 Data Synthesis

A thematic synthesis approach, comprising three key stages of coding, descriptive synthesis, and analytic synthesis, was adopted to analyse the data (Thomas and Harden, 2008). The extracted definitions were coded by two independent reviewers who identified the unique ideas in each definition using the text-highlight function of Microsoft Word, version 16.0 (Microsoft Corporation, Redmond, Washington DC, USA). Similar codes were grouped. A descriptive theme was then created to capture the meaning of each group of similar codes.

The analytical themes were conceptualised by considering how descriptive themes might be related. The lead author categorised the dimensions and invited all the reviewers to do the same

while reflecting on the fitness of information in DHTs for clinical purposes and its impact on patient safety. The conceptualisation of the analytical themes from the descriptive themes was challenging due to its subjective nature, as the perspectives of the reviewers could influence it. To reduce bias, the lead author did not reveal his proposed categories to other reviewers. Each reviewer was asked to send their proposed categories along with rationale to the lead author individually without copying other team members. Two reviewers jointly considered all the proposed categories alongside the rationale and carefully assigned categories to dimensions based on the most popular suggestions. Some dimensions that fit into multiple categories were assigned to a category considered best-fit after careful consideration as deemed the reviewers' submissions. The new framework was then shared with all the team members to improve concordance and for further inputs as necessary.

Thus, the initial CLIQ framework was developed by synthesising existing information quality frameworks for DHTs. The information quality dimensions in the CLIQ framework were the descriptive themes from the extracted data. The information quality categories were generated from higher-order analytical synthesis, which went beyond the data.

2.3 Results

2.3.1 Selection of Studies

The literature search yielded 19,377 records, which were reduced to 11,615 after duplicates removal and 338 after titles and abstracts screening. Ten papers were included in the study following the full-text review. Although the information quality frameworks from three of the included papers (Weiskopf and Weng, 2013; Dungey *et al.*, 2014; Kahn *et al.*, 2016) concern the secondary use of health information for research, they were included because of their relevance to the clinical context of DHTs. However, sensitivity analysis (i.e., thematic synthesis with and without these three papers) revealed that their inclusion did not affect the

components of the resulting framework but enhanced a better understanding of the definition of the dimensions. The PRISMA flow diagram illustrating the study selection process is presented in Figure 3.

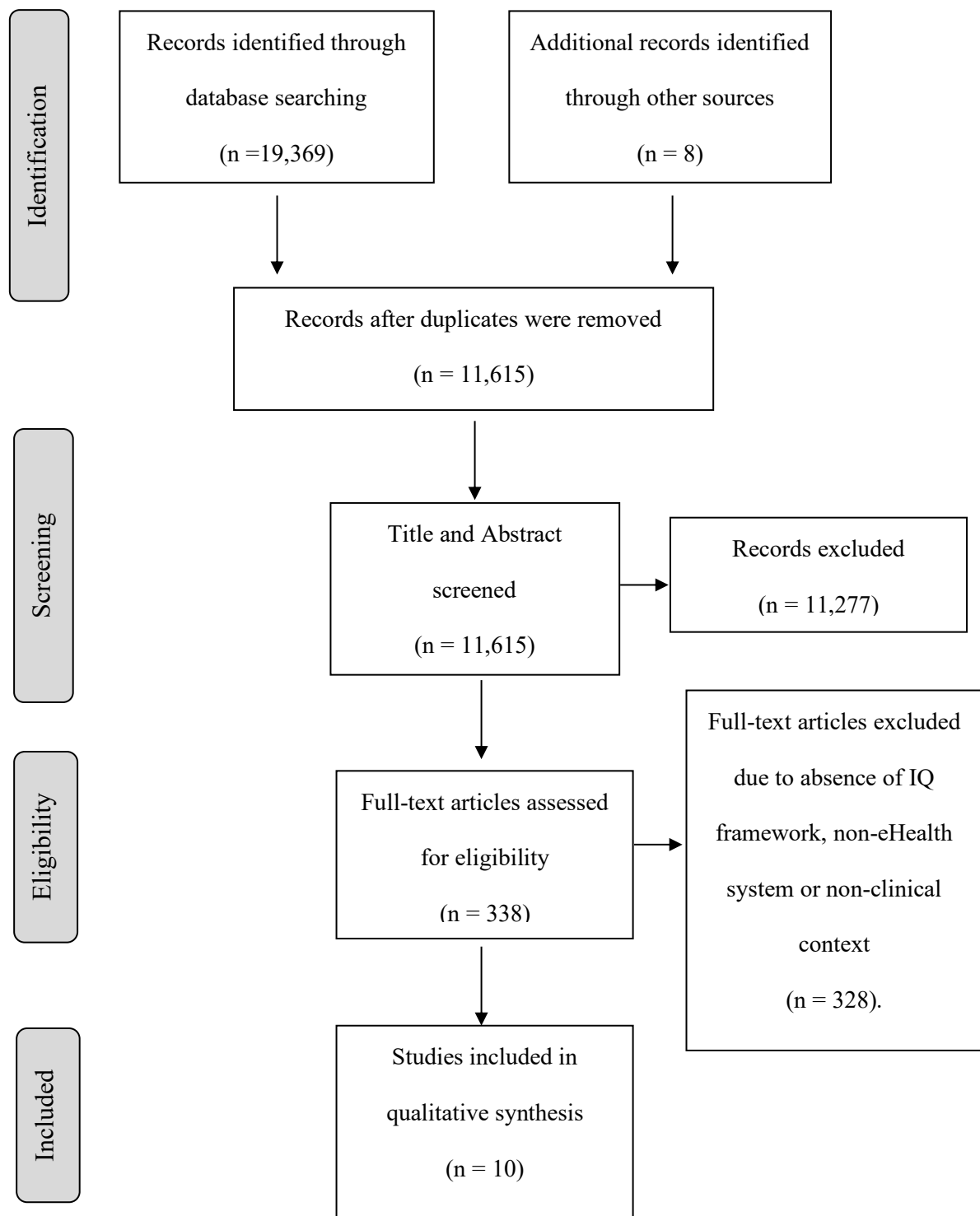


Figure 3: PRISMA Flow Diagram

2.3.2 Included Papers

The papers included in the qualitative synthesis were published from 2007 to 2017. The summary of the included ten papers is presented in Appendix 2. Five of the included papers (McCormack and Ash, 2012; Stetson *et al.*, 2012; Weiskopf and Weng, 2013; Davoudi *et al.*, 2015; Kahn *et al.*, 2016) were published in the United States of America and three (Almutiry *et al.*, 2013; Dungey *et al.*, 2014; Almutiry, 2017) in the United Kingdom. Bowen (2003) and Bolt, Kano and Kodate (2007) were published in Canada and Japan, respectively. Almutiry (2017), although published in the United Kingdom, was conducted in Saudi Arabia. Four of the studies (Bolt, Kano and Kodate, 2007; Stetson *et al.*, 2012; Weiskopf and Weng, 2013; Kahn *et al.*, 2016) were journal publications, three (McCormack and Ash, 2012; Almutiry *et al.*, 2013; Dungey *et al.*, 2014) were conference proceedings, and two (Bowen, 2012; Davoudi *et al.*, 2015) were institutional reports. Almutiry (2017) was a PhD thesis.

Three studies (Bolt, Kano and Kodate, 2007; Stetson *et al.*, 2012; Dungey *et al.*, 2014) modified existing frameworks. Although Davoudi *et al.* (2015) reported having updated a previous framework, no information was provided on how this was achieved. Two studies (Bolt, Kano and Kodate, 2007; McCormack and Ash, 2012) used qualitative methods (interviews and ethnographic study respectively). Two studies (Almutiry *et al.*, 2013; Weiskopf and Weng, 2013) were literature reviews. Three studies (Dungey *et al.*, 2014; Kahn *et al.*, 2016; Almutiry, 2017) used a combination of methods from modification of existing framework, literature review, and consultation, interviews and focus group discussions with users and stakeholders. There was no information on how the framework in Bowen (2003) was developed. Five frameworks (Stetson *et al.*, 2012; Weiskopf and Weng, 2013; Dungey *et al.*, 2014; Kahn *et al.*, 2016; Almutiry, 2017) addressed information quality in EHRs. Dungey *et al.* (2014) focussed on primary care databases, Almutiry *et al.* (2013) on cloud-based health information systems, Bowen (2003) on electronic medical records, McCormack and Ash (2012) on CDSSs and Bolt,

Kano and Kodate (2007) on mobile and web-based applications for telemedicine. The underrepresentation of newer DHTs, such as mHealth, suggests a lag in information quality research in contrast to the rapid evolution of DHTs.

2.3.3 Quality of Included Studies

Although the studies comprehensively describe information quality frameworks, most did not report a robust process of developing the frameworks. The quality of two institutional reports (Bowen, 2012; Davoudi *et al.*, 2015) could not be assessed with the CASP checklist. Recruitment strategy was reported in only one of the studies (Almutiry, 2017). Similarly, the search strategy or study selection methods were not reported in the literature reviews (Almutiry *et al.*, 2013; Weiskopf and Weng, 2013; Kahn *et al.*, 2016; Almutiry, 2017). Only three studies (McCormack and Ash, 2012; Stetson *et al.*, 2012; Almutiry, 2017) reported on data analysis methods and ethical issues. These findings strengthen the justification for the current study, which employed a robust and transparent approach to developing an information quality framework for DHTs. The quality assessment result is summarised in Appendix 3.

2.3.4 Information Quality Requirements for Digital Health Technologies

A total of 38 information quality dimensions and 70 definitions were extracted from the ten included papers. In addition, 160 codes were identified from the extracted information quality dimensions definitions.

The extracted verbatim definitions from the papers are presented in Appendix 4. Aggregation of similar codes resulted in thirteen descriptive themes that reflected all the relevant dimensions in the existing frameworks and eliminated redundant ones. The descriptive themes, which are the information quality dimensions in the resulting CLIQ framework, include accessibility, accuracy, completeness, conformance, consistency, interpretability, relevance, security,

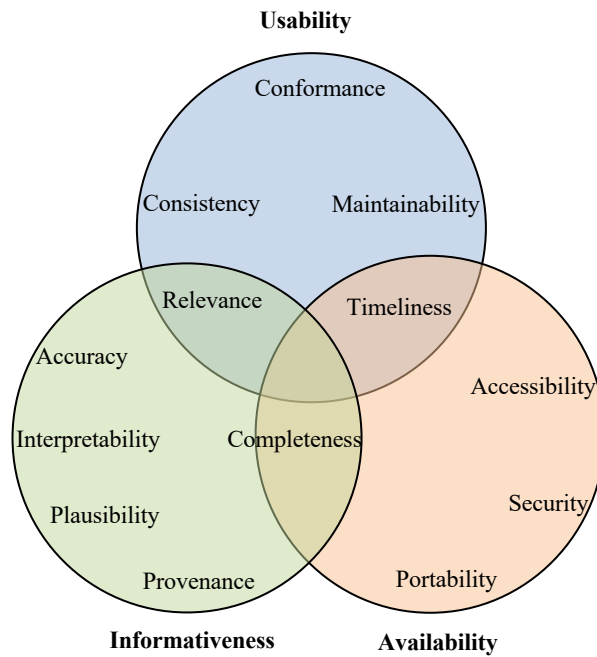
portability, timeliness, plausibility, provenance, and maintainability. Each information quality dimension was then defined based on the codes from which they were generated.

The subsequent analytical synthesis classified the information quality dimensions into higher-order categories of availability, informativeness and usability. The dimensions and categories of the resulting CLIQ framework for DHTs are presented in Figure 4 (Fadahunsi *et al.*, 2021). The Venn diagram shows the overlap in the categories based on the reviewers' suggestions. The accompanying table shows the final single category considered as best fit and assigned to each dimension. For example, completeness was assigned to the informativeness category, although it fit both the availability and informativeness categories.

2.3.5 Metrics of Measurement

Only three (Bowen, 2012; Dungey *et al.*, 2014; Almutiry, 2017) of the included frameworks guided the measurement of the information quality dimensions. The remaining frameworks conceptualised the information quality of DHTs without providing metrics of measurement.

These papers reported quantitative measures in the form of Likert scale questionnaires and mathematical measures (e.g., ratios, percentages, and fractions). Almutiry (2017) measured usability, relevance, provenance, secure access, confidentiality, and privacy with Likert scale questionnaires on how well information is considered by the users to satisfy each information quality requirement. Mathematical measures were reported for accuracy, completeness, comprehensibility, concordance, consistency, informative sufficiency, integrity, interpretability, relevance, reliability, timeliness, and validity (Bowen, 2012; Dungey *et al.*, 2014; Almutiry, 2017).



Informativeness directly concerns the usefulness of digital information for clinical purposes	Accuracy	The extent to which information is correct.
	Completeness	The extent to which no required information is missing.
	Interpretability	The extent to which information can be understood.
	Plausibility	The extent to which information makes sense based on common knowledge.
	Provenance	The extent to which the source of information is trustworthy.
	Relevance	The extent to which information is useful for the intended task.
Availability concerns the functionality of the system holding clinical information	Accessibility	The extent to which existing information is easily obtainable.
	Portability	The extent to which information is accessible in different systems.
	Security	The extent to which information is protected from unauthorized access and corruption.
	Timeliness	The extent to which current information is available on time.
Usability concerns the ease of use of clinical information	Conformance	The extent to which information is presented in the desired format.
	Consistency	The extent to which information is presented in the same format.
	Maintainability	The extent to which information can be maintained.

Figure 4: Preliminary CLIQ Framework for Digital Health Technologies²

² Figure 4 was originally published in an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in the Journal of Medical Internet Research (<https://www.jmir.org>), 17.05.2021, is properly cited. Kayode Philip Fadahunsi, Siobhan O'Connor, James Tosin Akinlua, Petra A Wark, Joseph Gallagher, Christopher Carroll, Josip Car, Azeem Majeed, John O'Donoghue.

Mathematical measures were based on whether a desired or an undesired attribute was present or absent. For example, Almutiry (2017) considered misspellings, out-of-range values, and erroneous values as undesired attributes relating to accuracy. The quality score for accuracy was then calculated by finding the proportion of the total data units without each undesired attribute. Similarly, Dungey *et al.* (2014) measured accuracy based on the proportion of implausible values to the total dataset. However, Bowen, (2012) used the proportion of the desired attribute to the total data units. Correctness was calculated as the positive predictive value, which is the proportion of true positives to all positives.

2.4 Discussion

2.4.1 Principal Findings

The qualitative synthesis of ten existing frameworks led to the development of the preliminary CLIQ framework which comprises thirteen unique information quality dimensions related to assessing DHTs. The dimensions are classified into three categories: informativeness, availability and usability.

The informativeness category, encompassing accuracy, completeness, interpretability, plausibility, provenance, and relevance, concerns the usefulness of the information in the DHTs for clinical purposes. Problems with information quality within this category can compromise patient safety (Magrabi *et al.*, 2016; Kim, Coiera and Magrabi, 2017). This study demonstrates that information quality is not limited to accuracy alone (Wang and Strong, 1996). Instead, it is a multidimensional concept with accuracy being one of the dimensions (Pipino, Lee and Wang, 2002). Although provenance and plausibility can be used as proxies for accuracy, especially when an objective assessment of accuracy is impracticable, both are unique dimensions. For example, it is reassuring when information is provided by a reputable institution, such as the National Health Service (NHS). Mild fever in a child with upper

respiratory tract infection is plausible. It is also essential for clinical information in DHTs to be interpretable and relevant to patient care. For example, including additional relevant information with laboratory investigation results, such as the reference range, enhances the interpretation of the results and subsequent use in clinical decisions.

The availability category of dimensions relates to the functionality of the DHTs holding the information. This category encompasses accessibility, portability, security, and timeliness dimensions which are critical to the quality of care. Inaccessible clinical information cannot be used in patient care, so it offers no real value. Portability of clinical information is essential for continuity of care as decisions regarding current management are often influenced by past medical history. Timely availability of up-to-date clinical information could be lifesaving, especially in emergencies. Making clinical information available only to authorised users is necessary to maintain confidentiality and protect patients' information from damage and loss.

Consistency, conformance, and maintainability are the dimensions in the usability category. These concern the ease of use of information. While consistency refers to the presentation of information in the same format, conformance indicates adherence to local, national, or international standards. For example, blood glucose should be presented consistently using either g/dL or mmol/L, as the cut-off values for both units are entirely different. It is also essential to avoid confusion by conforming to the recommended units in the guidelines. Maintainability, the last dimension in this category, ensures that information continues to meet other information quality requirements. Maintainability entails various activities, including review, audit, update, storage etc. For example, automatic updating of information in the DHTs ensures that information remains timely.

2.4.2 Comparison with Previous Research

The CLIQ framework shares several features with validated information quality frameworks within and beyond healthcare. There is an overlap between the CLIQ framework and one of the earliest information quality frameworks used as a reference point in information quality research (Wang and Strong, 1996). Wang and Strong's framework was developed for business databases (Wang and Strong, 1996). Seven dimensions (accuracy, accessibility, completeness, interpretability, relevance, security, and timeliness) are common to both frameworks. However, two novel dimensions (portability and maintainability) not in Wang and Strong's are included in the CLIQ framework. These dimensions reflect information technology advances with a resulting need to maintain and share information.

Similarly, the CLIQ framework overlaps with the product quality properties and sub-characteristics of the International Organisation for Standardization and International Electrotechnical Commission guidelines (ISO/IEC 25010) comprising eight characteristics – compatibility, functional suitability, maintainability, operability, performance efficiency, reliability, security, and transferability (ISO/IEC, 2011). Maintainability and security are included as CLIQ Framework dimensions and ISO/IEC 25010 product characteristics. Other CLIQ framework dimensions are regarded as sub-characteristics in ISO/IEC 25010. This is not unexpected as DHTs are software products, and information quality is an aspect of product quality. However, it is worthy of note that ISO/IEC 25010 is based on a computer engineering perspective of Systems and software Quality Requirements and Evaluation (SQuaRE), while the CLIQ framework is based on a healthcare perspective with a special interest in quality and safety of care.

2.4.3 Strengths and Weaknesses

The main strength of this study is the adoption of a rigorous systematic review approach to developing a preliminary framework for DHTs. This approach provides the depth and breadth needed for a comprehensive and methodically sound framework. Synthesising the definitions of information quality dimensions is more meaningful compared to the traditional practice of simply cross-matching dimensions across multiple frameworks. This is important as a named dimension usually has heterogeneous definitions across different frameworks. In addition, this study developed a framework that is relevant to assessing clinical information in DHTs. This is unlike previous frameworks focussing on individual DHTs such as CDSS (McCormack and Ash, 2012) and EMR (Bowen, 2012). The focus on the clinical context in this study rather than the ever-changing individual DHTs resulted in a framework that applies to different DHTs, including novel DHTs. The choice of clinical purposes of DHTs is also supported by the ‘fit-for-purpose’ definition of information quality (Lee *et al.*, 2002). Finally, interoperability has improved significantly, and different DHTs can communicate and use the same clinical information (e.g., EHR information for CDSS). This further justifies a context-specific framework rather than multiple frameworks for individual DHTs.

The limitations of this study include a lack of information about the relative relevance and metrics of measurement of the dimensions in the preliminary CLIQ framework. Although the systematic review approach provided a broad coverage of all existing dimensions, it does not incorporate inputs from clinical information users as recommended in the information quality literature (Eppler and Wittig, 2000; Lee *et al.*, 2002). Therefore, an international eDelphi study, presented in the next chapter, was conducted to address these limitations.

2.5 Chapter Conclusion

The systematic review identified, integrated, and defined 13 information quality dimensions that are relevant to assessing clinical information in DHTs. The information quality dimensions were grouped into three categories (i.e., informativeness, availability and usability) following a rigorous thematic synthesis procedure. The next chapter presents an international eDelphi study conducted to obtain inputs from clinicians regarding the relative relevance and metrics of measurement of information quality dimensions in the CLIQ framework.

Chapter 3

Clinical Information Quality in Digital Health Technologies

3.1 Chapter Introduction

Drawing on the findings of the systematic review in the previous chapter, the eDelphi study was conducted to build international consensus among clinicians on a pragmatic approach to assessing the quality of clinical information in DHTs. This study was designed to address the gaps identified by the systematic review, including a lack of a pragmatic tool for clinical information quality assessment and the limited involvement of clinicians in the development of existing frameworks (Fadahunsi *et al.*, 2021). The study sought to contextualise the CLIQ framework to the needs of clinicians by exploring their perspectives on relevance, definition, and assessment of information quality dimensions in the framework. This chapter discusses the study design, participant recruitment, survey content and administration, data analysis and study result as reported in previous publications (Fadahunsi *et al.*, 2022a; Fadahunsi *et al.*, 2022b).

3.2 Methods

3.2.1 Study Design

The eDelphi method, used in this study, is a systematic method of engaging experts and stakeholders to obtain consensus on a topic of interest (Diamond *et al.*, 2014; Trevelyan and Robinson, 2015). The eDelphi study offered a suitable approach to receiving direct input of the clinicians on the CLIQ framework. The online nature of the study allowed participation of clinicians from different countries around the world. Equal participation was enhanced by the asynchronous administration, which allowed each participant to make their submissions at a

time that was convenient for them. This design gave all participants an equal voice, unlike physical meetings that could be dominated by a few outspoken individuals (Hasson and Keeney, 2011). Participants could also provide feedback and reconsider their stance based on the results of the preceding round (Niederberger and Spranger, 2020). Finally, the method allowed for collecting both quantitative and qualitative data, which were useful for statistical ranking of the dimensions' relevance and exploring the participants' thoughts on the dimensions' definition.

3.2.2 Ethics Approval

Ethics approval (Appendix 5) was obtained from the Imperial College Research Ethics Committee (20IC6396).

3.2.3 Steering Committee

A steering committee comprising of seven clinicians and digital health researchers coordinated the study. My role, as a steering committee member, spanned study design, participant recruitment, data collection, data analysis and report writing. The steering committee developed the initial CLIQ framework (Fadahunsi *et al.*, 2021) and the accompanying questionnaire based on evidence from the literature. The committee was also responsible for recruiting participants and making decisions regarding retention, removal and redefinition of information quality dimensions based on prespecified decision rules.

3.2.4 Decision and Stoppage Rules

The decision rules on what constituted a consensus were prespecified to prevent bias while analysing the data (Niederberger and Spranger, 2020). An information quality dimension was to be considered relevant and retained when at least 70% of the participants chose the options 'strongly relevant' or 'somewhat relevant' in any survey round. Conversely, an information quality dimension was to be considered irrelevant and removed when at least 70% of the

participants chose the options ‘strongly irrelevant’ or ‘somewhat irrelevant’ in any survey round. Using 70% as the threshold for consensus was a pragmatic choice based on the literature, which indicated that most Delphi studies use 60% agreement or higher for the consensus cut-off point (Hasson and Keeney, 2011). Regarding the stoppage rule, the study was to be concluded when consensus was reached on at least 80% of the dimensions or at the end of the third round, irrespective of the level of agreement (Niederberger and Spranger, 2020).

3.2.5 Participant Recruitment

A heterogenous group of clinicians, comprising doctors, nurses, pharmacists, and other health care professionals, was recruited to participate in the study based on the following eligibility criteria:

1. Prior or current experience of using DHTs in patient care
2. Information governance role or personal interest in information governance
3. Willingness to participate in multiple eDelphi rounds (up to 3 rounds).

Although the literature recommends about 8-12 participants for a Delphi study, the study aimed for a higher sample size of 50 to accommodate the heterogenous participants from different professions and countries. The heterogeneity of the participants enhanced the study’s external validity and provided a wide range of perspectives. Participants were recruited by purposive and snowball sampling techniques. The study targeted clinicians with information governance roles (e.g., chief clinical information officer, chief nursing information officer, and Caldicott guardian) because of their information governance expertise and DHTs’ user experience. Given that these roles do not exist in many low- and middle-income countries, clinicians without formal information governance roles but with a personal interest in information governance were also recruited. These included clinicians working in closely related fields (e.g., Medication Safety) and those who have published papers relating to information governance.

Eligible clinicians were nominated by the steering committee members from within and beyond their professional networks. The clinicians were invited with an introductory email containing a link to the first round of the survey. The invited clinicians were encouraged to share the invitation with other eligible clinicians. Two reminders, at least two weeks apart, were sent to the clinicians to encourage participation.

3.2.6 Survey Content and Administration

The semi-structured survey for the first round of the eDelphi study (Appendix 6) was generated from the preliminary CLIQ framework developed in chapter 2 and the accompanying assessment questionnaire developed by the steering committee. The introductory section of the survey provided brief information about the study, a link to the participant information sheet, and the electronic consent form. Participants who gave informed consent were then asked to provide demographic data and continue with the rest of the survey.

The main section of the survey consisted of questions on the relevance, assessment, and definition of the information quality dimensions in the CLIQ framework. The first part of this section comprised 5-point Likert scale questions on the relevance of the information quality dimensions in the CLIQ framework to quality and safety of care. The range of options in the Likert scale (strongly relevant, somewhat relevant, neither relevant nor irrelevant, somewhat irrelevant, and strongly irrelevant) did not require a heavy cognitive load because these represent categories people create naturally. The second part of the main section contained multiple-choice and free-text questions on definition, assessment, and categories of dimensions in the CLIQ framework.

Finally, the email addresses of consented participants were collected for feedback purposes and as a contact method for the next survey round. The survey was set up using Qualtrics (Qualtrics,

Provo, Utah, USA) and piloted by the steering committee members before its administration. The study was administered in English between June 2021 and March 2022.

3.2.7 Data Analysis

The responses to the Likert-scale questions on the relevance of the dimensions and the multiple-choice questions on the definition, assessment, and categories of dimensions were summarised using descriptive statistics. The free-text suggestions were analysed using a reflexive thematic analysis approach, which allowed the steering committee members to go beyond the text to decode the meaning intended by the participants (Braun and Clarke, 2021). The thematic analysis process was adapted to include the following key stages:

1. Studying the free-text suggestions to become familiar with the contributions of the participants
2. Data coding to highlight the key issues identified by the participants about the definition and assessment of the dimensions
3. Identifying patterns in the suggested modifications, developing themes, reflecting on the themes in the context of the overall data set, and defining the theme's essence.

The themes were then used to revise the definitions and the assessment of the dimensions as appropriate. The changes made, based on the free-text suggestions and feedback in the first survey round, were incorporated into the second round.

3.3 Results

3.3.1 Statistical Summary of the First-Round Results

The sociodemographic characteristics of the participants are presented in Table 1. Thirty-five clinicians from 10 countries participated in the first round of this eDelphi study, with most being doctors (n=26, 74%) and males (n=23, 66%).

Table 1: Sociodemographic Characteristics of the eDelphi Participants (N=35)

Characteristics	Participants n (%)
Occupation	
Doctor	26 (74)
Nurse/nurse practitioner/advanced care practitioner	5 (14)
Pharmacist/clinical pharmacist	2 (6)
Dietician	1 (3)
Health system specialist	1 (3)
DHTs user experience	
Less than ten years	17 (49)
Ten years or more	18 (51)
Country	
Croatia	1 (3)
The Gambia	1 (3)
Germany	1 (3)
Ireland	5 (14)
The Netherlands	3 (9)
Nigeria	2 (6)
Singapore	1 (3)
United Arab Emirates	1 (3)
United Kingdom	18 (51)
United States of America	2 (6)
Sex	
Male	23 (66)
Female	12 (34)

About half of the participants were from the United Kingdom (n=18, 51%), and about half had more than 10 years of DHT user experience (n=18, 51%). Participants were mainly from high-income countries (n=8, 80%). Nigeria was the only lower-middle-income country, and the Gambia was the only low-income country. Most clinicians (n=30, 86%) provided their email for the subsequent rounds.

In the first round of the study, between 86% and 97% of the clinicians regarded the information quality dimensions in the CLIQ framework as relevant. This indicated consensus among the participating clinicians on the relevance of all the 13 proposed dimensions in the framework because the values were above the prespecified threshold of 70%. The ranking of the information quality dimensions is shown in Table 2.

3.3.2 CLIQ Framework Modification Based on the First Round Suggestions

The themes developed from the free-text suggestions are summarised in Textbox 1. The themes were used to inform multiple changes in the questionnaire which are presented in Appendix 7.

Textbox 1: Themes from the Free-text Suggestions in the First Round

- Avoiding ambiguity: this expresses the need to avoid ambiguous terms and phrases.
- Relatable examples: this indicates the recommendation to include examples relating to daily activities to make the questions and definitions more explicit.
- Renaming the dimensions: this relates to suggestions for naming and renaming dimensions.
- Rephrasing for clarity: this expresses the need to rephrase aspects of the questionnaire to improve clarity.

Table 2: Ranking of the Dimensions in the CLIQ Framework

	Information quality dimension	Strongly relevant n (%)	Somewhat relevant n (%)	Combined relevance³ n (%)
1	Accuracy	30 (86)	2 (6)	32 (92)
2	Completeness	18 (51)	14 (40)	32 (91)
3	Interpretability	23 (66)	8 (23)	31 (89)
4	Plausibility	13 (37)	18 (51)	31 (89)
5	Provenance	27 (77)	7 (20)	34 (97)
6	Relevance	18 (51)	15 (43)	33 (94)
7	Accessibility	28 (80)	4 (11)	32 (91)
8	Portability	18 (51)	12 (34)	30 (86)
9	Security	25 (71)	5 (14)	30 (86)
10	Timeliness	25 (71)	9 (26)	34 (97)
11	Conformance	15 (43)	16 (46)	31 (89)
12	Consistency	10 (29)	20 (57)	30 (86)
13	Maintainability	20 (57)	14 (40)	34 (97)

³ Combined relevance is the total of respondents who picked the strongly relevant and somewhat relevant options.

Avoiding Ambiguity

The participants emphasised the need to avoid ambiguous terms in the questionnaire. They referred to some terms as being “vague,” “odd,” and “confusing.” For example, a participant described the term “errors” used in the definition of accuracy as being vague.

The term “errors” needs to be further defined, now it is too vague, and I have no idea what to think of when I read it.

The participants also regarded some definitions as being too complex to be understood by clinicians without informatics experience, as demonstrated in the comment below:

Just at this point, I am thinking that it is relevant to understand who your audience is with these questions. Not all clinicians would understand these questions, but clinical informatics professionals would.

Multiple changes were made in the CLIQ questionnaire to avoid ambiguity, such as replacing or removing terms such as “free of errors,” “occasionally,” and “very” that were considered ambiguous by the participating clinicians.

Relatable Examples

All the participants acknowledged that relatable examples relevant to the daily activities of the clinicians were useful in making the questionnaire clearer and more user-friendly. They suggested relatable examples for each option.

Phone call to IT [information technology] dept is not sufficiently accessible, it’s another barrier (with a potential to fail- on hold, engaged, deadline, etc).

Pharma/tobacco or any other commercial marketing would be “very untrustworthy.”

However, they expressed different opinions on how the examples should be presented. One of the participants suggested that examples should be included in each option:

Give examples in each of the options, that would make it easier to differentiate.

Whereas another participant advocated including the example in the main question:

Perhaps include the example within the question, rather than the choice of answers.

The participants also acknowledged that finding suitable examples to illustrate some response options might be difficult.

I'm struggling with the plausible/very plausible examples but can't at this time think of an alternative.

In relation to relatable examples, “two-factor authentication” was introduced as an example to describe secure information and “access requiring a phone call to the IT department” was reassigned under “inaccessible” information.

Renaming Dimensions

Although all 13 dimensions were ranked as relevant, the free-text suggestions indicated a need to rename some of the dimensions:

I don't like the use of the word “interpretable” in the context of digital health records as it is too similar to “interoperable” and easily mis-read. Comprehensibility? Information clarity?

Multiple participant comments indicated that “currency” was favoured over “timeliness.”

You could quickly log into a system that doesn't contain the most up to date patient information which would be far more concerning in terms of data quality than logging in slowly to a system with the most recent info in it.

Other suggestions implied a need for a new dimension. While commenting on accessibility, a participant expressed concerns about how searching for information in a system holding the data might be challenging.

I'd have the second option in the list, information is present in EHR [electronic health record] but have to spend time looking for it.

“Timeliness,” “provenance,” and “consistency” were renamed as “currency,” “trustworthiness,” and “consistency of presentation,” respectively. A new dimension, “searchability,” was introduced to account for the ease of locating needed information in the system holding data. Suggestions relating to renaming “interpretability” and “portability” were not adopted to avoid ambiguity.

Rephrasing for Clarity

The need to rephrase parts of the questionnaire for clarity dominated the free-text suggestions. Suggested modifications ranged from simple correction of typographical errors to significant changes that introduced new ideas. The suggestions relating to rephrasing were addressed as appropriate on a case-by-case basis.

The definition of an adverse event is too narrow. Consider reflecting both critical (patient safety) and non-critical (quality of care). Also, there is an implicit assumption that data will directly impact care - maybe use “contribute to” as opposed to “lead to.”

Therefore, “adverse event” was replaced with an explanation of the likelihood that inaccurate information would affect the quality and safety of care. Similarly, “patient care” replaced “intended task” as it is more all-encompassing. Other instances of rephrasing are presented in Appendix 7.

3.3.3 Results of the Second Round

The second round of the eDelphi study became necessary due to the introduction of an additional new dimension. The second-round survey, presented in Appendix 8, also allowed the presentation of the first-round results to the participants to obtain further feedback on the changes made to the questionnaire in the first round.

Of the 30 clinicians who provided their email addresses during the first round, 22 (73%) completed the second round of the eDelphi study.

Consensus was reached on the relevance of the new dimension “searchability” with all the participants supporting its introduction. Most participants agreed with the modifications made to the assessment of the dimensions, ranging from 86% (n=19) for consistency of presentation to 100% (n=22) for accuracy, completeness, interpretability, and maintainability, with no further changes suggested. Participants suggested minor changes regarding rephrasing the definitions of plausibility, trustworthiness, accessibility, portability, security, conformance, and consistency of presentation.

Multiple free-text suggestions indicated that the new term “currency” introduced in the first round was not as acceptable as “timeliness” which was the original term in the questionnaire:

I think timeliness and currency are two different terms that could not be used interchangeably. Therefore, I would prefer timeliness was not removed. If a result of an investigation is timely, it means it would be useful for decision making.

I don't like the word currency in this context (it sounds like it's referring to money).

Therefore, the dimension “currency” was reverted to “timeliness”, which was its original name. The modified CLIQ framework has 14 dimensions, as presented in Table 3. The accompanying assessment questionnaire is presented in Appendix 9.

Table 3: Clinical Information Quality Framework for Digital Health Technologies

Informativeness	The usefulness of digital information for clinical purposes.
Accuracy	The extent to which information is accurate.
Completeness	The extent to which no required information is missing.
Interpretability	The extent to which information can be interpreted.
Plausibility	The extent to which information makes sense based on clinical knowledge.
Trustworthiness	The extent to which the source of information is trustworthy and verifiable.
Relevance	The extent to which information is useful for patient care.
Availability	The functionality of the system holding clinical information.
Accessibility	The extent to which information is accessible.
Portability	The extent to which information can be moved or transferred between different systems.
Searchability	The extent to which needed information can be found.
Security	The extent to which information is protected from unauthorized access, damage, and loss.
Timeliness	The extent to which information is up to date.
Usability	The ease of use of clinical information.
Conformance	The extent to which information is presented in a format that complies with institutional, national, or international standards.
Consistency of presentation	The extent to which presentation of information adheres to the same set of institutional, national, or international standards.
Maintainability	The extent to which information can be maintained (e.g., modified, corrected, updated, adapted, and upgraded) to achieve intended improvement.

3.4 Discussion

3.4.1 Principal Findings

This study was conducted to contextualise the CLIQ framework to the needs of clinicians and build international consensus on a pragmatic approach to assessing clinical information in DHTs. Consensus was reached on the relevance of all the existing dimensions and categories of the CLIQ framework. A new dimension, “searchability”, was introduced to account for the ease of finding the needed information in the DHTs. The dimensions “provenance” and “consistency” were renamed “trustworthiness” and “consistency of presentation”, respectively. Multiple changes were made to the questionnaire to avoid ambiguities which could confuse users and affect its validity. Nonspecific terms with meanings that vary based on context were removed. The clarity of the questionnaire was also improved by rephrasing some questions, incorporating relatable examples, and renaming or redefining certain dimensions as appropriate. Overall, the modifications improved the face and content validity of the questionnaire and its user-friendliness.

3.4.2 Comparison with Prior Work

This study addressed the lack of a pragmatic tool for clinical information quality assessment and the limited involvement of clinicians in the development of existing frameworks as identified in the systematic review of information quality frameworks (Fadahunsi *et al.*, 2021). Unlike existing theoretical frameworks (Bolt, Kano and Kodate, 2007; McCormack and Ash, 2012; Stetson *et al.*, 2012; Almutiry *et al.*, 2013; Weiskopf and Weng, 2013; Davoudi *et al.*, 2015; Kahn *et al.*, 2016), the CLIQ framework is accompanied by a pragmatic questionnaire for assessing clinical information in DHTs. The CLIQ framework further differs from existing frameworks in that clinicians across ten countries were involved in its development. Many existing frameworks (Bolt, Kano and Kodate, 2007; Bowen, 2012; Stetson *et al.*, 2012;

Almutiry *et al.*, 2013; Weiskopf and Weng, 2013; Davoudi *et al.*, 2015; Kahn *et al.*, 2016) were developed without input from clinicians. Finally, the CLIQ framework applies to different DHTs, while existing frameworks are only applicable to specific DHTs, such as EHRs (Bolt, Kano and Kodate, 2007; Stetson *et al.*, 2012; Weiskopf and Weng, 2013; Davoudi *et al.*, 2015; Kahn *et al.*, 2016; Almutiry, 2017).

3.4.3 Strengths and Limitations

The eDelphi study allowed a systematic, practical, affordable, and transparent approach to integrating views of clinicians from ten countries. The rejection of the attempt to rename “timeliness” as “currency” demonstrated the importance of feedback in multiple Delphi rounds (Diamond *et al.*, 2014; Trevelyan and Robinson, 2015). This study also leveraged the clinical experience and information governance expertise of the participating clinicians to combine practical DHTs user experience and subject matter expertise. Furthermore, the heterogeneous composition of the expert panel with different professionals from ten countries enhanced the external validity of the CLIQ framework.

However, the external validity of the findings may be limited by the low proportion of participating clinicians from low- and middle-income countries. The adoption of the snowball sampling technique might have contributed to the disproportionately higher number of participating doctors and participants from the United Kingdom. Nevertheless, the participants actively engaged with the study. They went out of their way to scrutinise the questionnaire and offer valuable suggestions which improved the CLIQ framework. Although the proportion of participants that completed the second round was modest (22/30, 73%), this was more than the recommended 8 to 15 experts for a Delphi study (Trevelyan and Robinson, 2015).

3.5 Chapter Conclusion

The CLIQ framework reached a high expert consensus and clarity of language relating to the information quality dimensions. The modification of the CLIQ framework has made the framework user-friendly by incorporating the views of clinicians who are users of clinical information in DHTs, as recommended in the information quality literature. The modified CLIQ framework offers a pragmatic approach to assessing clinical information in DHTs and could be used in practice to identify and forestall information quality problems that can compromise the quality and safety of care. However, the adopted expert panel approach mainly improved the face and content validity of the framework (Bolarinwa, 2015). Therefore, a follow-up study, presented in Chapter 4, was conducted to evaluate the reliability and construct validity of the CLIQ framework.

Chapter 4

Pilot Assessment of Clinical Information Quality

4.1 Chapter Introduction

This chapter describes the pilot assessment of clinical information in SystmOne EHRs using the CLIQ framework. The study was conducted to assess the applicability, reliability, and construct validity of the framework. This study was a follow-up to the eDelphi study, reported in the last chapter, which addressed the face and content validity of the CLIQ framework.

4.2 Methods

4.2.1 Study Design

This study was conducted as an online cross-sectional survey of healthcare professionals across the UK who use SystmOne EHRs (The Phoenix Partnership Ltd (TPP) Horsforth, Leeds, UK). The cross-sectional survey approach was considered suitable because the CLIQ framework is a survey questionnaire (Appendix 9). Cross-sectional survey allowed the assessment of the applicability, internal consistency, and construct validity of the CLIQ framework. The online approach offered a convenient, affordable, and pragmatic way of data collection. The choice of SystmOne was informed by its wide use across different healthcare settings in the UK, including general practices, urgent care centres, social care services, hospitals, and prison medical services. Ethical approval (Appendix 10) was obtained from the Imperial College Research Ethics Committee (21IC7415).

4.2.2 Study Participants

Eligibility criteria for the study included being a healthcare professional with a clinical role and a regular user of SystmOne (defined as using SystmOne as part of routine professional

activities to document clinical information). Administrative staff using SystmOne and healthcare professionals using SystmOne occasionally (e.g., to check clinical records) were not eligible to participate in the study. Recruitment was done by convenience and snowball sampling through emails and social media platforms, including Facebook, LinkedIn, WhatsApp, Yammer, Digital Health Networks, and the Future NHS Collaboration platform. Although there is no consensus about the adequate sample size needed to validate a questionnaire, the literature recommends recruiting at least ten participants for each item of the scale being validated as a rule of thumb (Boateng *et al.*, 2018). As there are 14 dimensions of the CLIQ framework, this was equivalent to 140 participants in our study.

4.2.3 Data Collection

Healthcare professionals were invited to use the CLIQ framework to evaluate the information quality of SystmOne. The survey questionnaire comprised the 14 items of the CLIQ framework and two questions about the occupation of the respondents to assess their eligibility (Appendix 11). The responses were made mandatory to avoid missing data, which could limit the assessment of the construct validity (Woulfe *et al.*, 2022). An invitation containing a link to the participant information sheet, the consent form, and the questionnaire was shared with the healthcare professionals electronically through the channels described earlier. Two reminders, at least two weeks apart, were sent to encourage participation. Healthcare professionals were also encouraged to share the invitation with colleagues. Participation was voluntary. Participants could withdraw from the study at any time without giving any reasons. However, once the participant submitted the survey, their data could not be withdrawn as the responses were anonymous. The questionnaire was administered through an online survey platform, Qualtrics (Qualtrics, Provo, Utah, USA).

4.2.4 Data Analysis

The survey data was downloaded from Qualtrics in an excel format and imported into SPSS version 20 (IBM Statistics, Armonk, New York, USA). SPSS was used to conduct descriptive statistical analyses and compute correlation coefficients and Cronbach's alpha scores.

The three options for each dimension (e.g., not accurate, partly accurate and accurate) were recoded into the integers 1, 2 and 3, representing low, modest, and good quality, respectively. A descriptive statistical analysis was conducted and interpreted to demonstrate the applicability of the CLIQ framework. The distribution of the responses was expressed as frequencies, percentages, means and standard deviations.

Spearman's correlation coefficients were computed to investigate the linear relationship between the dimensions in the CLIQ framework. The ordinal nature of the data informed the choice of Spearman's coefficients. Correlation coefficients of 0.1 – 0.2 were regarded as poor, 0.3 – 0.5 as fair, 0.6 – 0.7 as moderate, and 0.8 – 0.9 as very strong (Chan, 2003).

The Cronbach's alpha coefficient was computed to assess the internal consistency of the global scale (i.e., CLIQ framework) and the sub-scales (i.e., the informativeness, availability and usability categories). A Cronbach's alpha coefficient of 0.7 or above was regarded as an indication of the reliability of the scale, and an alpha coefficient between 0.6 and 0.7 was considered acceptable (Taherdoost, 2018).

The SPSS data file was subsequently exported to SPSS Amos version 28 (IBM Statistics, Armonk, New York, USA) to assess the construct validity of the CLIQ framework. Confirmatory factor analysis, a structural equation modelling technique, was used to assess the extent to which the survey data supported the construct validity of the CLIQ framework (Ullman and Bentler, 2013). Confirmatory factor analysis was adopted because the CLIQ

framework has multiple sub-scales (i.e., informativeness, availability and usability categories) that were pre-determined as described in the second chapter (Fadahunsi *et al.*, 2021).

The maximum likelihood estimation method was used for the confirmatory factor analysis. The model fit was assessed based on the Standardised Root Mean Square Residual (SRMR) and Comparative Fit Index (CFI) as recommended in the literature for studies with a sample size of less than 250 (Hu and Bentler, 1999). A CFI greater than 0.9 and an SRMR less than 0.08 indicate model fit (Boateng *et al.*, 2018).

4.3 Results

4.3.1 Participants Characteristics

A total of 109 healthcare professionals completed the survey, with the majority (n = 67; 61.5%) being doctors and almost a quarter (n = 26; 23.9%) being nurses or advanced nurse practitioners. The rest of the participants had other clinical occupations. Table 4 presents the distribution of the participants by occupation.

Table 4: Distribution of the Occupation of the Survey Participants (N = 109)

Occupation	n (%)
Doctors	67 (61.5)
Nurses and Advanced Nurse Practitioners	26 (23.9)
Health Care Assistant	5 (4.6)
Physiotherapists and Occupational Therapists	4 (3.7)
Pharmacists	2 (1.8)
Podiatrists	2 (1.8)
Physician Associates	1 (0.9)
Therapy Support Workers	1 (0.9)
Community Health Workers	1 (0.9)

4.3.2 Participants' Assessment of Quality of the Dimensions

The mean quality score assigned to each dimension ranged from 2.2 for portability to 2.9 for security (1, 2, and 3 indicate low, modest, and good quality respectively). Most participants (n = 97; 89%) ranked security of clinical information in SystmOne as good while only more than a third of the participants (n = 42; 38.5%) ranked portability of clinical information in SystmOne as good. The summary of the assessment result is presented in Table 5.

Table 5: Clinical Information Quality of SystmOne as Assessed by the Participants

Dimension	Assessment of the Quality of the Dimension n (%)			Mean score (SD)
	Good	Modest	Low	
Accuracy	73 (67.0)	32 (29.4)	4 (3.7)	2.6 (0.6)
Completeness	63 (57.8)	43 (39.4)	3 (2.8)	2.6 (0.6)
Interpretability	82 (75.2)	26 (23.9)	1 (0.9)	2.7 (0.5)
Plausibility	92 (84.4)	17 (15.6)	0	2.8 (0.4)
Relevance	89 (81.7)	20 (18.3)	0	2.8 (0.4)
Trustworthiness	94 (86.2)	15 (13.8)	0	2.9 (0.3)
Accessibility	77 (70.6)	31 (28.4)	1 (0.9)	2.7 (0.5)
Portability	42 (38.5)	49 (45.0)	18 (16.5)	2.2 (0.7)
Searchability	56 (51.4)	49 (45.0)	4 (3.7)	2.4 (0.6)
Security	97 (89.0)	12 (11.0)	0	2.9 (0.3)
Timeliness	71 (65.1)	35 (32.1)	3 (2.8)	2.6 (0.5)
Conformance	77 (70.6)	27 (24.8)	5 (4.6)	2.7 (0.6)
Consistency of presentation	77 (70.6)	22 (20.2)	10 (9.2)	2.6 (0.7)
Maintainability	70 (64.2)	33 (30.3)	6 (5.5)	2.6 (0.6)

4.3.3 Inter-Item Correlation

There were positive correlations between all possible pairs of dimensions in the CLIQ framework as shown in Table 6. All the correlation coefficients were statistically significant (represented as asterisks) except for the correlations of portability with each of plausibility, relevance, trustworthiness, and security. There was a strong statistically significant correlation between conformance and consistency (Spearman's $\rho = 0.751$, $p < 0.01$)

4.3.4 Internal Consistency of the CLIQ Framework

The Cronbach's alpha coefficients and corresponding 95% confidence intervals (CI) for the informativeness, availability, and usability sub-scales were 0.78 (95% CI: 0.70 – 0.84), 0.69 (95% CI: 0.58 – 0.77) and 0.83 (95% CI: 0.77 – 0.88), respectively. Once security was removed from the availability subscale, the Cronbach's alpha coefficient for the availability sub-scale increased marginally to 0.70 (95% CI: 0.60 – 0.78). The Cronbach's alpha coefficient for the overall CLIQ framework was 0.89 (95% CI: 0.85 – 0.92).

4.3.5 Construct Validity of the CLIQ Framework

Although the Chi-square Goodness of Fit test ($\chi^2 = 155.69$; $P < 0.001$; $\chi^2 / df = 2.10$) did not demonstrate the fitness of the model, CFI (0.86) and SRMR (0.08) suggested that the model fits modestly with the data. Similarly, all the factor loadings (i.e., covariance estimates) were positive and statistically significant, as shown in Table 7. Significant tests (Standard Error, Critical Ratio, and p value) were not reported for the first item in each category (i.e., accuracy, accessibility, and conformance) because their unstandardised covariance values were fixed at 1 and not estimated. Fixing unstandardised covariance at 1 is a standard procedure in Confirmatory Factor Analysis.

Table 6: Inter-items Correlation Matrix

	Accuracy	Completeness	Interpretability	Plausibility	Relevance	Trustworthiness	Accessibility	Portability	Searchability	Security	Timeliness	Conformance	Consistency	Maintainability
Accuracy	1.00	0.56**	0.36**	0.20*	0.38**	0.34**	0.38**	0.24*	0.44**	0.23*	0.38**	0.47**	0.49**	0.38**
Completeness		1.00	0.46**	0.35**	0.41**	0.43**	0.39**	0.25**	0.50**	0.41**	0.51**	0.49**	0.52**	0.53**
Interpretability			1.00	0.33**	0.27**	0.32**	0.28**	0.22*	0.36**	0.40**	0.34**	0.65**	0.51**	0.39**
Plausibility				1.00	0.45**	0.56**	0.21*	0.08	0.31**	0.33**	0.27**	0.28**	0.34**	0.38**
Relevance					1.00	0.43**	0.42**	0.13	0.36**	0.29**	0.30**	0.27**	0.29**	0.44**
Trustworthiness						1.00	0.32**	0.15	0.30**	0.46**	0.34**	0.26**	0.39**	0.35**
Accessibility							1.00	0.41**	0.42**	0.22*	0.26**	0.39**	0.41**	0.35**
Portability								1.00	0.44**	0.04	0.36**	0.30**	0.36**	0.39**
Searchability									1.00	0.28**	0.35**	0.47**	0.46**	0.60**
Security										1.00	0.30**	0.32**	0.39**	0.38**
Timeliness											1.00	0.35**	0.38**	0.46**
Conformance												1.00	0.75**	0.52**
Consistency													1.00	0.56**
Maintainability														1.00
P < 0.05* P < 0.01** P < 0.001**														

Table 7: Standardised and Unstandardised Estimates of the Covariance

	Standardised covariance estimates	Unstandardised covariance estimates	Standard Error	Critical Ratio	P-value
Accuracy	0.64	1.00	N/A	N/A	N/A
Completeness	0.76	1.18	0.18	6.41	P<0.001
Interpretability	0.59	0.77	0.15	5.27	P<0.001
Plausibility	0.52	0.53	0.11	4.72	P<0.001
Relevance	0.56	0.61	0.12	5.00	P<0.001
Trustworthiness	0.59	0.57	0.11	5.24	P<0.001
Accessibility	0.60	1.00	N/A	N/A	N/A
Portability	0.45	1.13	0.28	3.99	P<0.001
Searchability	0.72	1.43	0.25	5.66	P<0.001
Security	0.46	0.50	0.13	4.03	P<0.001
Timeliness	0.56	1.05	0.22	4.73	P<0.001
Conformance	0.82	1.00	N/A	N/A	N/A
Consistency	0.85	1.20	0.12	9.64	P<0.001
Maintainability	0.73	0.94	0.12	8.05	P<0.001

The statistically significant positive standardised covariance estimates for all information quality dimensions supports the placement of the dimensions in their respective categories. This is further illustrated in the path diagram presented in Figure 5. The high values of estimated covariances between the latent variables and the observed variables support the construct validity of the model. However, the high covariance estimates between the latent variables (informativeness, availability and usability) indicate the overlap of the categories.

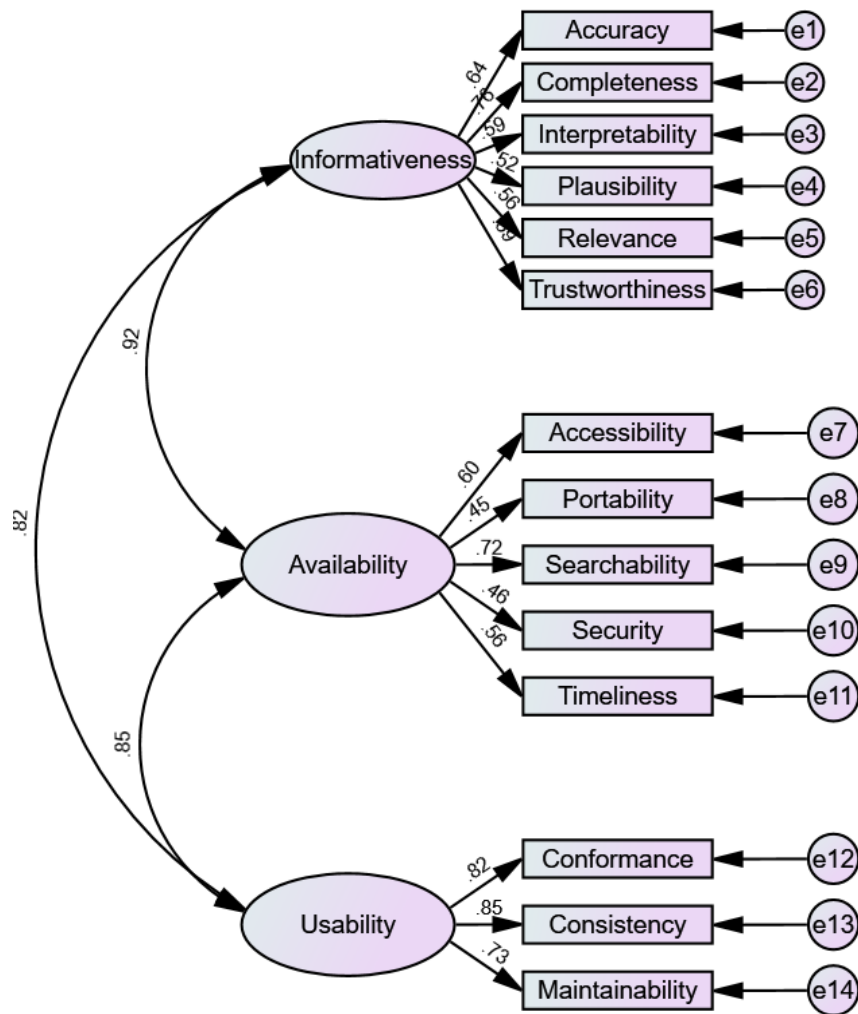


Figure 5: Path Diagram for Confirmatory Factor Analysis⁴

⁴ The rectangular shapes represent the observed variables (i.e., information quality dimensions) that were directly measured in the survey. The circular shapes represent the latent variables (i.e., information quality categories) that could be inferred from the measured variables. The abbreviation e represents error. The connecting arrows represent covariances, with the accompanying numbers representing their estimates.

4.4 Discussion

4.4.1 Principal Findings

The study investigated the applicability, internal consistency, and construct validity of the CLIQ framework based on the pilot assessment of clinical information in SystmOne EHRs. Overall, all the CLIQ dimensions have good quality scores except for portability which has a modest quality score. Security has the highest quality score while portability has the lowest quality score. The inter-item correlations are all positive and not likely due to chance. The Cronbach's alpha scores indicate good internal consistency of the CLIQ framework and thus its reliability. The confirmatory factor analysis provides a modest support for the construct validity of the CLIQ framework.

4.4.2 Comparison with Previous Literature

The combination of good security and modest portability scores indicates the possibility of trade-off between security and portability. Portability might have been limited inadvertently to improve the security of clinical information. Similar trade-offs, such as between accessibility and security, have been documented in the literature (Eppler and Wittig, 2000). Software developers need to be vigilant to identify potential trade-offs that may compromise the quality and safety of care.

The positive and mostly significant inter-item correlations signifies a close relationship between the dimensions (Akoglu, 2018). This was not unexpected because all dimensions are components of the same CLIQ framework. The generally low values of the correlations demonstrates that the dimensions, although related, are distinct (Akoglu, 2018). The high correlation between conformance and consistency of presentation is understandable, as both concern presentation of information.

This study used similar methods as a study on the validation of the Modified Enlight Suite (MES), a generic mHealth app assessment questionnaire (Woulfe *et al.*, 2022). Woulfe *et al.* (2022) demonstrated an overall good internal consistency and modest construct validity of the MES based on a survey of 800 healthcare students and healthcare professionals who assessed a freely downloadable Irish COVID-19 app (Wolfe et al., 2022). The differences in the uptakes of the two studies were probably related to the choice of DHTs and study population. While the current study population was limited to healthcare professionals using SystemOne EHRs, the MES study was open to all healthcare professionals and medical students who could download the Irish COVID-19 app.

4.4.3 Importance of Context in the Development of CLIQ Framework

As discussed in the first chapter, information quality requirements are influenced by context and the contextual factors considered in the development of the CLIQ framework include digital information, clinicians and clinical use which correspond to type, user, and purpose of information respectively. The CLIQ framework was developed to address the lack of consensus on information quality requirements for DHTs against a background of compromised quality and safety of care due to information quality problems (Fadahunsi *et al.*, 2021). The CLIQ framework was developed from systematic review of literature, revised based on international consensus of clinicians and validated among a multidisciplinary sample of healthcare professionals to ensure that the framework is grounded in systematic evidence from literature and contextualised to the needs of the information users (Eppler and Wittig, 2000). The CLIQ framework is thus a pragmatic evidence-based information quality framework for DHTs.

4.4.4 Strengths and Weaknesses

To the best of my knowledge, the CLIQ framework is the first information quality framework for DHTs, of which the reliability and construct validity have been assessed. Only the face and content validity of most existing information quality frameworks were assessed (Fadahunsi *et al.*, 2021). In addition, the choice of SystmOne EHRs for testing the CLIQ framework ensured participation of a multidisciplinary population of healthcare professionals across different settings thus enhancing a wider applicability of the framework. The use of mandatory responses in the survey to avoid missing values is also a strength. Rather than relying on statistical methods to address missingness, this study used actual data from participants, thus producing a more reliable result.

However, the low response rate limited the demonstration of the construct validity of the CLIQ framework (Boateng *et al.*, 2018). The low uptake of the current survey was probably due to the busy schedules of the healthcare professionals at a time when the NHS was under immense pressure due to COVID-19 pandemic. As such, this study could not rely on fit indices primarily influenced by sample size, such as the Chi-square goodness of fit index, but the index least affected by sample size, the SRMR (Hu and Bentler, 1999), supports the model fit. Therefore, the modest construct validity of the CLIQ framework, as demonstrated in this study, should be interpreted with caution. Nevertheless, the sample size was sufficient to demonstrate the applicability and reliability of the CLIQ framework. The CLIQ framework will likely be used within individual healthcare institutions with a limited population of healthcare professionals. Thus, a large sample size was less relevant to assessing its applicability. In addition, the narrow confidence intervals for the Cronbach's alpha coefficients showed that the sample size was sufficient for the reliability study.

4.5 Chapter Conclusion

Overall, the pilot assessment of quality of clinical information in SystemOne showed that the CLIQ framework is applicable and reliable. All pairs of the framework's dimensions were positively correlated with each other. The Cronbach's alpha coefficients indicated internal consistency of the overall CLIQ framework and of its subscales. The confirmatory factor analysis provides modest evidence for the construct validity of the CLIQ framework. The implications of these findings and the overall applicability of the CLIQ framework will be discussed in the last chapter.

Chapter 5

Conclusions and Recommendations

5.1 Chapter Introduction

The overall aim of the thesis was to develop a framework to assess the quality of clinical information in DHTs. The following objectives were addressed:

- i. Identify, define, and integrate information quality dimensions that are relevant to assessing the quality of clinical information in DHTs.
- ii. Develop a novel approach to assessing the quality of clinical information in DHTs.
- iii. Build international consensus among clinicians on the novel approach to assessing the quality of clinical information in DHTs.
- iv. Evaluate the novel approach to assessing the quality of clinical information in DHTs.

The CLIQ framework was developed as a novel approach to assessing the quality of clinical information in DHTs. The framework is discussed in this chapter as well as the implications of the overall thesis for practice, policy, and future research.

5.2 The CLIQ Framework

The CLIQ framework identifies, defines, and integrates 14 information quality dimensions that are relevant to assessing clinical information in DHTs. The dimensions of the CLIQ framework are grouped into three meaningful categories – informativeness, availability and usability.

The informativeness category relates to the usefulness of clinical information in patient care. Dimensions in the informativeness category include accuracy, completeness, interpretability,

plausibility, relevance, and trustworthiness. Accuracy reflects the impact of information on the quality and safety of care. Completeness assesses the extent of missing information. Interpretability is assessed based on the need for additional resources when interpreting clinical information. Plausibility assesses the likelihood of clinical information being true. Relevance assesses usefulness of information in patient care. Trustworthiness is assessed based on the source of information.

The availability category relates to the functionality of DHTs holding clinical information. Dimensions in this category include accessibility, portability, searchability, security, and timeliness. Accessibility relates to the ease of reaching information in the DHTs at the point of care. Portability is assessed based on the ease of transferring clinical information. Searchability assesses the ease of retrieving needed information from DHTs. Security assesses the strategies used to protect clinical information from unauthorized access, damage, and loss. Timeliness assesses the availability of up-to-date information for patient care.

The usability category concerns the ease of use of clinical information and encompasses conformance, consistency of presentation, and maintainability. Conformance assesses the extent to which information format complies with local, national, or international standards. Consistency of presentation reflects the extent to which information adheres to the same set of standards. Maintainability assesses the ease of implementing intended maintenance activities such as audit, correction, and update.

5.3 Implications for Practice

5.3.1 Informatics Training

The CLIQ framework demonstrates that information quality is multidimensional, and understanding its meaning, relevance, and assessment requires informatics training. The

participants of the eDelphi study expressed concerns that healthcare professionals without informatics training might be unfamiliar with information quality terminologies (Fadahunsi *et al.*, 2022b). In addition, information quality problems, such as missing and inaccurate information, could result from human errors (Magrabi *et al.*, 2016). Therefore, informatics training could enhance healthcare professionals' understanding of information quality as well as equip them with strategies, such as proper documentation and adequate record keeping, that can be used to prevent information quality problems.

Informatics training should be included in healthcare professionals' pre- and post-qualification competencies to keep them up to date of the ever-changing information landscape in digital health (Davies *et al.*, 2022). However, care should be taken not to complicate an already-complex medical curriculum with extensive informatics training (Davies *et al.*, 2022). Rather, efforts should be made to provide appropriate level of informatics training that is commensurate with needs. Although informatics training could build health professional's competencies around information quality, mistakes will continue to occur because 'to err is human' (Institute of Medicine, 2000). Therefore, it is important to institute systems that reduce incidence and impact of errors in addition to organising informatics training.

5.3.2 Information Quality Assurance System

This thesis highlights the importance of information quality and its relevance to the quality and safety of care. Therefore, establishing a robust system for information quality assurance is essential. Such an information quality assurance system entails regular checks and monitoring, data validation, and information quality audits (World Health Organization, 2022). The CLIQ framework could be a useful tool for information quality audits. The information quality assurance system could be integrated into the information governance system, where one already exists, to prevent duplication and fragmentation. Designating clinicians with additional

informatics training to oversee such information quality assurance system is necessary to ensure its successful implementation because they understand the clinical and technological aspects of patient care (Lee, 2022). Although healthcare institutions within high-income countries have designated clinical informatics roles, such as the chief clinical information officer, the job description is still evolving (Sridharan, Priestman and Sebire, 2018). It is therefore vital to expand these roles to include information quality assurance and introduce them where they do not exist.

5.3.3 Automated Error Detection and Data Validation Systems

The quality of clinical information could be improved by setting up automated error detection and data validation systems in DHTs. Machine learning (ML) and Artificial Intelligence (AI) algorithms could be applied for automated data validation and real-time error detection with errors flagged during data entry (Khan and Yairi, 2018). Automated error detection and data validation systems could reduce the likelihood of wrong data entry as well as prompt early correction of errors before patient safety is compromised. However, lack of trust in ML and AI could make healthcare professionals ignore or override automated warnings and alerts (Nicora *et al.*, 2022).

5.3.4 Interoperability and Integration of Digital Health Systems

Interoperability enhances seamless flow of information across different DHTs such as EHRs, laboratory information system and electronic triage system (Iroju *et al.*, 2013). Seamless health information exchange between multiple platforms improves quality of clinical information (Lehne *et al.*, 2019). Accuracy is enhanced because information is obtained directly from source with elimination of possible changes during transcription (Iroju *et al.*, 2013). Since the same information is shared across different platforms, the format of presentation will be

consistent. Communication between systems enhances timely access to up-to-date information in or near real-time (Lehne *et al.*, 2019). Although interoperability of digital health systems is desirable, a huge cost is often required for its implementation. Concerns about security may also be an obstacle due to increased access to information (Iroju *et al.*, 2013).

5.3.5 User-friendly Design Interface

The quality of data entry could be improved with a user-friendly design interface (Wilbanks and Moss, 2021). Accuracy and completeness of clinical information in DHTs could be enhanced with features such as drop-down menus, pre-population fields and validation prompts. Faulty design interface can affect consistency of presentation. A drop down with different units of the same medication can lead to medication errors (Kim, Coiera and Magrabi, 2017). Searchability of information improves when the design interface allows smooth navigation through the digital system.

5.3.6 Consumer Health Data

Nowadays, patients are increasingly viewing and contributing data to their health records especially since the COVID-19 pandemic (Clarke, Pariza and Wolters, 2020). Multiple DHTs, such as AskmyGp (Evergreen Health Solution Ltd, Salford, Manchester UK), eConsult (eConsult Health Ltd, Marsh Wall, London, UK) and Accurx (Accurx Ltd, Shoreditch, London, UK) allow patients to enter texts and upload photos which are then saved into EHRs. In addition, patients generate personalised health information through mobile apps and wearable devices which can be shared with healthcare professionals (Lai *et al.*, 2017). Patient-generated information need to be of high quality for it to be useful for clinical decision making. The CLIQ framework can be used as an information quality requirement guide and as an assessment tool for patient-generated health information.

5.4 Implications for Policy

5.4.1 Information Quality Requirements

Policies, guidelines, and regulatory standards are needed to define and communicate information quality requirements for DHTs. Policies should communicate the official position of an institution on information quality requirements while guidelines should provide clear guidance on how to meet the requirements. The CLIQ framework could be used as a conceptual guide for information quality requirements. Policies and guidelines are needed to address issues relating to information quality, including interoperability, privacy and confidentiality, information format, design interface, training etc. These issues can be addressed collectively in a single information quality policy and/or individually with different guidelines based on the needs of the institution. The process of formulating, implementing, and disseminating the policies needs to involve all stakeholders, as described subsequently.

5.4.2 Collaboration and Partnerships among Information Stakeholders

The development of the CLIQ framework demonstrates the importance of multidisciplinary and international collaboration in the development of information quality standards. The CLIQ framework was developed with inputs of healthcare professionals from over ten countries. Establishing and implementing information quality standards require collaboration among healthcare organisations, software developers and vendors, regulatory bodies, patient support group, professional organisations etc. Collaboration will ensure buy-in of all information stakeholders and facilitate the implementation process.

5.4.3 Certification and Regulation

Enforcement of information quality standards for DHTs requires regulatory oversight. Regulatory bodies for DHTs in different countries and regions, such as the United States Food

and Drug Administration (FDA) and Medicines and Healthcare Regulatory Agency (MHRA), need to include information quality requirements as part of prequalification criteria for DHTs. Only DHTs that meet prequalification criteria, including information quality requirements, should be certified by the regulatory bodies. Information quality of DHTs should be assessed using evidence-based approach, such as the CLIQ framework, before they are certified for use in healthcare facilities.

5.5 Implications for Future Research

5.5.1 Evidence-based Approach

The CLIQ framework was developed and validated using an approach which combined evidence from literature and empirical studies. The systematic review synthesized frameworks, rather than interventions, based on the BeHeMoTh procedure (Fadahunsi *et al.*, 2019). The international eDelphi study obtained quantitative and qualitative evidence from clinicians across ten countries (Fadahunsi *et al.*, 2022b). The Pilot CLIQ assessment used a systematic approach to investigate the reliability and validity of this novel framework. Overall, the evidence-based approach of developing the CLIQ framework provides a methodological model which could be adopted in future research while developing other pragmatic frameworks.

5.5.2 Information Quality Research

The systematic review of literature shows a dearth of information quality research relating to DHTs (Fadahunsi *et al.*, 2021). The CLIQ framework demonstrates the importance of information quality research in addressing contemporary issues relating to DHTs. Some information quality dimensions, which were hitherto not included in most existing information quality frameworks for DHTs, are included in the CLIQ framework. Searchability and maintainability are more relevant due to technological advancement which has made it possible

to capture, process and store an increasing volume of digital information. Searchability, that is, locating needed information from the wide range of available information, is thus essential. Maintainability of information is also important to ensure that information quality is not sacrificed with increasing quantity of information. Similarly, portability has become more relevant than ever with the current tendency towards integration and interoperability of DHTs. Therefore, there is an increased need for information quality research to match the growth in technological innovations.

5.7 Study Limitations

Although the CLIQ framework was developed with inputs of healthcare professionals from different countries, low-income and middle-income countries were less represented among the participants. This may limit the applicability of the CLIQ framework in such settings. Further studies would be necessary to contextualise the CLIQ framework to the needs of information users in low- and middle-income settings.

Similarly, the CLIQ framework was developed and validated based on inputs of healthcare professionals as end-users of clinical information. Patients were not involved in the development of the CLIQ framework. As earlier discussed, patients are increasingly viewing and contributing to the information in DHTs. Therefore, incorporating patients' views and perspectives into the framework will be useful in future research.

Moreover, some dimensions of the CLIQ framework may become less relevant especially with increasing application of AI and ML technologies. New dimensions might also be required because of technological evolutions, necessitating revision of the CLIQ framework. Recognising the dynamic nature of digital health, the CLIQ framework will be made available

under a Creative Commons (CC BY) license to facilitate its use in future works by other researchers who are interested in adapting it based on their needs.

5.8 Conclusion

This thesis highlights the importance of information quality and its relevance to the quality and safety of care. The CLIQ framework offers a pragmatic approach to assessing the quality of clinical information in DHTs and can be used as part of information quality assurance systems to maintain the quality of clinical information in DHTs. Informatics training for health care professionals, automated error detection systems and integration of digital health systems can further improve the quality of clinical information in DHTs. The thesis identifies a need to match information quality research with rapid innovations in digital health. Policies, guidelines, and regulatory standards are needed to drive the translation of information quality research into clinical practice.

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Appendix 1: Search Strategies

Database: HMIC Health Management Information Consortium 1979 to July 2019

#	Searches	Results
1	(information adj1 quality).ab,ti.	254
2	(data adj1 quality).ab,ti.	435
3	(information adj1 accura\$).ab,ti.	180
4	(data adj1 accura\$).ab,ti.	126
5	(information adj1 reliab\$).ab,ti.	123
6	(data adj1 reliab\$).ab,ti.	115
7	(information adj1 valid\$).ab,ti.	33
8	(data adj1 valid\$).ab,ti.	88
9	framework\$.ab,ti.	13858
10	model\$.ab,ti.	24453
11	scale\$.ab,ti.	7686
12	dimension\$.ab,ti.	3031
13	indicator\$.ab,ti.	6439
14	guideline\$.ab,ti.	9796
15	metric\$.ab,ti.	407
16	criteri\$.ab,ti.	8085
17	standard\$.ab,ti.	21343
18	(ehealth or e-health).ab,ti.	246
19	electronic health.ab,ti.	449
20	(telemedicine or tele-medicine).ab,ti.	828
21	(teleconsult\$ or tele-consult\$).ab,ti.	126
22	(telehealth or tele-health).ab,ti.	353
23	(telemonitor\$ or tele-monitor\$).ab,ti.	107
24	(telecardiology or tele-cardiology).ab,ti.	9
25	"remote consultation".ab,ti.	9
26	(telecommunication\$ or tele-communication\$).ab,ti.	253
27	("video conferenc\$" or videoconferenc\$ or video-conferenc\$).ab,ti.	225
28	telephone\$.ab,ti.	3424
29	(teleconferenc\$ or tele-conferenc\$).ab,ti.	27
30	(mHealth or m-Health or "mobile Health").ab,ti.	78
31	("mobile telephone\$" or "mobile phone\$").ab,ti.	258
32	("cell\$ phone\$" or cellphone\$ or cell-phone\$).ab,ti.	43
33	("smart phone\$" or "smartphone\$" or smart-phone\$).ab,ti.	85
34	("handheld computer\$" or "hand-held computer\$").ab,ti.	43
35	("tablet computer\$" or "tablet PC").ab,ti.	11
36	"personal digital assistant\$ ".ab,ti.	32
37	"mobile app\$".ab,ti.	23
38	"medical app\$".ab,ti.	131
39	"health app\$".ab,ti.	325
40	"short messag\$ service\$".ab,ti.	41
41	("text messag\$" or text-messag\$).ab,ti.	115
42	("mp3 player\$" or mp3-player\$).ab,ti.	1
43	("handheld device\$" or "hand-held device\$").ab,ti.	13
44	"mobile device\$".ab,ti.	28
45	"software app\$".ab,ti.	22
46	"computer-assisted decision\$".ab,ti.	6
47	(CDSS or CDS).ab,ti.	120
48	"decision support system\$".ab,ti.	230
49	"computer app\$".ab,ti.	92
50	"computer software\$".ab,ti.	118
51	"computer-assisted instruction\$".ab,ti.	13
52	"clinical decision support".ab,ti.	92
53	"health information system\$".ab,ti.	192
54	"medical information system\$".ab,ti.	55
55	"laboratory information system\$".ab,ti.	6

56	"electronic health record\$.ab,ti.	391
57	"electronic medical record\$.ab,ti.	279
58	"clinical information system\$.ab,ti.	181
59	"computerized medical record\$.ab,ti.	19
60	EHR.ab,ti.	162
61	"hospital information system\$.ab,ti.	176
62	internet.ab,ti.	1918
63	"social media".ab,ti.	164
64	blog\$.ab,ti.	47
65	facebook.ab,ti.	45
66	(twitter or tweet\$.ab,ti.	53
67	instagram.ab,ti.	0
68	e-mail.ab,ti.	224
69	("electronic prescri\$" or eprescri\$ or e-prescri\$.ab,ti.	189
70	computer\$ physician order entry.ab,ti.	29
71	"health 2.0".ab,ti.	9
72	(web or website\$.ab,ti.	5405
73	(email or "electronic mail").ab,ti.	356
74	linkedin.ab,ti.	4
75	(computeri#ed medical record\$ or computeri#ed health record\$.ab,ti.	60
76	(EHR or EMR or "electronic patient record\$.ab,ti.	649
77	(fitbit or wearable\$.ab,ti.	23
78	("patient health record\$" or PHR).ab,ti.	26
79	"information audit\$.ab,ti.	16
80	"data audit\$.ab,ti.	11
81	measur\$.ab,ti.	32286
82	Computer software/	521
83	Computer applications/	1101
84	Decision support systems/	216
85	Information systems/	2448
86	Health records/ or electronic patient records/	1580
87	Medical information systems/	380
88	Computerised information systems/	132
89	District information support systems/	4
90	Drug information systems/	122
91	Health service information systems/	34
92	Medical information systems/	380
93	Online information systems/	197
94	telemedicine/	1307
95	telecare/	723
96	Mobile telephones/	279
97	Telephones/	45
98	Telecommunications/	241
99	Videoconferencing/	28
100	Personal digital assistants/	2
101	Text messaging/	84
102	Email/	147
103	Electronic prescribing/	185
104	Internet portals/ or Internet/ or Internet websites/	2153
105	Broadband/	2
106	Electronic data interchange/	56
107	World Wide Web/	103
108	Lifelong electronic health records/	54
109	Frameworks/	1354
110	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 79 or 80	1329
111	9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 109	77585
112	18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87 or 88 or 89 or	51539

	90 or 91 or 92 or 93 or 94 or 95 or 96 or 97 or 98 or 99 or 100 or 101 or 102 or 103 or 104 or 105 or 106 or 107 or 108 or 109	
113	skype.mp.	10
114	112 or 113	51540
115	110 and 111 and 114	270

Database: **Maternity & Infant Care Database (MIDIRS)** 1971 to September 2019

#	Searches	Results
1	(information adj1 quality).ab,ti.	68
2	(data adj1 quality).ab,ti.	267
3	(information adj1 accura\$).ab,ti.	254
4	(data adj1 accura\$).ab,ti.	103
5	(information adj1 reliab\$).ab,ti.	113
6	(data adj1 reliab\$).ab,ti.	85
7	(information adj1 valid\$).ab,ti.	21
8	(data adj1 valid\$).ab,ti.	90
9	framework\$.ab,ti.	3745
10	model\$.ab,ti.	20986
11	scale\$.ab,ti.	9587
12	dimension\$.ab,ti.	3064
13	indicator\$.ab,ti.	4272
14	guideline\$.ab,ti.	10676
15	metric\$.ab,ti.	330
16	criteri\$.ab,ti.	11775
17	standard\$.ab,ti.	17276
18	(ehealth or e-health).ab,ti.	38
19	electronic health.ab,ti.	187
20	(telemedicine or tele-medicine).ab,ti.	89
21	(teleconsult\$ or tele-consult\$).ab,ti.	6
22	(telehealth or tele-health).ab,ti.	22
23	(telemonitor\$ or tele-monitor\$).ab,ti.	8
24	(telecardiology or tele-cardiology).ab,ti.	3
25	"remote consultation".ab,ti.	4
26	(telecommunication\$ or tele-communication\$).ab,ti.	24
27	("video conferenc\$" or videoconferenc\$ or video-conferenc\$).ab,ti.	34
28	telephone\$.ab,ti.	2060
29	(teleconferenc\$ or tele-conferenc\$).ab,ti.	23
30	(mHealth or m-Health or "mobile Health").ab,ti.	80
31	("mobile telephone\$" or "mobile phone\$").ab,ti.	136
32	("cell\$ phone\$" or cellphone\$ or cell-phone\$).ab,ti.	56
33	("smart phone\$" or "smartphone\$" or smart-phone\$).ab,ti.	114
34	("handheld computer\$" or "hand-held computer\$").ab,ti.	4
35	("tablet computer\$" or "tablet PC").ab,ti.	4
36	"personal digital assistant\$ ".ab,ti.	14
37	"mobile app\$".ab,ti.	48
38	"medical app\$".ab,ti.	55
39	"health app\$".ab,ti.	117
40	"short messag\$ service\$".ab,ti.	23
41	("text messag\$" or text-messag\$).ab,ti.	119
42	("mp3 player\$" or mp3-player\$).ab,ti.	3
43	("handheld device\$" or "hand-held device\$").ab,ti.	5
44	"mobile device\$".ab,ti.	23
45	"software app\$".ab,ti.	8
46	"computer-assisted decision\$".ab,ti.	3
47	(CDSS or CDS).ab,ti.	89
48	"decision support system\$".ab,ti.	34
49	"computer app\$".ab,ti.	6
50	"computer software\$".ab,ti.	47
51	"computer-assisted instruction\$".ab,ti.	8
52	"clinical decision support".ab,ti.	29
53	"health information system\$".ab,ti.	125
54	"medical information system\$".ab,ti.	6
55	"laboratory information system\$".ab,ti.	4
56	"electronic health record\$".ab,ti.	163
57	"electronic medical record\$".ab,ti.	305
58	"clinical information system\$".ab,ti.	13

59	"computerized medical record\$.ab,ti.	11
60	EHR.ab,ti.	46
61	"hospital information system\$.ab,ti.	18
62	internet.ab,ti.	1156
63	"social media".ab,ti.	254
64	blog\$.ab,ti.	97
65	facebook.ab,ti.	124
66	(twitter or tweet\$.ab,ti.	58
67	instagram.ab,ti.	4
68	e-mail.ab,ti.	207
69	("electronic prescri\$ or eprescri\$ or e-prescri\$).ab,ti.	8
70	computer\$ physician order entry.ab,ti.	24
71	"health 2.0".ab,ti.	1
72	Decision support systems.de.	29
73	Telemedicine.de.	46
74	Telephone.de.	37
75	Mobile phone.de.	1
76	Computers - handheld.de.	7
77	Mobile applications.de.	25
78	Software.de.	34
79	Mobile telephone.de.	57
80	Text messaging.de.	20
81	Internet.de.	891
82	Social media.de.	142
83	Internet.de.	891
84	Information systems.de.	134
85	Medical records.de.	602
86	Electronic health records.de.	80
87	(web or website\$.ab,ti.	2613
88	(email or "electronic mail").ab,ti.	220
89	linkedin.ab,ti.	4
90	(computeri#ed medical record\$ or computeri#ed health record\$).ab,ti.	16
91	(EHR or EMR or "electronic patient record\$").ab,ti.	142
92	(fitbit or wearable\$.ab,ti.	14
93	("patient health record\$ or PHR).ab,ti.	9
94	"information audit\$.ab,ti.	3
95	"data audit\$.ab,ti.	5
96	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 94 or 95	983
97	measur\$.ab,ti.	44125
98	9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 97	93072
99	18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87 or 88 or 89 or 90 or 91 or 92 or 93	8465
100	96 and 98 and 99	70

Database: **Embase Classic+Embase** 1947 to 2019 October 23

#	Searches	Results
1	(information adj1 quality).ti,ab,kw.	2744
2	(data adj1 quality).ti,ab,kw.	16166
3	(information adj1 reliab*).ti,ab,kw.	5495
4	(data adj1 reliab*).ti,ab,kw.	7178
5	(information adj1 valid*).ti,ab,kw.	1382
6	(data adj1 valid*).ti,ab,kw.	9702
7	(information adj1 audit*).ti,ab,kw.	2048
8	(data adj1 audit*).ti,ab,kw.	2127
9	(information adj1 accura*).ti,ab,kw.	7124
10	(data adj1 accura*).ti,ab,kw.	5483
11	framework*.ti,ab,kw.	279717
12	dimension*.ti,ab,kw.	584869
13	scale*.ti,ab,kw.	1042015
14	indicator*.ti,ab,kw.	355689
15	guideline*.ti,ab,kw.	525019
16	metric*.ti,ab,kw.	78947
17	measur*.ti,ab,kw.	4452237
18	criteri*.ti,ab,kw.	1001109
19	model*.ti,ab,kw.	3514436
20	standard*.ti,ab,kw.	1782018
21	ehealth.ti,ab,kw.	3428
22	e-health.ti,ab,kw.	3518
23	telemedicine.ti,ab,kw.	15699
24	tele-medicine*.ti,ab,kw.	243
25	teleradio*.ti,ab,kw.	2123
26	tele-radio*.ti,ab,kw.	80
27	telepathology.ti,ab,kw.	878
28	tele-pathology.ti,ab,kw.	33
29	telerehabilitation.ti,ab,kw.	867
30	tele-rehabilitation.ti,ab,kw.	196
31	teleconsult*.ti,ab,kw.	1470
32	tele-consult*.ti,ab,kw.	169
33	(telehealth or tele-health).ti,ab,kw.	5554
34	(telecare or tele-care).ti,ab,kw.	903
35	teledermatology.ti,ab,kw.	1069
36	tele-dermatology.ti,ab,kw.	29
37	telecardiology.ti,ab,kw.	298
38	tele-cardiology.ti,ab,kw.	31
39	"remote consultation*".ti,ab,kw.	462
40	(telemonitor* or tele-monitor*).ti,ab,kw.	2503
41	(telepsychiatry or tele-psychiatry).ti,ab,kw.	711
42	tediagn*.ti,ab,kw.	251
43	tele-diagn*.ti,ab,kw.	47
44	telesurgery.ti,ab,kw.	350
45	tele-surgery.ti,ab,kw.	57
46	teletherapy.ti,ab,kw.	1949
47	tele-therapy.ti,ab,kw.	29
48	Telenursing/	258
49	Telenursing.ti,ab,kw.	203
50	Tele-nursing.ti,ab,kw.	31
51	Telepharmacy.ti,ab,kw.	146
52	Tele-pharmacy.ti,ab,kw.	14
53	"electronic health".ti,ab,kw.	22032
54	"mobile health".ti,ab,kw.	3675
55	mHealth.ti,ab,kw.	3378
56	m-Health.ti,ab,kw.	646
57	"digital health".ti,ab,kw.	1460
58	("hand-held computer*" or "handheld computer*").ti,ab,kw.	845
59	("handheld device*" or "hand-held device*").ti,ab,kw.	1659

60	"tablet computer*".ti,ab,kw.	1067
61	"Tablet PC*".ti,ab,kw.	391
62	"personal digital assistant*".ti,ab,kw.	1194
63	telecommunication*.ti,ab,kw.	4067
64	tele-communication*.ti,ab,kw.	22
65	videoconferenc*.ti,ab,kw.	2843
66	video-conferenc*.ti,ab,kw.	1195
67	"video conference*".ti,ab,kw.	387
68	"cell phone*".ti,ab,kw.	3443
69	"cellular phone*".ti,ab,kw.	1226
70	cellphone*.ti,ab,kw.	490
71	cell-phone*.ti,ab,kw.	3443
72	smartphone*.ti,ab,kw.	12617
73	smart-phone*.ti,ab,kw.	2208
74	"smart phone*".ti,ab,kw.	2208
75	"Short messag* service*".ti,ab,kw.	1221
76	("Multimedia messag* service*" or "Multi-media messag* service*").ti,ab,kw.	52
77	"MMS".ti,ab,kw.	6402
78	"SMS".ti,ab,kw.	7545
79	"mobile phone*".ti,ab,kw.	9616
80	"Mobile app*".ti,ab,kw.	4834
81	"medical app*".ti,ab,kw.	13412
82	"health app*".ti,ab,kw.	6873
83	("text messag*" or text-messag*).ti,ab,kw.	4889
84	Mobile Applications/	8003
85	MP3-Player/	192
86	MP3 player*.ti,ab,kw.	185
87	MP3-player*.ti,ab,kw.	185
88	internet/ or blogging/ or social media/	119607
89	internet.ti,ab,kw.	67816
90	blog*.ti,ab,kw.	2705
91	social media.ti,ab,kw.	13535
92	facebook.ti,ab,kw.	5043
93	twitter.ti,ab,kw.	3847
94	Whatsapp.ti,ab,kw.	526
95	Instagram.ti,ab,kw.	571
96	Linked-In.ti,ab,kw.	5049
97	"Medical information system*".ti,ab,kw.	1201
98	"laboratory information system*".ti,ab,kw.	2284
99	"pharmacy information system*".ti,ab,kw.	177
100	"Hospital Information system*".ti,ab,kw.	3828
101	"nursing information system*".ti,ab,kw.	267
102	("clinical decision Support" or "decision support system").ti,ab,kw.	9014
103	electronic health records/ or medical records systems, computerized/	13833
104	("Electronic Health Record*" or "Computeri#ed Health Record*" or EHR).ti,ab,kw.	22995
105	("Electronic Medical Record*" or "Computeri#ed Medical Record*" or EMR).ti,ab,kw.	42627
106	conceptual framework/	24894
107	telehealth/ or telemedicine/ or telecardiology/ or teleconsultation/ or teleradiology/ or teleradiotherapy/ or telesurgery/ or teletherapy/	41087
108	personal digital assistant/	1390
109	mobile application/ or mobile phone/ or smartphone/	31168
110	telecommunication/ or teleconference/ or telehealth/	31266
111	blogging/ or e-mail/ or internet/ or mobile phone/ or modem/ or social media/ or telecommunication/ or telephone/ or text messaging/ or videoconferencing/ or wireless communication/	213341
112	decision support system/ or clinical decision support system/	23748
113	medical information system/ or nursing information system/	20468
114	hospital information system/ or laboratory information system/ or operating room information system/ or physician order entry system/ or "point of care system"/ or radiology information system/	23295
115	computerized provider order entry/ or electronic prescribing/	4663
116	"electronic prescri*".ti,ab,kw.	2210

117	computer assisted radiotherapy/ or computer assisted therapy/ or computer assisted drug therapy/	15079
118	computer assisted diagnosis/	39534
119	computer assisted surgery/	9197
120	computer assisted surgery system/	119
121	mobile application/	9242
122	"portable software".ti,ab,kw.	28
123	mp3 player/	192
124	("palm-top computer*" or "palmtop computer*").ti,ab,kw.	142
125	skype.ti,ab,kw.	673
126	"Health* information system* ".ab,kw,ti.	4741
127	"clinical information system* ".ab,kw,ti.	2075
128	(PDA or PDAs).ab,kw,ti.	16202
129	("electronic patient record*" or "patient health record*" or "patient portal" or PHR).ab,kw,ti.	7242
130	("computer-assisted decision" or "computer-assisted therapy" or "computer-assisted diagnosis" or "computer-assisted surgery").ab,kw,ti.	3021
131	("electronic order entry" or "computer* physician order entry").ab,kw,ti.	1514
132	(web or website*).ab,kw,ti.	161579
133	("electronic mail" or email or e-mail).ab,kw,ti.	26448
134	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10	58079
135	11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 106	10289384
136	21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87 or 88 or 89 or 90 or 91 or 92 or 93 or 94 or 95 or 96 or 97 or 98 or 99 or 100 or 101 or 102 or 103 or 104 or 105 or 107 or 108 or 109 or 110 or 111 or 112 or 113 or 114 or 115 or 116 or 117 or 118 or 119 or 120 or 121 or 122 or 123 or 124 or 125 or 126 or 127 or 128 or 129 or 130 or 131 or 132 or 133	659761
137	134 and 135 and 136	4560

Database: **Global Health** 1973 to 2019 Week 42

#	Searches	Results
1	(information adj1 quality).ab,id,ti.	392
2	(data adj1 quality).ab,id,ti.	2615
3	(information adj1 accura\$).ab,id,ti.	933
4	(data adj1 accura\$).ab,id,ti.	677
5	(information adj1 reliab\$).ab,id,ti.	696
6	(data adj1 reliab\$).ab,id,ti.	1050
7	(information adj1 audit\$).ab,id,ti.	20
8	(data adj1 audit\$).ab,id,ti.	159
9	(information adj1 valid\$).ab,id,ti.	182
10	(data adj1 valid\$).ab,id,ti.	1192
11	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10	7736
12	framework\$.ab,id,ti.	33867
13	model\$.ab,id,ti.	368714
14	scale\$.ab,id,ti.	91684
15	dimension\$.ab,id,ti.	28457
16	indicator\$.ab,id,ti.	64998
17	guideline\$.ab,id,ti.	60796
18	metric\$.ab,id,ti.	4817
19	measur\$.ab,id,ti.	468933
20	criteri\$.ab,id,ti.	82616
21	standard\$.ab,id,ti.	230183
22	(ehealth or e-health).ab,id,ti.	611
23	"electronic health".ab,id,ti.	1458
24	(telemedicine or tele-medicine).ab,id,ti.	732
25	(telenursing or tele-nursing).ab,id,ti.	11
26	(telepharmacy or tele-pharmacy).ab,id,ti.	13
27	(teleconsult\$ or tele-consult\$).ab,id,ti.	100
28	(telerehabilitation or tele-rehabilitation).ab,id,ti.	7
29	(telehealth or tele-health or telecare or tele-care).ab,id,ti.	415
30	(telediagn\$ or tele-diagn\$).ab,id,ti.	17
31	(telemonitor\$ or tele-monitor\$).ab,id,ti.	59
32	(teleradio\$ or tele-radio\$).ab,id,ti.	28
33	(telepathology or tele-pathology).ab,id,ti.	21
34	(telepsychiatry or tele-psychiatry).ab,id,ti.	33
35	(telecardiology or tele-cardiology).ab,id,ti.	12
36	(teledermatology or tele-dermatology).ab,id,ti.	57
37	(teletherapy or tele-therapy).ab,id,ti.	18
38	"remote consultation".ab,id,ti.	26
39	(telecommunication\$ or tele-communication\$).ab,id,ti.	326
40	("video conferenc\$" or videoconferenc\$ or video-conferenc\$).ab,id,ti.	246
41	telephone\$.ab,id,ti.	11223
42	(teleconferenc\$ or tele-conferenc\$).ab,id,ti.	127
43	(mHealth or m-Health or "mobile Health").ab,id,ti.	825
44	("mobile telephone\$" or "mobile phone\$").ab,id,ti.	1996
45	("cell\$ phone\$" or cellphone\$ or cell-phone\$).ab,id,ti.	756
46	("smart phone\$" or "smartphone\$" or smart-phone\$).ab,id,ti.	1138
47	("handheld computer\$" or "hand-held computer\$").ab,id,ti.	110
48	("palmtop computer\$" or "palm-top computer\$").ab,id,ti.	11
49	("tablet computer\$" or "tablet PC").ab,id,ti.	86
50	("personal digital assistant\$" or PDA or PDAs).ab,id,ti.	1919
51	"mobile app\$".ab,id,ti.	450
52	"medical app\$".ab,id,ti.	1038
53	"health app\$".ab,id,ti.	2247
54	"short messag\$ service\$".ab,id,ti.	302
55	("text messag\$" or text-messag\$).ab,id,ti.	1165
56	("multimedia messag\$ servic\$" or "multi-media messag\$ servic\$").ab,id,ti.	4
57	("mp3 player\$" or mp3-player\$).ab,id,ti.	13
58	("handheld device\$" or "hand-held device\$").ab,id,ti.	119
59	"mobile device\$".ab,id,ti.	245

60	"software app\$.ab,id,ti.	180
61	"clinical decision support".ab,id,ti.	242
62	"computer-assisted decision\$.ab,id,ti.	7
63	"computer-assisted diagnosis".ab,id,ti.	4
64	"computer-assisted therapy".ab,id,ti.	1
65	(CDSS or CDS).ab,id,ti.	1027
66	"computer-assisted surgery".ab,id,ti.	10
67	"decision support system\$.ab,id,ti.	594
68	"computer app\$.ab,id,ti.	898
69	"computer software\$.ab,id,ti.	466
70	"computer-assisted instruction\$.ab,id,ti.	24
71	decision support systems/ or computer software/	4706
72	"health information system\$.ab,id,ti.	1038
73	"medical information system\$.ab,id,ti.	48
74	"laboratory information system\$.ab,id,ti.	169
75	"pharmacy information system\$.ab,id,ti.	4
76	("electronic health record\$ or "electronic patient record\$ or EHR or "patient health record\$ or PHR).ab,id,ti.	1674
77	("electronic medical record\$ or EMR).ab,id,ti.	2280
78	"clinical information system\$.ab,id,ti.	58
79	("computeri#ed medical record\$ or "computeri#ed health record\$).ab,id,ti.	108
80	("wearable\$ or fitbit or "digital health").ab,id,ti.	416
81	("hospital information system\$ or "healthcare information system\$).ab,id,ti.	444
82	information systems/	4182
83	medical records/	2658
84	internet.ab,id,ti.	8632
85	"social network\$.ab,id,ti.	3601
86	"social media".ab,id,ti.	1540
87	blog\$.ab,id,ti.	240
88	facebook.ab,id,ti.	559
89	(twitter or tweet\$.ab,id,ti.	426
90	whatsapp.ab,id,ti.	48
91	instagram.ab,id,ti.	58
92	linked-in.ab,id,ti.	404
93	(e-mail or email or electronic mail).ab,id,ti.	1711
94	("electronic prescri\$ or eprescri\$ or e-prescri\$).ab,id,ti.	94
95	("computer\$ physician order entry" or "electronic order entry").ab,id,ti.	40
96	(web or website\$.ab,id,ti.	19259
97	"medicine 2.0".ab,id,ti.	17
98	"health 2.0".ab,id,ti.	39
99	mobile telephones/ or telephones/	3120
100	telemedicine/ or telecommunications/	1944
101	skype.ab,id,ti.	47
102	internet/ or telecommunications/ or web sites/	9369
103	social media/	1628
104	12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21	1106982
105	22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87 or 88 or 89 or 90 or 91 or 92 or 93 or 94 or 95 or 96 or 97 or 98 or 99 or 100 or 101 or 102 or 103	70398
106	11 and 104 and 105	604

Database: **PsycINFO** 1806 to October Week 2 2019

#	Searches	Results
1	(information adj1 quality).ab,id,ti.	1035
2	(data adj1 quality).ab,id,ti.	1935
3	(information adj1 accura\$).ab,id,ti.	1862
4	(data adj1 accura\$).ab,id,ti.	767
5	(information adj1 reliab\$).ab,id,ti.	1051
6	(data adj1 reliab\$).ab,id,ti.	1527
7	(information adj1 audit\$).ab,id,ti.	1464
8	(data adj1 audit\$).ab,id,ti.	193
9	(information adj1 valid\$).ab,id,ti.	654
10	(data adj1 valid\$).ab,id,ti.	2462
11	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10	12711
12	framework\$.ab,id,ti.	184547
13	model\$.ab,id,ti.	709343
14	scale\$.ab,id,ti.	361958
15	dimension\$.ab,id,ti.	164666
16	indicator\$.ab,id,ti.	64906
17	guideline\$.ab,id,ti.	59884
18	metric\$.ab,id,ti.	13788
19	measur\$.ab,id,ti.	771160
20	criteri\$.ab,id,ti.	163125
21	standard\$.ab,id,ti.	205140
22	models/	65035
23	(ehealth or e-health).ab,id,ti.	1636
24	"electronic health".ab,id,ti.	1856
25	(telemedicine or tele-medicine).ab,id,ti.	1880
26	(telenursing or tele-nursing).ab,id,ti.	61
27	(telepharmacy or tele-pharmacy).ab,id,ti.	5
28	(teleconsult\$ or tele-consult\$).ab,id,ti.	176
29	(telerehabilitation or tele-rehabilitation).ab,id,ti.	200
30	(telehealth or tele-health or telecare or tele-care).ab,id,ti.	1696
31	(telediagn\$ or tele-diagn\$).ab,id,ti.	17
32	(telemonitor\$ or tele-monitor\$).ab,id,ti.	183
33	(teleradio\$ or tele-radio\$).ab,id,ti.	43
34	(telepathology or tele-pathology).ab,id,ti.	14
35	(telepsychiatry or tele-psychiatry).ab,id,ti.	469
36	(telecardiology or tele-cardiology).ab,id,ti.	14
37	(teledermatology or tele-dermatology).ab,id,ti.	43
38	(teletherapy or tele-therapy).ab,id,ti.	80
39	"remote consultation".ab,id,ti.	31
40	(telecommunication\$ or tele-communication\$).ab,id,ti.	2040
41	("video conferenc\$" or videoconferenc\$ or video-conferenc\$).ab,id,ti.	1769
42	telephone\$.ab,id,ti.	23483
43	(teleconferenc\$ or tele-conferenc\$).ab,id,ti.	444
44	telecommunications media/ or telephone systems/ or teleconferencing/ or telemedicine/	8590
45	(mHealth or m-Health or "mobile Health").ab,id,ti.	1263
46	("mobile telephone" or "mobile phone\$").ab,id,ti.	3447
47	("cell\$ phone\$" or cellphone\$ or cell-phone\$).ab,id,ti.	2082
48	("smart phone\$" or "smartphone\$" or smart-phone\$).ab,id,ti.	3711
49	("handheld computer\$" or "hand-held computer\$").ab,id,ti.	389
50	("palmtop computer\$" or "palm-top computer\$").ab,id,ti.	133
51	("tablet computer\$" or "tablet PC").ab,id,ti.	400
52	("personal digital assistant\$" or PDA or PDAs).ab,id,ti.	1065
53	"mobile app\$".ab,id,ti.	1257
54	"medical app\$".ab,id,ti.	1120
55	"health app\$".ab,id,ti.	2276
56	"short messag\$ service\$".ab,id,ti.	426
57	("text messag\$" or text-messag\$).ab,id,ti.	2113
58	("multimedia messag\$ servic\$" or "multi-media messag\$ servic\$").ab,id,ti.	19

59	("mp3 player\$" or mp3-player\$).ab,id,ti.	143
60	("handheld device\$" or "hand-held device\$" or "mobile device\$").ab,id,ti.	2292
61	("assist\$ living device\$" or wearable\$ or fitbit or "digital health").ab,id,ti.	1282
62	mobile devices/ or cellular phones/ or text messaging/	6981
63	"software app\$".ab,id,ti.	550
64	"clinical decision support".ab,id,ti.	400
65	"computer-assisted decision\$".ab,id,ti.	21
66	"computer-assisted diagnos#s".ab,id,ti.	51
67	"computer-assisted therapy".ab,id,ti.	88
68	(CDSS or CDS).ab,id,ti.	1343
69	"computer-assisted surgery".ab,id,ti.	7
70	"decision support system\$".ab,id,ti.	1916
71	"computer app\$".ab,id,ti.	1134
72	"computer software\$".ab,id,ti.	1642
73	"computer-assisted instruction\$".ab,id,ti.	1802
74	computer applications/ or computer assisted diagnosis/ or computer assisted instruction/ or computer assisted testing/ or computer assisted therapy/	31947
75	decision support systems/ or computer software/	13170
76	"health\$ information system\$".ab,id,ti.	275
77	"medical information system\$".ab,id,ti.	62
78	"laboratory information system\$".ab,id,ti.	13
79	"pharmacy information system\$".ab,id,ti.	5
80	("electronic health record\$" or EHR).ab,id,ti.	1682
81	("electronic medical record\$" or EMR or "electronic patient record\$" or "patient health record\$" or PHR or "patient portal").ab,id,ti.	2661
82	"clinical information system\$".ab,id,ti.	114
83	"computeri#ed medical record\$".ab,id,ti.	74
84	"computeri#ed health record\$".ab,id,ti.	4
85	skype.ab,id,ti.	428
86	"hospital information system\$".ab,id,ti.	85
87	information systems/	5329
88	medical records/	2854
89	internet.ab,id,ti.	38769
90	"world wide web".ab,id,ti.	1614
91	("social media" or "social network\$").ab,id,ti.	33596
92	blog\$.ab,id,ti.	3113
93	facebook.ab,id,ti.	4831
94	(twitter or tweet\$).ab,id,ti.	2679
95	whatsapp.ab,id,ti.	110
96	instagram.ab,id,ti.	359
97	linkedin.ab,id,ti.	271
98	(e-mail or email or "electronic mail").ab,id,ti.	7686
99	computer mediated communication/ or electronic communication/ or blog/ or online community/ or online social networks/ or online therapy/ or social media/	23658
100	internet/ or websites/	31599
101	("electronic prescri\$" or eprescri\$ or e-prescri\$).ab,id,ti.	105
102	("computer\$ physician order entry" or "electronic order entry").ab,id,ti.	54
103	(web or website\$).ab,id,ti.	42674
104	"medicine 2.0".ab,id,ti.	21
105	"health 2.0".ab,id,ti.	79
106	23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87 or 88 or 89 or 90 or 91 or 92 or 93 or 94 or 95 or 96 or 97 or 98 or 99 or 100 or 101 or 102 or 103 or 104 or 105	204984
107	12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22	1926514
108	11 and 106 and 107	1107

Database: **Ovid MEDLINE(R) ALL** 1946 to October 22, 2019

#	Searches	Results
1	(information adj1 quality).ti,ab,kw.	2053
2	(data adj1 quality).ti,ab,kw.	11608
3	(information adj1 reliab*).ti,ab,kw.	3982
4	(data adj1 reliab*).ti,ab,kw.	5310
5	(information adj1 valid*).ti,ab,kw.	1036
6	(data adj1 valid*).ti,ab,kw.	6674
7	(information adj1 audit*).ti,ab,kw.	1692
8	(data adj1 audit*).ti,ab,kw.	922
9	data accuracy/ or (data adj1 accura*).ti,ab,kw. or (information adj1 accura*).ti,ab,kw.	10861
10	framework*.ti,ab,kw.	254226
11	dimension*.ti,ab,kw.	544302
12	scale*.ti,ab,kw.	772185
13	indicator*.ti,ab,kw.	264171
14	guideline*.ti,ab,kw.	327002
15	metric*.ti,ab,kw.	55858
16	measur*.ti,ab,kw.	3332908
17	criteri*.ti,ab,kw.	612815
18	model*.ti,ab,kw.	2721661
19	standard*.ti,ab,kw.	1200229
20	Models, Theoretical/	146181
21	(ehealth or e-health or "electronic health").ti,ab,kw.	19309
22	telemedicine/ or telepathology/ or teleradiology/ or telerehabilitation/	22733
23	(telemedicine or tele-medicine).ti,ab,kw.	11416
24	(teleradio* or tele-radio*).ti,ab,kw.	1638
25	(telepathology or tele-pathology).ti,ab,kw.	688
26	(telerehabilitation or tele-rehabilitation).ti,ab,kw.	808
27	(teleconsult* or tele-consult*).ti,ab,kw.	1222
28	(telehealth or tele-health).ti,ab,kw.	4318
29	(teledermatology or tele-dermatology).ti,ab,kw.	705
30	(telecardiology or tele-cardiology).ti,ab,kw.	230
31	"remote consultation*".ti,ab,kw.	326
32	(telemonitor* or tele-monitor*).ti,ab,kw.	1570
33	(tediagn* or tele-diagn*).ti,ab,kw.	220
34	(telesurgery or tele-surgery).ti,ab,kw.	286
35	(telepsychiatry or tele-psychiatry).ti,ab,kw.	559
36	(teletherapy or tele-therapy).ti,ab,kw.	1349
37	Telenursing/	205
38	(telenursing or tele-nursing).ti,ab,kw.	198
39	(telepharmacy or tele-pharmacy).ti,ab,kw.	84
40	(mHealth or m-Health or "mobile health").ti,ab,kw.	5938
41	("digital health" or fitbit or wearable*).ti,ab,kw.	11771
42	computers, handheld/	3444
43	("hand-held computer*" or "handheld computer*" or "hand-held device*" or "handheld device").ti,ab,kw.	1746
44	("palmtop computer*" or "palm-top computer").ti,ab,kw.	132
45	("tablet computer*" or tablet PC).ti,ab,kw.	893
46	skype.ti,ab,kw.	319
47	("personal digital assistant*" or PDA or PDAs).ti,ab,kw.	11752
48	"assist* living device".ti,ab,kw.	1
49	telecommunications/ or telephone/ or videoconferencing/	17289
50	(telecommunication* or tele-communication*).ti,ab,kw.	4104
51	(videoconferenc* or video-conferenc* or "video conferenc").ti,ab,kw.	2642
52	(cellphone* or cell-phone* or "cell phone*" or "cellular phone").ti,ab,kw.	3540
53	cell phones/ or smartphone/ or text messaging/	13094
54	(smartphone* or smart-phone* or "smart phone").ti,ab,kw.	10313
55	("Short messag* service*" or SMS).ti,ab,kw.	5802
56	("Multimedia messag* service*" or "Multi-media messag* service*" or MMS).ti,ab,kw.	4580
57	"mobile device".ti,ab,kw.	2836
58	"software app".ti,ab,kw.	1903
59	"mobile phone".ti,ab,kw.	7920

60	"Mobile app*".ti,ab,kw.	3914
61	"medical app*".ti,ab,kw.	10047
62	"health app*".ti,ab,kw.	5616
63	("text messag*" or text-messag*).ti,ab,kw.	3736
64	Mobile Applications/	4682
65	MP3-Player/	181
66	MP3 player*.ti,ab,kw.	114
67	MP3-player*.ti,ab,kw.	114
68	internet/ or blogging/ or social media/	75832
69	(internet or web or website*).ti,ab,kw.	159917
70	blog*.ti,ab,kw.	1706
71	social media.ti,ab,kw.	9496
72	facebook.ti,ab,kw.	3131
73	(twitter or tweet*).ti,ab,kw.	3740
74	Whatsapp.ti,ab,kw.	304
75	Instagram.ti,ab,kw.	360
76	LinkedIn.ti,ab,kw.	140
77	health information systems/ or clinical laboratory information systems/ or clinical pharmacy information systems/ or hospital information systems/	15020
78	Health Information system*.ti,ab,kw.	3381
79	("Medical information system*" or "Clinical information system").ti,ab,kw.	2426
80	"laboratory information system".ti,ab,kw.	957
81	"pharmacy information system".ti,ab,kw.	96
82	"Hospital Information system".ti,ab,kw.	2559
83	"Nursing Information System".ti,ab,kw.	248
84	"Decision Support".ti,ab,kw.	13567
85	electronic health records/ or medical records systems, computerized/	36228
86	("electronic health record*" or "electronic medical record*" or "electronic patient record*" or "patient health record*" or EHR or EMR or PHR or "computeri#ed health record*" or "computeri#ed medical record*" or "patient portal").ti,ab,kw.	37353
87	"Electronic Medical Record".ti,ab,kw.	14857
88	Electronic Prescribing/	976
89	"electronic prescri*".ti,ab,kw.	1047
90	hospital information systems/ or ambulatory care information systems/ or medical order entry systems/ or operating room information systems/	14383
91	medical order entry systems/ or online systems/ or decision support systems, clinical/	17233
92	decision making, computer-assisted/ or diagnosis, computer-assisted/ or image interpretation, computer-assisted/ or radiographic image interpretation, computer-assisted/ or therapy, computer-assisted/ or drug therapy, computer-assisted/ or radiotherapy, computer-assisted/ or surgery, computer-assisted/	105689
93	("computer* physician order entry" or "electronic order entry").ti,ab,kw.	915
94	("medicine 2.0" or "health 2.0").ti,ab,kw.	196
95	(email or e-mail or "electronic mail").ti,ab,kw.	12668
96	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9	42802
97	21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87 or 88 or 89 or 90 or 91 or 92 or 93 or 94 or 95	506048
98	10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20	7763544
99	96 and 97 and 98	3543

Interface - EBSCOhost Research Databases

Database – CINAHL

Search modes - Boolean/Phrase

Friday, October 25, 2019 8:21:28 AM

#	Query	Results
S68	S65 AND S66 AND S67	1,744
S67	S48 OR S49 OR S50 OR S51 OR S52	13,857
S66	S53 OR S54 OR S55 OR S56 OR S57 OR S58 OR S59 OR S60 OR S61 OR S62 OR S63 OR S64	1,460,243
S65	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32 OR S33 OR S34 OR S35 OR S36 OR S37 OR S38 OR S39 OR S40 OR S41 OR S42 OR S43 OR S44 OR S45 OR S46 OR S47	275,283
S64	(MH "Models, Theoretical")	41,146
S63	(MH "Conceptual Framework")	39,808
S62	TI standard* OR AB standard*	263,577
S61	TI criteri* OR AB criteri*	152,590
S60	TI measur* OR AB measur*	622,527
S59	TI metric* OR AB metric*	12,879
S58	TI guideline* OR AB guideline*	124,798
S57	TI indicator* OR AB indicator*	54,469
S56	TI dimension* OR AB dimension*	67,532
S55	TI scale* OR AB Scale*	194,059
S54	TI model* OR AB model*	427,257
S53	TI framework* OR AB framework*	73,896
S52	TI information N1 audit* OR AB information N1 audit* OR TI data N1 audit* OR AB data N1 audit*	1,020
S51	TI information N1 reliab* OR AB information N1 reliab* OR TI data N1 reliab* OR AB data N1 reliab*	3,070
S50	TI information N1 valid* OR AB information N1 valid* OR TI information N1 valid* OR AB information N1 valid*	575
S49	TI information N1 accura* OR AB information N1 accura* OR TI information N1 accura* OR AB information N1 accura*	2,291
S48	TI information N1 quality OR AB information N1 quality OR TI data N1 quality OR AB data N1 quality	7,214
S47	(MH "Blogs")	2,935
S46	(MH "Social Media")	11,694
S45	(MH "Internet")	44,106
S44	TI (internet or "social media" or "social network*" or web or website or facebook or email or e-mail or "electronic mail" or linkedin or whatsapp or skype or instagram or blog*) OR AB (internet or "social media" or "social network*" or web or website or facebook or email or e-mail or "electronic mail" or linkedin or whatsapp or skype or instagram or blog*)	99,829
S43	(MH "Electronic Order Entry")	2,926
S42	TI ("electronic order entry" or "computeri#ed order entry" or "computeri#ed physician order entry" or eprescri* or e-prescri*) OR AB ("electronic order entry" or "computeri#ed order entry" or "computeri#ed physician order entry" or eprescri* or e-prescri*)	1,068
S41	TI ("computeri#ed medical record*" or "computeri#ed patient record*" or "computeri#ed health record*") OR AB ("computeri#ed medical record*" or "computeri#ed patient record*" or "computeri#ed health record*")	412
S40	(MH "Computerized Patient Record")	481
S39	TI ("electronic health record*" or "electronic medical record*" or "EMR" or "EHR" or "patient health record*" or "PHR" or "electronic patient record*" or "patient portal") OR AB ("electronic health record*" or "electronic medical record*" or "EMR" or "EHR" or "patient health record*" or "PHR" or "electronic patient record*" or "patient portal")	20,249
S38	(MH "Nursing Information Systems") OR (MH "Radiology Information Systems")	2,540
S37	(MH "Clinical Pharmacy Information Systems")	1,041
S36	(MH "Clinical Laboratory Information Systems")	882
S35	(MH "Health Information Systems") OR (MH "Home Health Care Information Systems") OR (MH "Hospital Information Systems") OR (MH "Operating Room Information Systems") OR (MH "Clinical Information Systems") OR (MH "Patient Record Systems") OR (MH "Clinical Pharmacy Information Systems") OR (MH "Emergency Service Information Systems")	21,042
S34	TI ("health information system*" OR "healthcare information system*" OR "medical information system*" OR "laboratory information system*" OR "pharmacy information	477

	system*" OR "nursing information system*" OR "clinical information system*" OR "hospital information system*") AND AB ("health information system*" OR "healthcare information system*" OR "medical information system*" OR "laboratory information system*" OR "pharmacy information system*" OR "nursing information system*" OR "clinical information system*" OR "hospital information system*")	
S33	(MH "Diagnosis, Computer Assisted") OR (MH "Surgery, Computer-Assisted") OR (MH "Therapy, Computer Assisted") OR (MH "Radiographic Image Interpretation, Computer-Assisted") OR (MH "Drug Therapy, Computer Assisted") OR (MH "Radiotherapy, Computer-Assisted") OR (MH "Image Interpretation, Computer Assisted") OR (MH "Decision Making, Computer Assisted")	27,834
S32	(MH "Decision Support Systems, Clinical")	4,524
S31	TI ("computer app*" or "computer software*") OR AB ("computer app*" or "computer software*")	1,643
S30	TI ("software app*" or "clinical decision support" or "decision support system*" or "computer-assisted decision*" or "computer-assisted diagnos#s" or "computer-assisted therapy" or "CDS" or "CDSS" or "computer-assisted surgery" or "computer-assisted radiology") OR AB ("software app*" or "clinical decision support" or "decision support system*" or "computer-assisted decision*" or "computer-assisted diagnos#s" or "computer-assisted therapy" or "CDS" or "CDSS" or "computer-assisted surgery" or "computer-assisted radiology")	5,024
S29	(MH "Smartphone") OR (MH "Text Messaging") OR (MH "Mobile Applications") OR (MH "Computers, Hand-Held") OR (MH "Cellular Phone")	14,471
S28	TI ("mp3 player*" or "mp3-player*") OR AB ("mp3 player*" or "mp3-player*")	81
S27	TI ("short messag* service*" or "text messag*" or text-messag* or "multimedia messag* service*" or "multi-media messag* service*") OR AB ("short messag* service*" or "text messag*" or text-messag* or "multimedia messag* service*" or "multi-media messag* service*")	2,643
S26	TI ("mobile app*" or "medical app*" or "health app*") OR AB ("mobile app*" or "medical app*" or "health app*")	6,084
S25	TI ("personal digital assistant*" or "PDA" or "PDAs") OR AB ("personal digital assistant*" or "PDA" or "PDAs")	2,076
S24	TI ("palmtop computer*" or "palm-top computer*" or "tablet computer*" or "tablet PC") OR AB ("palmtop computer*" or "palm-top computer*" or "tablet computer*" or "tablet PC")	523
S23	TI ("handheld computer*" or "hand-held computer*" or "handheld device*" or "hand-held device*") OR AB ("handheld computer*" or "hand-held computer*" or "handheld device*" or "hand-held device*")	705
S22	TI (smartphone* or smart-phone* or "smart phone*") OR AB (smartphone* or smart-phone* or "smart phone*")	4,827
S21	TI ("cell* phone*" or cellphone* or cell-phone*) OR AB ("cell* phone*" or cellphone* or cell-phone*)	1,648
S20	TI ("mobile phone*" or "mobile telephone*" or "mobile device*") OR AB ("mobile phone*" or "mobile telephone*" or "mobile device*")	4,282
S19	TI (mhealth or "mobile health" or m-health) OR AB (mhealth or "mobile health" or m-health)	2,262
S18	(MH "Remote Consultation") OR (MH "Telephone Consultation (Iowa NIC)")	1,742
S17	(MH "Teleconferencing")	1,319
S16	(MH "Telehealth")	6,825
S15	(MH "Telepathology")	142
S14	(MH "Telecommunications")	2,145
S13	(MH "Telephone")	15,379
S12	(MH "Teleradiology")	463
S11	(MH "Telepsychiatry")	300
S10	(MH "Telenursing")	1,926
S9	(MH "Telemedicine") OR (MH "Telepsychiatry") OR (MH "Telehealth")	16,471
S8	TI (teleconferenc* or tele-conferenc*) OR AB (teleconferenc* or tele-conferenc*) OR TI (videoconferenc* or video-conferenc* or "video conferenc*") OR AB (videoconferenc* or video-conferenc* or "video conferenc*")	1,985
S7	TI (tele-phone* or telephone* or telecommunication* or tele-communication*) OR AB (tele-phone* or telephone* or telecommunication* or tele-communication*)	27,326
S6	TI "remote consultation" OR AB "remote consultation"	46
S5	TI (telepathology or telecardiology or telepsychiatry or teleradio* or teledermatology) OR AB (telepathology or telecardiology or telepsychiatry or teleradio* or teledermatology) OR	1,090

	TI (tele-pathology or tele-cardiology or tele-psychiatry or tele-radio* or tele-dermatology) OR AB (tele-pathology or tele-cardiology or tele-psychiatry or tele-radio* or tele-dermatology)	
S4	TI (telenursing or telepharmacy or telerehabilitation or tele-nursing or tele-pharmacy or tele-rehabilitation) OR AB (telenursing or telepharmacy or telerehabilitation or tele-nursing or tele-pharmacy or tele-rehabilitation)	647
S3	TI (teleconsult* or telediag* or telemonitor* or tele-consult* or tele-diag* or tele-monitor* or teletherapy or tele-therapy) OR AB (teleconsult* or telediag* or telemonitor* or tele-consult* or tele-diag* or tele-monitor* or teletherapy or tele-therapy)	1,214
S2	TI (telemedicine or telehealth or telecare or tele-medicine or tele-health or tele-care) OR AB (telemedicine or telehealth or telecare or tele-medicine or tele-health or tele-care)	7,614
S1	TI ("electronic health" or ehealth or e-health) OR AB ("electronic health" or ehealth or e-health)	12,120

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Set#	Searched for	Results
S2	ti(framework* OR model* OR scale* OR dimension* OR indicator* OR guideline* OR standard* OR measur* OR metric* OR criteri*) OR ab(framework* OR model* OR scale* OR dimension* OR indicator* OR guideline* OR standard* OR measur* OR metric* OR criteri*)	2001228
S3	(ti(information NEAR/1 quality) OR ab(information NEAR/1 quality) OR ti(data NEAR/1 quality) OR ab(data NEAR/1 quality)) OR (ti(information NEAR/1 accura*) OR ab(information NEAR/1 accura*) OR ti(data NEAR/1 accura*) OR ab(data NEAR/1 accura*)) OR (ti(information NEAR/1 reliab*) OR ab(information NEAR/1 reliab*) OR ti(data NEAR/1 reliab*) OR ab(data NEAR/1 reliab*)) OR (ti(information NEAR/1 valid*) OR ab(information NEAR/1 valid*) OR ti(data NEAR/1 valid*) OR ab(data NEAR/1 valid*))	23135
S4	(ti("health information system*" OR "healthcare information system*" OR "medical information system*" OR "laboratory information system*" OR "pharmacy information system*" OR "nursing information system*" OR "clinical information system*" OR "hospital information system*") OR ab("health information system*" OR "healthcare information system*" OR "medical information system*" OR "laboratory information system*" OR "pharmacy information system*" OR "nursing information system*" OR "clinical information system*" OR "hospital information system*")) OR (ti("electronic health record*" OR "electronic medical record*" OR "EMR" OR "EHR" OR "patient health record*" OR "PHR" OR "electronic patient record*" OR "patient portal") OR ab("electronic health record*" OR "electronic medical record*" OR "EMR" OR "EHR" OR "patient health record*" OR "PHR" OR "electronic patient record*" OR "patient portal")) OR (ti("clinical decision support" OR "decision support system*" OR "computer-assisted decision*" OR "computer-assisted diagnos#s" OR "computer-assisted therapy" OR "CDS" OR "CDSS" OR "computer-assisted surgery" OR "computer-assisted radio*") OR ab("clinical decision support" OR "decision support system*" OR "computer-assisted decision*" OR "computer-assisted diagnos#s" OR "computer-assisted therapy" OR "CDS" OR "CDSS" OR "computer-assisted surgery" OR "computer-assisted radio*")) OR (ti("electronic order entry" OR "computerized order entry" OR "computerized physician order entry" OR eprescri* OR e-prescri* OR "computerised order entry" OR "computerised physician order entry") OR ab("electronic order entry" OR "computerized order entry" OR "computerized physician order entry" OR eprescri* OR e-prescri* OR "computerised order entry" OR "computerised physician order entry")) OR (ti("computerized medical record*" OR "computerized patient record*" OR "computerized health record*" OR ab("computerized medical record*" OR "computerized patient record*" OR "computerized health record*")) OR (ti(medical NEAR/4 app*) OR ab(medical NEAR/4 app*) OR ti(health NEAR/4 app*) OR ab(health NEAR/4 app*)) OR (ti(telepathology OR telecardiology OR telepsychiatry OR teleradio* OR teledermatology) OR ab(telepathology OR telecardiology OR telepsychiatry OR teleradio* OR teledermatology)) OR (ti(telemedicine OR telehealth OR telecare OR tele-medicine OR tele-health OR tele-care) OR ab(telemedicine OR telehealth OR telecare OR tele-medicine OR tele-health OR tele-care)) OR (ab(teleconsult* OR telediag* OR telemonitor* OR tele-consult* OR tele-diag* OR tele-monitor* OR teletherapy OR tele-therapy) OR ti(teleconsult* OR telediag* OR telemonitor* OR tele-consult* OR tele-diag* OR tele-monitor* OR teletherapy OR tele-therapy)) OR (ab(telenursing OR telepharmacy OR telerehabilitation OR tele-nursing OR tele-pharmacy OR tele-rehabilitation) OR ti(telenursing OR telepharmacy OR telerehabilitation OR tele-nursing OR tele-pharmacy OR tele-rehabilitation)) OR (ti("remote consultation") OR ab("remote consultation")) OR (ti(tele-pathology OR tele-cardiology OR tele-psychiatry OR tele-radio* OR tele-dermatology) OR ab(tele-pathology OR tele-cardiology OR tele-psychiatry OR tele-radio* OR tele-dermatology)) OR (ti("electronic health" OR ehealth OR e-health)) OR ab("electronic health" OR ehealth OR e-health))	18163
S5	(ti(framework* OR model* OR scale* OR dimension* OR indicator* OR guideline* OR standard* OR measur* OR metric* OR criteri*) OR ab(framework* OR model* OR scale* OR dimension* OR indicator* OR guideline* OR standard* OR measur* OR metric* OR criteri*)) AND ((ti(information NEAR/1 quality) OR ab(information NEAR/1 quality) OR ti(data NEAR/1 quality) OR ab(data NEAR/1 quality)) OR (ti(information NEAR/1 accura*) OR ab(information NEAR/1 accura*) OR ti(data NEAR/1 accura*) OR ab(data NEAR/1 accura*)) OR (ti(information NEAR/1 reliab*) OR ab(information NEAR/1 reliab*) OR ti(data NEAR/1 reliab*) OR ab(data NEAR/1 reliab*)) OR (ti(information NEAR/1 valid*) OR ab(information NEAR/1 valid*) OR ti(data NEAR/1 valid*) OR ab(data NEAR/1 valid*))) AND ((ti("health information system*" OR "healthcare information system*" OR "medical information system*" OR "laboratory information system*" OR "pharmacy information system*" OR "nursing information system*" OR "clinical information system*" OR "hospital information system*") OR ab("health information system*" OR "healthcare information system*" OR "medical information system*" OR "laboratory information system*" OR "pharmacy information system*" OR "nursing information system*" OR "clinical information system*" OR "hospital information system*"))	334

"hospital information system*")) OR (ti("electronic health record*" OR "electronic medical record*" OR "EMR" OR "EHR" OR "patient health record*" OR "PHR" OR "electronic patient record*" OR "patient portal") OR ab("electronic health record*" OR "electronic medical record*" OR "EMR" OR "EHR" OR "patient health record*" OR "PHR" OR "electronic patient record*" OR "patient portal")) OR (ti("clinical decision support" OR "decision support system*" OR "computer-assisted decision*" OR "computer-assisted diagnos#s" OR "computer-assisted therapy" OR "CDS" OR "CDSS" OR "computer-assisted surgery" OR "computer-assisted radio*") OR ab("clinical decision support" OR "decision support system*" OR "computer-assisted decision*" OR "computer-assisted diagnos#s" OR "computer-assisted therapy" OR "CDS" OR "CDSS" OR "computer-assisted surgery" OR "computer-assisted radio*")) OR (ti("electronic order entry" OR "computerized order entry" OR "computerized physician order entry" OR eprescri* OR e-prescri* OR "computerised order entry" OR "computerised physician order entry") OR ab("electronic order entry" OR "computerized order entry" OR "computerized physician order entry" OR eprescri* OR e-prescri* OR "computerised order entry" OR "computerised physician order entry")) OR (ti("computerized medical record*" OR "computerized patient record*" OR "computerized health record*") OR ab("computerized medical record*" OR "computerized patient record*" OR "computerized health record*")) OR (ti(medical NEAR/4 app*) OR ab(medical NEAR/4 app*) OR ti(health NEAR/4 app*) OR ab(health NEAR/4 app*)) OR (ti(telepathology OR telecardiology OR telepsychiatry OR teleradio* OR teledermatology) OR ab(telepathology OR telecardiology OR telepsychiatry OR teleradio* OR teledermatology)) OR (ti(telemedicine OR telehealth OR telecare OR tele-medicine OR tele-health OR tele-care) OR ab(telemedicine OR telehealth OR telecare OR tele-medicine OR tele-health OR tele-care)) OR (ab(teleconsult* OR telediag* OR telemonitor* OR tele-consult* OR tele-diag* OR tele-monitor* OR teletherapy OR tele-therapy) OR ti(teleconsult* OR telediag* OR telemonitor* OR tele-consult* OR tele-diag* OR tele-monitor* OR teletherapy OR tele-therapy)) OR (ab(telenursing OR telepharmacy OR telerehabilitation OR tele-nursing OR tele-pharmacy OR tele-rehabilitation) OR ti(telenursing OR telepharmacy OR telerehabilitation OR tele-nursing OR tele-pharmacy OR tele-rehabilitation)) OR (ti("remote consultation") OR ab("remote consultation")) OR (ti(telepathology OR tele-cardiology OR tele-psychiatry OR tele-radio* OR tele-dermatology) OR ab(telepathology OR tele-cardiology OR tele-psychiatry OR tele-radio* OR tele-dermatology)) OR (ti("electronic health" OR ehealth OR e-health) OR ab("electronic health" OR ehealth OR e-health)))	
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Database: Scopus

History Count	Search Terms	Results
12	((TITLE-ABS-KEY (information W/1 quality) OR TITLE-ABS-KEY (data W/1 quality) OR TITLE-ABS-KEY (information W/1 valid*) OR TITLE-ABS-KEY (data W/1 valid*) OR TITLE-ABS-KEY (data W/1 reliab*) OR TITLE-ABS-KEY (information W/1 reliab*) OR TITLE-ABS-KEY (data W/1 accura*) OR TITLE-ABS-KEY (information W/1 accura*) OR TITLE-ABS-KEY (data W/1 audit*) OR TITLE-ABS-KEY (information W/1 audit*))) AND ((TITLE-ABS-KEY (framework*) OR TITLE-ABS-KEY (model*) OR TITLE-ABS-KEY (scale*) OR TITLE-ABS-KEY (dimension*) OR TITLE-ABS-KEY (indicator*) OR TITLE-ABS-KEY (guideline*) OR TITLE-ABS-KEY (metric*) OR TITLE-ABS-KEY (measur*) OR TITLE-ABS-KEY (criteri*) OR TITLE-ABS-KEY (standard*))) AND ((TITLE-ABS-KEY (ehealth) OR TITLE-ABS-KEY (e-health) OR TITLE-ABS-KEY ("electronic health") OR TITLE-ABS-KEY (telemedicine) OR TITLE-ABS-KEY (telemedicine) OR TITLE-ABS-KEY (telenursing) OR TITLE-ABS-KEY (tele-nursing) OR TITLE-ABS-KEY (telepharmacy) OR TITLE-ABS-KEY (telepharmacy) OR TITLE-ABS-KEY (teleconsult*) OR TITLE-ABS-KEY (teleconsult*) OR TITLE-ABS-KEY (telerehabilitation) OR TITLE-ABS-KEY (telerehabilitation) OR TITLE-ABS-KEY (teleradio*) OR TITLE-ABS-KEY (teleradio*) OR TITLE-ABS-KEY (telehealth) OR TITLE-ABS-KEY (telehealth) OR TITLE-ABS-KEY (telediagn*) OR TITLE-ABS-KEY (telediagn*) OR TITLE-ABS-KEY (telepathology) OR TITLE-ABS-KEY (telepathology) OR TITLE-ABS-KEY (telepsychiatry) OR TITLE-ABS-KEY (telepsychiatry) OR TITLE-ABS-KEY (telecardiology) OR TITLE-ABS-KEY (telecardiology) OR TITLE-ABS-KEY (teledermatology) OR TITLE-ABS-KEY (teledermatology) OR TITLE-ABS-KEY ("remote consultation") OR TITLE-ABS-KEY (teletherapy) OR TITLE-ABS-KEY (teletherapy) OR TITLE-ABS-KEY (telecare) OR TITLE-ABS-KEY (tele-care)))) OR ((TITLE-ABS-KEY ("mobile health") OR TITLE-ABS-KEY (mhealth) OR TITLE-ABS-KEY (mhealth) OR TITLE-ABS-KEY ("health W/4 app*") OR TITLE-ABS-KEY ("medical W/4 app*"))) OR ((TITLE-ABS-KEY ("clinical decision support") OR TITLE-ABS-KEY ("computer-assisted decision*") OR TITLE-ABS-KEY ("computer-assisted diagnosis") OR TITLE-ABS-KEY ("computer-assisted therapy") OR TITLE-ABS-KEY ("computer-assisted surgery") OR TITLE-ABS-KEY ("computer-assisted radiology") OR TITLE-ABS-KEY ("decision support system*")))) OR ((TITLE-ABS-KEY ("health information system*") OR TITLE-ABS-KEY ("medical information system*") OR TITLE-ABS-KEY ("healthcare information system*") OR TITLE-ABS-KEY ("clinical information system*") OR TITLE-ABS-KEY ("laboratory information system*") OR TITLE-ABS-KEY ("pharmacy information system*") OR TITLE-ABS-KEY ("nursing information system*") OR TITLE-ABS-KEY ("hospital information system*") OR TITLE-ABS-KEY ("operating room information system*")))) OR ((TITLE-ABS-KEY ("digital health") OR TITLE-ABS-KEY (wearable*) OR TITLE-ABS-KEY (fitbit) OR TITLE-ABS-KEY ("assistive living device*") OR TITLE-ABS-KEY ("assisted living device*")))) OR ((TITLE-ABS-KEY (epriscr*) OR TITLE-ABS-KEY ("electronic order entry") OR TITLE-ABS-KEY ("computer physician order entry") OR TITLE-ABS-KEY ("computeri#ed physician order entry") OR TITLE-ABS-KEY ("electronic physician order entry") OR TITLE-ABS-KEY (e-prescr*)))) OR ((TITLE-ABS-KEY ("web-based health service*") OR TITLE-ABS-KEY ("health 2.0") OR TITLE-ABS-KEY ("medicine 2.0")))) OR ((TITLE-ABS-KEY ("electronic health record*") OR TITLE-ABS-KEY ("electronic medical record*") OR TITLE-ABS-KEY ("electronic patient record*") OR TITLE-ABS-KEY ("computeri#ed health record*") OR TITLE-ABS-KEY ("computeri#ed medical record*") OR TITLE-ABS-KEY ("patient portal") OR TITLE-ABS-KEY ("patient health record*") OR TITLE-ABS-KEY (ehr) OR TITLE-ABS-KEY (emr) OR TITLE-ABS-KEY (phr)))) ...View More	5,461 document results

11	((TITLE-ABS-KEY (ehealth) OR TITLE-ABS-KEY (e-health) OR TITLE-ABS-KEY ("electronic health") OR TITLE-ABS-KEY (telemedicine) OR TITLE-ABS-KEY (telemedicine) OR TITLE-ABS-KEY (telenursing) OR TITLE-ABS-KEY (tele-nursing) OR TITLE-ABS-KEY (telepharmacy) OR TITLE-ABS-KEY (tele-pharmacy) OR TITLE-ABS-KEY (teleconsult*) OR TITLE-ABS-KEY (tele-consult*) OR TITLE-ABS-KEY (telerehabilitation) OR TITLE-ABS-KEY (tele-rehabilitation) OR TITLE-ABS-KEY (teleradio*) OR TITLE-ABS-KEY (tele-radio*) OR TITLE-ABS-KEY (telehealth) OR TITLE-ABS-KEY (tele-health) OR TITLE-ABS-KEY (tediagn*) OR TITLE-ABS-KEY (tele-diagn*) OR TITLE-ABS-KEY (telepathology) OR TITLE-ABS-KEY (tele-pathology) OR TITLE-ABS-KEY (telepsychiatry) OR TITLE-ABS-KEY (tele-psychiatry) OR TITLE-ABS-KEY (telecardiology) OR TITLE-ABS-KEY (tele-dermatology) OR TITLE-ABS-KEY (teledermatology) OR TITLE-ABS-KEY ("remote consultation") OR TITLE-ABS-KEY (teletherapy) OR TITLE-ABS-KEY (teletherapy) OR TITLE-ABS-KEY (telecare) OR TITLE-ABS-KEY (tele-care))) OR ((TITLE-ABS-KEY ("mobile health") OR TITLE-ABS-KEY (mhealth) OR TITLE-ABS-KEY (m-health) OR TITLE-ABS-KEY ("health W/4 app*") OR TITLE-ABS-KEY ("medical W/4 app*"))) OR ((TITLE-ABS-KEY ("clinical decision support") OR TITLE-ABS-KEY ("computer-assisted decision*") OR TITLE-ABS-KEY ("computer-assisted diagnosis") OR TITLE-ABS-KEY ("computer-assisted therapy") OR TITLE-ABS-KEY ("computer-assisted surgery") OR TITLE-ABS-KEY ("computer-assisted radiology") OR TITLE-ABS-KEY ("decision support system*"))) OR ((TITLE-ABS-KEY ("health information system*") OR TITLE-ABS-KEY ("medical information system*") OR TITLE-ABS-KEY ("healthcare information system*") OR TITLE-ABS-KEY ("clinical information system*") OR TITLE-ABS-KEY ("laboratory information system*") OR TITLE-ABS-KEY ("pharmacy information system*") OR TITLE-ABS-KEY ("nursing information system*") OR TITLE-ABS-KEY ("hospital information system*") OR TITLE-ABS-KEY ("operating room information system*")))) OR ((TITLE-ABS-KEY ("digital health") OR TITLE-ABS-KEY (wearable*) OR TITLE-ABS-KEY (fitbit) OR TITLE-ABS-KEY ("assistive living device*") OR TITLE-ABS-KEY ("assisted living device*"))) OR ((TITLE-ABS-KEY (epriscr*) OR TITLE-ABS-KEY ("electronic order entry") OR TITLE-ABS-KEY ("computer physician order entry") OR TITLE-ABS-KEY ("computeri#ed physician order entry") OR TITLE-ABS-KEY ("electronic physician order entry") OR TITLE-ABS-KEY (e-prescr*))) OR ((TITLE-ABS-KEY ("web-based health service*") OR TITLE-ABS-KEY ("health 2.0") OR TITLE-ABS-KEY ("medicine 2.0"))) OR ((TITLE-ABS-KEY ("electronic health record*") OR TITLE-ABS-KEY ("electronic medical record*") OR TITLE-ABS-KEY ("electronic patient record*") OR TITLE-ABS-KEY ("computeri#ed health record*") OR TITLE-ABS-KEY ("computeri#ed medical record*") OR TITLE-ABS-KEY ("patient portal") OR TITLE-ABS-KEY ("patient health record*") OR TITLE-ABS-KEY (ehr) OR TITLE-ABS-KEY (emr) OR TITLE-ABS-KEY (phr))) ...View More	404,296 document results
10	(TITLE-ABS-KEY ("electronic health record*") OR TITLE-ABS-KEY ("electronic medical record*") OR TITLE-ABS-KEY ("electronic patient record*") OR TITLE-ABS-KEY ("computeri#ed health record*") OR TITLE-ABS-KEY ("computeri#ed medical record*") OR TITLE-ABS-KEY ("patient portal") OR TITLE-ABS-KEY ("patient health record*") OR TITLE-ABS-KEY (ehr) OR TITLE-ABS-KEY (emr) OR TITLE-ABS-KEY (phr)) ...View More	76,225 document results
9	(TITLE-ABS-KEY ("web-based health service*") OR TITLE-ABS-KEY ("health 2.0") OR TITLE-ABS-KEY ("medicine 2.0"))	245 document results
8	(TITLE-ABS-KEY (epriscr*) OR TITLE-ABS-KEY ("electronic order entry") OR TITLE-ABS-KEY ("computer physician order entry") OR TITLE-ABS-KEY ("computeri#ed physician order entry") OR TITLE-ABS-KEY ("electronic physician order entry") OR TITLE-ABS-KEY (e-prescr*))	944 document results
7	(TITLE-ABS-KEY ("digital health") OR TITLE-ABS-KEY (wearable*) OR TITLE-ABS-KEY (fitbit) OR TITLE-ABS-KEY ("assistive living device*") OR TITLE-ABS-KEY ("assisted living device*"))	51,106 document results
6	(TITLE-ABS-KEY ("health information system*") OR TITLE-ABS-KEY ("medical information system*") OR TITLE-ABS-KEY ("healthcare information system*") OR TITLE-ABS-KEY ("clinical information system*") OR TITLE-ABS-KEY ("laboratory information system*") OR TITLE-ABS-KEY ("pharmacy information system*") OR TITLE-ABS-KEY ("nursing information system*") OR TITLE-ABS-	55,678 document results

	KEY ("hospital information system*") OR TITLE-ABS-KEY ("operating room information system*")	
5	(TITLE-ABS-KEY ("clinical decision support") OR TITLE-ABS-KEY ("computer-assisted decision*") OR TITLE-ABS-KEY ("computer-assisted diagnosis") OR TITLE-ABS-KEY ("computer-assisted therapy") OR TITLE-ABS-KEY ("computer-assisted surgery") OR TITLE-ABS-KEY ("computer-assisted radiology") OR TITLE-ABS-KEY ("decision support system*"))	167,343 document results
4	(TITLE-ABS-KEY ("mobile health") OR TITLE-ABS-KEY (mhealth) OR TITLE-ABS-KEY (m-health) OR TITLE-ABS-KEY ("health W/4 app*") OR TITLE-ABS-KEY ("medical W/4 app*"))	15,722 document results
3	(TITLE-ABS-KEY (chealth) OR TITLE-ABS-KEY (e-health) OR TITLE-ABS-KEY ("electronic health") OR TITLE-ABS-KEY (telemedicine) OR TITLE-ABS-KEY (telemedicine) OR TITLE-ABS-KEY (telenursing) OR TITLE-ABS-KEY (tele-nursing) OR TITLE-ABS-KEY (telepharmacy) OR TITLE-ABS-KEY (telepharmacy) OR TITLE-ABS-KEY (teleconsult*) OR TITLE-ABS-KEY (teleconsult*) OR TITLE-ABS-KEY (telerehabilitation) OR TITLE-ABS-KEY (telerehabilitation) OR TITLE-ABS-KEY (teleradio*) OR TITLE-ABS-KEY (teleradio*) OR TITLE-ABS-KEY (telehealth) OR TITLE-ABS-KEY (telehealth) OR TITLE-ABS-KEY (telediagn*) OR TITLE-ABS-KEY (telediagn*) OR TITLE-ABS-KEY (telepathology) OR TITLE-ABS-KEY (telepathology) OR TITLE-ABS-KEY (telepsychiatry) OR TITLE-ABS-KEY (telepsychiatry) OR TITLE-ABS-KEY (telecardiology) OR TITLE-ABS-KEY (telecardiology) OR TITLE-ABS-KEY (teledermatology) OR TITLE-ABS-KEY (teledermatology) OR TITLE-ABS-KEY ("remote consultation") OR TITLE-ABS-KEY (teletherapy) OR TITLE-ABS-KEY (teletherapy) OR TITLE-ABS-KEY (telecare) OR TITLE-ABS-KEY (tele-care))	98,510 document results
2	(TITLE-ABS-KEY (framework*) OR TITLE-ABS-KEY (model*) OR TITLE-ABS-KEY (scale*) OR TITLE-ABS-KEY (dimension*) OR TITLE-ABS-KEY (indicator*) OR TITLE-ABS-KEY (guideline*) OR TITLE-ABS-KEY (metric*) OR TITLE-ABS-KEY (measur*) OR TITLE-ABS-KEY (criteri*) OR TITLE-ABS-KEY (standard*))	26,767,311 document results
1	(TITLE-ABS-KEY (information W/1 quality) OR TITLE-ABS-KEY (data W/1 quality) OR TITLE-ABS-KEY (information W/1 valid*) OR TITLE-ABS-KEY (data W/1 valid*) OR TITLE-ABS-KEY (data W/1 reliab*) OR TITLE-ABS-KEY (information W/1 reliab*) OR TITLE-ABS-KEY (data W/1 accura*) OR TITLE-ABS-KEY (information W/1 accura*) OR TITLE-ABS-KEY (data W/1 audit*) OR TITLE-ABS-KEY (information W/1 audit*))	235,782 document results

Appendix 2: Included Papers

Study Details	Bolt 2007	McCormack 2012	Stetson 2012	Weiskopf 2012	Almutiry 2013	Bowen 2014	Dungey 2014	Davoudi 2015	Kahn 2016	Almutiry 2017
Study Methods	Modification of an existing framework through interviews with developers and users during a pilot of an electronic personal care record.	Ethnographic study – interviews & observation	Modification of existing PDQI through factor analysis, internal consistency assessment	Literature review	Literature Review – DQ dimensions gathering, filtering, mapping & clustering	Not stated	Modification of two existing frameworks and consultation with user group to develop measures	Update of previous practice briefs (1998 and 2012)	Literature review & stakeholders meeting	Mixed – literature review, survey, semi-structured interviews and focus group
Publication type	Journal article	Conference paper	Journal article	Journal article	Conference paper	Evaluation Guide	Conference paper	Practice brief	Journal article	PhD Thesis
Country	Japan	USA	USA	USA	UK	Canada	UK	USA	USA	UK/ Saudi
Digital Health Technology	Web & mobile phone app for telemedicine	CDS	EHR	EHR	Cloud based Health Information System	Electronic Medical Records	Primary care databases	EHR	EHR	EHR
Name of IQ Framework	Information quality in home care coordination services	A descriptive model of factors impacting data quality of CDS	PDQI-9	DQ assessment in the context of EHR data reuse for research	A framework of DQ in cloud-based health information systems	eHealth Observatory Electronic Medical Records DQ Dimensions	Proposed framework for measuring DQ in primary care research databases	Data Quality Management Model	Harmonized DQ assessment terminology and framework for the secondary use of EHR data	The framework of data quality in EHR

DQ – Data Quality, PDQI – Physician Documentation Quality Instrument, EHR – Electronic Health Records, CDS – Clinical Decision Support,

Appendix 3: Quality Assessment Result

CASP Checklist	Bolt 2007	McCormack 2012	Stetson 2012	Weiskopf 2012	Almutiry 2013	Bowen 2014	Dungey 2014	Davoudi 2015	Kahn 2016	Almutiry 2017
Was there a clear statement of the aims of the research?	Yes	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Is a qualitative methodology appropriate?	Yes	Yes	NA	NA	NA	NA	NA	NA	Yes	Yes
Was the research design appropriate to address the aims of the research?	Yes	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Was the recruitment strategy appropriate to the aims of the research?	Not clear	Not clear	Not clear	NA	Not clear	NA	Not clear	NA	Not clear	Yes
Was the data collected in a way that addressed the research issue?	Not clear	Yes	Yes	Yes	Yes	NA	Not clear	NA	Yes	Yes
Has the relationship between researcher and participants been adequately considered?	Not clear	No	NA	NA	NA	NA	No	NA	No	Yes
Have ethical issues been taken into consideration?	No	Yes	Yes	NA	No	NA	No	NA	No	Yes
Was the data analysis sufficiently rigorous?	No	Yes	Yes	No	No	NA	No	NA	No	Yes
Is there a clear statement of findings?	Yes	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
How valuable is the research?	Yes	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes

Appendix 4: Definition of IQ Dimensions within Existing IQ Frameworks for DHTs

S/N	Dimension	Extracted Definitions
Information quality in home care coordination services (Bolt 2007)		
1	Updateability	Personal data about an individual is likely to need periodic correction or updating by the service users, i.e. care recipients, care givers and care service providers
2	Interoperability	The extent to which an information service can exchange and cooperate in using information from various sources (both adherence to standards and whether systems are able to exchange data with other systems on a technical and policy level)
3	Portability	The ability of the information held by the service to be transferred to another service or service provider
Clinician perspectives on the quality of patient data used for clinical decision support (McCormack 2012)		
4	Data Accuracy	The clinicians also complained of inaccurate and unreliable patient data.
5	Data reliability	The clinicians also complained of inaccurate and unreliable patient data.
6	Completeness	Missing or incomplete patient information was the most frequent example clinicians gave of poor data impacting CDS. Data were considered missing when they did not exist in an electronic form
7	Data relevance to context	Many clinicians found that CDS was less effective because it failed to adapt to individual and clinical contexts.
8	Accessibility of the data	Data were considered inaccessible when the information existed, but could not be easily retrieved or used
Physician Documentation Quality Instrument (Stetson 2012)		
9	Accurate	The note is true. It is free of incorrect information
10	Internal consistent	No part of the note ignores or contradicts any other part
11	Up-to-date	The note contains the most recent test results and recommendations
12	Comprehensible	The note is clear, without ambiguity or sections that are difficult to understand
13	Thorough	The note is complete and documents all of the issues of importance to the patient
14	Useful	The note is extremely relevant, providing valuable information and/or analysis
15	Organised	The note is well-formed and structured in a way that helps the reader understand the patient's clinical course
16	Succinct	The note is brief, to the point, and without redundancy
17	Synthesized	The note reflects the author's understanding of the patient's status and ability to develop a plan of care
Methods and dimensions of electronic health record data quality assessment: Enabling reuse for clinical research (Weiskopf 2012)		
18	Completeness	Is a truth about a patient present in the EHR?
19	Correctness	Is an element that is present in the EHR true
20	Concordance	Is there agreement between elements in the EHR or between the EHR and another data source
21	Plausibility	Does an element in the EHR make sense in light of other knowledge about what that element is measuring
22	Currency	Is an element in the EHR a relevant representation of the patient state at a given point in time?
23	Completeness	Is the data free from significant gaps in coverage that may otherwise limit its ability to represent the true state of affairs?
A framework of DQ in cloud-based health information systems (Almutiry 2013)		
24	Accuracy	The extent to which registered data conforms to its actual value

25	Completeness	The state in which information is not missing and is sufficient for the task
26	Consistency	Representation of data values remains the same in multiple data items in multiple locations
27	Relevance	The extent to which information is appropriate and useful for the intended task
28	Timeliness	The state in which data is up to date and its availability is on time
29	Usability	The ease with which data can be accessed, used, updated, understood, maintained and managed
30	Provenance	The source of data, shown and linked to metadata about data
31	Interpretability	The degree to which data can be understood
32	Security	Security prevents personal data from being corrupted and controls access to ensure privacy and confidentiality
EMR Data Quality: Evaluation Guide (Bowen 2014)		
33	Correctness	Does the data accurately describe the true of affairs it is intended to represent?
34	Concordance	Is the data in relative agreement with other relevant reputable sources?
35	Comprehensibility	Is the average intended reviewer able to understand the data so as to be able to attempt to infer the author's intended interpretation of the true state of affairs?
36	Informative sufficiency	Does the body of available data adequately support <i>an inference</i> of the true state of affairs by an average intended reviewer irrespective of any objective level of completeness, correctness or consistency?
37	Consistency of capture	Are the desirable data elements consistently recorded?
38	Consistency of Form	Are the data elements consistently captured in the desirable form
A pragmatic approach for measuring data quality in primary care databases (Dungey 2014)		
39	Accuracy	Measurement or Recording Error: implausible or incorrect values Recording accuracy: Coding errors, Recorded date is date event actually happened Coverage: All events pertaining to a certain condition are recorded. No duplicate records for same event
40	Completeness	Unit non-response: Practice with no data for a period Item non-response: Practice contributed no data for a certain element or only partial data
41	Reliability	consistency/concordance: information mismatch between various or within the same EHR data source
42	Relevance	Coding specificity: to identify study population Relevant time intervals: Time intervals adequate for the intended use
43	Timeliness	Practice level timeliness: Practice contributing data to data centre on time Timeliness of individual records: Practice recording events at time that they happened
44	Integrity	Control of provenance of data
45	Validity	Correct/approved units or specified time intervals Valid proxy data.
Data quality management model (Davoudi 2015)		
46	Data Accuracy	The extent to which the data are free of identifiable errors
47	Data consistency	The extent to which the healthcare data are reliable and the same across applications
48	Data Relevancy	The extent to which healthcare-related data are useful for the purposes for which they were collected
49	Data Timeliness	Concept of data quality that involves whether the data is up-to-date and available within a useful time frame; timeliness is determined by manner and context in which the data are being used
50	Data Currency	The extent to which data are up-to-date; a datum value is up-to-date if it is current for a specific point in time, and it is outdated if it was current at a preceding time but incorrect at a later time

51	Data Accessibility	Data items that are easily obtainable and legal to access with strong protections and controls built into the process
52	Data Comprehensiveness	All required data items are included—ensures that the entire scope of the data is collected with intentional limitations documented
53	Data Definition	The specific meaning of a healthcare-related data element
54	Data Granularity	The level of detail at which the attributes and values of healthcare data are defined
55	Data precision	Data values should be strictly stated to support the purpose
A Harmonized Data Quality Assessment Terminology and Framework for the Secondary Use of Electronic Health Record Data (Khan 2016)		
56	Completeness	focuses on features that describe the frequencies of data attributes present in a data set without reference to data values.
57	Conformance	focuses on DQ features that describe the compliance of the representation of data against internal or external formatting, relational, or computational definitions.
58	Plausibility	focuses on features that describe the believability or truthfulness of data values.
The framework of data quality in EHR (Almutiry 2017)		
59	Accuracy	The extent to which registered data conforms to its actual value
60	Completeness	The state in which information is not missing and is sufficient for the task
61	Consistency	Representation of data values remains the same in multiple data items in multiple locations
62	Relevance	The extent to which information is appropriate and useful for the intended task
63	Timeliness	The state in which data is up to date and its availability is on time
64	Usability	The ease with which data can be accessed, used, updated, understood, maintained and managed
65	Provenance	The source of data, shown and linked to metadata about data
66	Interpretability	The degree to which data can be understood.
67	Secure access	Personal data being protected against unauthorised access
69	Confidentiality	The state of information being secret or accessibly restricted under a set of rules that limits the access
70	Privacy	The state of an individual or group being able to seclude themselves or their information

Appendix 5: Ethical Approval for the eDelphi Study

**Imperial College
London**

Imperial College Research Ethics Committee
Imperial College London
Room 221
Medical School Building
St Marys Campus
London
W2 1PG
Tel: +44 (0)207 594 1872

researchethicscommittee@imperial.ac.uk

06/11/2020

Dear Dr Car

Study Title: Clinicians' perspectives on information quality of digital health technologies: a protocol for an international e-Delphi Study

ICREC reference: 20IC6396

The above study was approved by your Head of Department on 02/11/20 and by the Joint Research Compliance Office on 06/11/20.

Under the Imperial College Research Ethics Committee process, a study that has been reviewed by the Joint Research Compliance Office and Head of Division/Department, where no significant ethical issues have been identified in the protocol or ethics application, can be granted JRCO approval without requiring it to go to full committee.

Documents

The documents reviewed were:

- ICREC/SETREC Application form (v1.3 05/11/20)
- Protocol (v1.4 03/11/20)
- Participant Information Sheet (v1.4 03/11/20)
- E-mail Invitation (v1.2 05/11/20)
- E-Delphi Questionnaire (v1.4 03/11/20)
- Information Quality Assessment Instrument (v1.2 05/11/20)

Yours sincerely



Ruth Nicholson
Head of Research Governance and Integrity
Imperial College London

Appendix 6: First Round eDelphi Survey

Clinical Information Quality Framework for Digital Health Technologies

Digital health technologies (DHTs), such as electronic health records, clinical decision support systems and electronic prescribing systems, are widely used in patient care. Researchers at Imperial College London have developed an instrument for assessing the quality of clinical information from DHTs based on evidence from literature. This could help to prevent injuries and deaths associated with poor quality clinical information from DHTs. This study aims to obtain your inputs as a healthcare professional using information from DHTs. Kindly read further information about the study in the [participant information sheet](#).

If you are happy to proceed the with this study, please complete the consent form below:

I confirm that I have read and understood the participant information sheet, version 1.4 dated 3 November 2020, and have had the opportunity to ask questions which have been answered fully.

- ☐ I give consent for information collected about me to be used to support other research in the future, including those outside of the European Economic Area (EEA).
- ☐ I give consent to being contacted about the potential to take part in other research studies.
- ☐ I understand that my participation is voluntary, and I am free to withdraw at any time, without giving any reason and without my legal rights being affected.
- ☐ I give permission for Imperial College London to access my research records that are relevant to this research.
- ☐ I consent to take part in the above study.

Please select which best describes your clinical role.

- ☐ Doctor
- ☐ Nurse/Nurse Practitioner/Advanced Care Practitioner
- ☐ Pharmacist/ Clinical Pharmacist
- ☐ Physiotherapist/Occupational Therapist
- ☐ Physician Associate
- ☐ Others (e.g., Community Health Worker, Healthcare Surveillance Officer)

If others, please specify

In which country do you currently reside?

▼ Afghanistan ... Zimbabwe

Gender

- ☐ Male
- ☐ Female
- ☐ Prefer not to say

Please state how long you have used digital health technologies such as electronic health record, electronic prescribing system, telemedicine and clinical decision support system in clinical practice?

- ☐ 1 year
- ☐ 2 years
- ☐ 3 years
- ☐ 4 years
- ☐ 5 years
- ☐ 6 years
- ☐ 7 years
- ☐ 8 years
- ☐ 9 years
- ☐ 10 years and above

How relevant to quality and safety of care do you consider each of these attributes of clinical information from DHTs?

	Strongly relevant	Somewhat relevant	Neither relevant nor irrelevant	Somewhat irrelevant	Strongly irrelevant
Accuracy: the extent to which information is free from errors.					
Completeness: the extent to which no needed information is missing.					
Interpretability: the extent to which information can be understood.					
Plausibility: the extent to which information makes sense in the light of existing knowledge.					
Provenance: the extent to which the source of information is trustworthy.					
Relevance: The extent to which information is useful for the intended task.					
Accessibility: the extent to which information is easily obtainable.					
Portability: the extent to which information is available in different systems.					
Security: the extent to which information is protected from unauthorized access.					
Timeliness: the extent to which up-to-date information is available when needed.					
Conformance: the extent to which information is presented in the desired format.					
Consistency: the extent to which information is presented in the same format.					
Maintainability: the extent to which information can be easily maintained.					

Would you include, exclude or modify the following question when assessing quality of clinical information from DHTs?

Accuracy: Is the information from the digital health technology free of errors?

- ☐ **Very Accurate.** The information from the digital health is completely free of errors.
- ☐ **Accurate:** The information from the digital health technology is free of errors that could lead to adverse events.
- ☐ **Inaccurate:** The information from the digital health technology contains few errors that could lead to adverse events.
- ☐ **Very inaccurate:** The information from the digital health technology contains several errors that could lead to adverse events. NB: Adverse event is an unintended physical injury resulting from or contributed to by medical care that requires additional monitoring, treatment or hospitalisation or that results in death.

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of accuracy?

Would you include, exclude, or modify the following question when assessing quality of clinical information from DHTs?

Completeness: Is no needed information missing from the digital health technology?

☐ **Very complete:** No information is missing from the digital health technology.

☐ **Complete:** No information required for clinical decision (diagnosis, treatment or prognosis) is missing from the digital health technology.

☐ **Incomplete:** Few information required for clinical decision (diagnosis, treatment or prognosis) are missing from the digital health technology.

☐ **Very incomplete:** Several information required for clinical decision (diagnosis, treatment or prognosis) are missing from the digital health technology.

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of completeness?

Would you include, exclude or modify the following question when assessing quality of clinical information from DHTs?

Interpretability: Could the information from the digital health technology be understood to make clinical decision?

☐ **Very interpretable:** Additional resources provided to aid interpretation of the information from the digital health technology (e.g. arrows or colour coding to indicate abnormal results, indications of medication)

☐ **Interpretable:** Standard resources provided to aid interpretation of the information from the digital health technology (e.g. reference range)

☐ **Uninterpretable:** Information from the digital health technology cannot be interpreted without seeking clarification from its author.

☐ **Very uninterpretable:** Completely meaningless information not suitable for clinical decision.

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of interpretability?

Would you include, exclude or modify the following question when assessing quality of clinical information from DHTs?

Plausibility. Does the information from the digital health technology make sense based on common knowledge?

☐ **Very plausible.** The information from the digital health technology agrees with common knowledge (e.g. raised inflammatory markers in a patient with sepsis).

☐ **Plausible.** The information from the digital health technology agrees with common knowledge if exceptional circumstances are considered (e.g. normal inflammatory markers in a patient with sepsis due to delayed immune response)

☐ **Implausible:** The information from the digital health technology disagrees with common knowledge (e.g. Arterial blood gasses with oxygen saturation of 60% when pulse oximeter records 94%)

☐ **Very implausible:** The information from the digital health technology makes no sense at all based on common knowledge (e.g. physiological parameters incompatible with life).

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of plausibility?

Would you include, exclude, or modify the following question when assessing quality of clinical information from DHTs?

Provenance: Is the source of the information in the digital health technology trustworthy?

☐ **Very trustworthy:** The information in the digital health technology is from highly trustworthy source (e.g., UN Agencies, Official Government Agencies, Academic institutions, Hospitals).

☐ **Trustworthy:** The information in the digital health technology is from recognised private corporations (e.g., non-governmental organisations, registered charities).

☐ **Untrustworthy:** The information in the digital health technology is from sources with obvious conflict of interest (e.g., pharmaceutical companies, tobacco companies).

☐ **Very untrustworthy:** Unverifiable source of information and unsubstantiated claims (e.g. broadcast information on social media, no references), unsuitable for clinical decision

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of provenance?

Would you include, exclude, or modify the following question when assessing quality of clinical information from DHTs?

Relevance: Is the information from the digital health technology useful for the intended task?

☐ **Very relevant:** All information from the digital health technology is useful for the intended task

☐ **Relevant:** Most of the information from the digital health technology is useful for the intended task?

☐ **Irrelevant:** Most of the information from the digital health technology not useful for the intended task

☐ **Very irrelevant:** None of the information from the digital health technology is useful for the intended task

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of relevance?

Would you include, exclude, or modify the following question when assessing quality of clinical information from DHTs?

Accessibility: Is the information easily obtainable from the digital health technology? ☐ **Very accessible:** The information from the digital health technology is obtainable with no difficulties at the point of care.

☐ **Accessible:** The information from the digital health technology is obtainable with minor difficulties that could be resolved at the point of care (e.g through a phone call to IT Department)

☐ **Inaccessible:** The information from the digital health technology is not obtainable at the point of care.

☐ **Very inaccessible:** The information from the digital health technology is not obtainable at all.

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of provenance?

Would you include, exclude, or modify the following question when assessing quality of clinical information from DHTs?

Portability: Is the information from the digital health technology accessible in different systems?

☐ **Very portable:** The information from the digital health technology is accessible at all levels of healthcare system (primary, secondary & tertiary).

☐ **Portable:** The information from the digital health technology is accessible at all levels of healthcare with minor difficulties that could be resolved at the point of care (e.g. transferable on request).

☐ **Unportable:** The information from the digital health technology is only accessible at the level of care where it was created.

☐ **Very unportable:** The information from the digital health technology is only accessible on the computer system where it was created.

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of provenance?

Would you include, exclude, or modify the following question when assessing quality of clinical information from DHTs?

Security: Is the information in the digital health technology protected from unauthorised access?

☐ **Very secure:** The information in the digital health technology is securely protected against unauthorized access using multiple strategies (e.g. password and swipe card).

☐ **Secure:** The information in the digital health technology is securely protected against unauthorised access using a single strategy (e.g. requires only password).

☐ **Insecure:** The information in the digital health technology is accessible to multiple healthcare professionals without a need for authorisation (e.g. information obtainable from the hospital without a need for personal log-in)

☐ **Very insecure:** The information is publicly accessible (e.g. information on hospital website)

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of provenance?

Would you include, exclude, or modify the following question when assessing quality of clinical information from DHTs?

Timeliness: Is up-to-date information from the digital health technology available when it is needed?

☐ **Very timely:** Up-to-date information is available from the digital health technology at the point of care with no delays.

☐ **Timely:** Up-to-date information is available from the digital health technology at the point of care with minor delays which do not affect the use of the information for clinical decision (e.g. slow log-in)

☐ **Untimely:** Up-to-date information is unavailable from the digital health technology at the point of care due to major delays which affect the use of the information for clinical decision (e.g. system is down for a couple of hours)

☐ **Very untimely:** The information from the digital health technology is outdated and/or not available when needed for clinical decision

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of provenance?

Would you include, exclude, or modify the following question when assessing quality of clinical information from DHTs?

Conformance: Is the information from the digital health technology presented in the desired format?

☐ **Very conformant:** All the information from the digital health technology conforms to international or local standards (e.g. SI units).

☐ **Conformant:** Most of the information from the digital health technology conforms to international or local standards.

☐ **Non-conformant:** Most of the information from the digital health technology do not conform to local or international standards.

☐ **Very non-conformant:** All the information from the digital health technology do not conform to local or international standards making it unsafe for clinical decision (e.g. medication doses presented without units).

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of provenance?

Would you include, exclude, or modify the following question when assessing quality of clinical information from DHTs?

Consistency: Is the information presented in the same format within the digital health technology?

☐ **Very consistent:** All the information is presented consistently in the same format (e.g. consistently expressing Hb as g/dL) within the digital health technology.

☐ **Consistent:** Most of the information is presented consistently in the same format within the digital health technology.

☐ **Inconsistent:** Most of the information is not presented in the same format within the digital health technology.

☐ **Very inconsistent:** Multiple formats of information which is potentially confusing and unsafe for clinical decision.

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of provenance?

Would you include, exclude, or modify the following question when assessing quality of clinical information from DHTs?

Maintainability: Could the information within the digital health technology be easily maintained?

☐ **Very maintainable:** The information within the digital health technology could be maintained without difficulties.

☐ **Maintainable:** The information within the digital health technology could be maintained with minor difficulties resolvable at the point of care.

☐ **Unmaintainable:** The information within the digital health technology could not be easily maintained.

☐ **Very unmaintainable:** The information within the digital health technology could not be maintained at all. NB: Maintenance includes activities such as storing, auditing, updating data.

☐ Include as it is

☐ Exclude

☐ Modify

If modify, please state any modification you would like to suggest regarding definition and assessment of provenance?

Q35 CLIQ Framework for Digital Health Technology

Informativeness directly concerns the usefulness of digital information for clinical purposes	Accuracy	the extent to which information is correct
	Completeness	the extent to which no required information is missing
	Interpretability	the extent to which information can be understood
	Plausibility	the extent to which information makes sense based on common knowledge
	Provenance	the extent to which the source of information is trustworthy
	Relevance	the extent to which information is useful for the intended task
Availability concerns the functionality of the system holding clinical information	Accessibility	the extent to which existing information is easily obtainable
	Portability	the extent to which information is accessible in different systems
	Security	the extent to which information is protected from unauthorized access and corruption
	Timeliness	the extent to which current information is available on time
Usability concerns the ease of use of clinical information	Conformance	the extent to which information is presented in the desired format
	Consistency	the extent to which information is presented in the same format
	Maintainability	the extent to which information can be maintained

Q36 Would you like to retain or modify the above categories?

- ☐ Retain the categories
- ☐ Modify the categories

If modify, please state how you would want the categories to be modified.

Thank you for taking part in this eDelphi survey. Please provide your email so we can share the summary of the findings with you and contact you for the subsequent round.

Appendix 7: Changes Based on Free-text Suggestions in the First eDelphi Round

Avoiding Ambiguity

1. Removal of all response options that started with ‘very’ thus reducing the number of possible options to three (e.g., accurate, partially accurate, inaccurate).
2. The phrase ‘free of error’ was replaced with ‘accurate’ as the former was considered ambiguous.
3. The term ‘accessible’ was removed from the definition of portability to avoid confusion with ‘accessibility’.
4. Words indicating frequency (e.g., occasionally) and quantity (e.g., few) were removed as these could convey different meanings.
5. The phrase “partly interpretable” rather than the suggested “barely interpretable” was used to ensure uniformity with other dimensions.
6. ‘Conformance’ was defined using simpler language to make it comprehensible to clinicians without informatics experience.

Relatable Examples

1. ‘Transfer requiring printing on paper’ was included as an example of ‘unportable’ information
2. Diagnosis, monitoring, and treatment were included as examples of tasks under ‘relevance’.
3. ‘Access requiring phone call to IT department’ was re-assigned under ‘inaccessible’ information.
4. Two-factor authentication, smart card, and role-based access were included as examples of ‘secure’ information.
5. Examples for ‘timeliness’ were changed to reflect the validity of information in the system.
6. Examples of presentation format were included under ‘conformance’ and ‘consistency’.
7. Drop-down options and free text were included as examples of structured and unstructured information.
8. Community level of healthcare was included under ‘portability’.
9. Examples were included in each response option rather than in the question to make it easier to differentiate between options.

Renaming Dimensions

1. ‘Searchability’ was introduced to account for the ease of locating needed information in the DHTs.
2. ‘Timeliness’ was renamed as ‘currency’.
3. ‘Provenance’ was renamed as ‘trustworthiness’ to make it more comprehensible to clinicians without informatics background.
4. ‘Consistency’ was renamed ‘consistency of presentation’ to remove ambiguity.
5. ‘Interpretability’ was retained rather than the suggested ‘comprehensibility’ and ‘information clarity’ because healthcare professionals are likely to be more familiar with interpretation of information (e.g., lab results).
6. ‘Inconsistent’ was not used instead of ‘implausible’ as suggested because it might create confusion with ‘consistency’.

7. 'Portability' was not changed to 'interoperability' as suggested because 'portability' describes an attribute of information while 'interoperability' describes the attribute of a digital system.

Rephrasing for Clarity

1. 'Adverse event' was replaced with explanation indicating likelihood and potential impact of inaccurate information on quality of care and patient safety.
2. Options for accuracy were rephrased to remove the implicit assumption that data will directly impact care.
3. 'Is no information missing?' was rephrased to 'Is any information missing?'
4. 'Clinical decision' was changed to 'decision making' which is more encompassing.
5. 'Intended task' was replaced with 'patient care' as the latter is all-encompassing.
6. Definitions of 'maintainability' and 'security' were rephrased to make them more explicit.
7. Transfer between different systems in addition to different levels of healthcare were included in the definition of 'portability'.
8. 'Healthcare institutions' was used instead of suggested 'NHS Trust' as the latter is specific to the UK.

Appendix 8: Second Round eDelphi Survey

Clinical Information Quality Framework for Digital Health Technologies

The aim of this study is to obtain inputs of clinicians on an instrument for assessing the quality of clinical information from digital health technologies. Thirty-five healthcare professionals (26 doctors, 5 nurses, 2 pharmacists, 1 dietician, 1 health system specialist) from 10 countries participated in the first round with more than half (51%) having over ten years digital health experience. All the 13 information quality dimensions in the proposed framework were ranked as relevant by the majority of the first-round participants with scores ranging from 86% to 94%. This final round seeks to obtain your feedback on the modifications that have been made. Please read the [participant information sheet](#) for further information about the study.

General Comments (Applicable to all dimensions)

1. We are grateful for all the comments. They are very useful in providing further insights into the assessment of each dimension.
2. Based on the comments, we have reduced the options from 4 to 3. We have removed the 'very' option as this might create some ambiguity.
3. We have also removed the phrase 'digital health technology' which was used repeatedly during the first survey. We believe that using this term once at the introduction to the instrument will suffice.
4. We have removed timeliness and introduced 2 new dimensions: currency and searchability based on comments during the first survey.
5. We have responded to the comments made during the first round one by one.
6. The responses are based on the discussion among the steering committee members for the eDelphi study made up of seven digital health researchers from Imperial College London.
7. We would appreciate further comments on each dimension.

Accuracy: Is the information accurate?

☐ **Accurate.** The information is accurate.

☐ **Partly accurate:** The digital health technology contains some inaccurate information which is unlikely to compromise patient safety or quality of care (i.e., unlikely to cause death, harms or disruption/delay in patient care).

☐ **Inaccurate:** The digital health technology contains some inaccurate information which is likely to compromise patient safety or quality of care (i.e., likely to cause death, harms or disruption/delay in patient care).

Response to comments during the first round of the survey

1. We acknowledge that the term “free of error” could be ambiguous and have replaced it with the term “accurate”
2. We agree that the definition of adverse event is narrow and have replaced it with likelihood and potential impact of inaccurate information on quality of care and patient safety.
3. We agree that adverse events and accuracy are not mutually exclusive. This is reflected in the ‘partly accurate’ and ‘inaccurate’. Similarly, we have used the term ‘likely’ and ‘unlikely’ to remove the implicit assumption that data will directly impact care.
4. We did not add the phrase ‘to the best of my knowledge’ to this question because this is applicable to all questions as responses are always based on the knowledge and experience of respondents to any questionnaire. We will make this clear in the introductory statement to the questionnaire.
5. We have not listed different types of errors (e.g., medication, history findings, etc.) because these differ across different digital health technologies and it is impracticable to list all of them.
6. We acknowledge that data input has an impact on information quality. We hope that this instrument will help with discovery of poor quality information which will in-turn help the relevant authorities to look closely at the possible causes including data entry error.

Please indicate whether you agree with these changes.

☐ Yes

☐ No

Please state any further modification you would like to suggest regarding the definition and assessment of accuracy.

Completeness: Is any information missing?

☐ **Complete:** No information reasonably expected to be documented/recorded is missing (e.g., name, dose and indication of medication prescribed).

☐ **Partly complete:** Information reasonably expected to be documented/recorded is partially recorded (e.g., name of medication recorded without the dose).

☐ **Absent:** Information reasonably expected to be documented is absent/missing (e.g., name, dose and indication of medication missing).

Response to comments during the first round of the survey

1. We have replaced “no” with “any” in the question as suggested.
2. We agree that the function of digital health technology is beyond clinical decision making, we have therefore removed this phrase.
3. We have however refrained from using words indicating frequency (e.g., occasionally, usually) and quantity (e.g., few) to avoid ambiguity as these could have different meanings for different people.

Please indicate whether you agree with these changes.

☐ Yes

☐ No

Please state any further modification you would like to suggest regarding the definition and assessment of completeness

Interpretability: Can the information be interpreted?

☐ **Interpretable:** The information can be interpreted without a need for additional resources (e.g., reference range included alongside laboratory results).

☐ **Partly interpretable:** The information can be interpreted only with additional resources or assistance (e.g., reference materials required because reference range not included with laboratory results)

☐ **Uninterpretable:** The information cannot be interpreted even with additional resources (e.g., unable to interpret laboratory results even after consulting reference materials).

Response to comments during the first round of the survey:

1. We have modified the options to demonstrate some sort of order across the interpretability dimension as suggested.
2. We acknowledge that the phrases very interpretable and very uninterpretable sound odd, we have therefore removed these terms.
3. We have used the phrase “partly interpretable” rather than “barely interpretable” suggested to ensure uniformity with other dimensions.
4. Although we acknowledge that the term “comprehensibility” and “information clarity” are similar, we have retained “interpretability” because we believe healthcare professionals are more familiar with interpretation of information (e.g., lab results) compared with other suggested alternatives.

Please indicate whether you agree with these changes?

☐ Yes

☐ No

Please state any further modification you would like to suggest regarding definition and assessment of interpretability.

Plausibility. Does the information seem credible, reasonable, or likely?

- ☐ **Plausible.** The information seems credible, reasonable, or likely/probable (e.g., fever in a child with sepsis).
- ☐ **Partly plausible.** The information seems probable only in exceptional circumstances (e.g., normal body temperature in a child with sepsis)
- ☐ **Implausible:** The information is unlikely to be true (e.g., body temperature of 100 degrees Celsius which is not compatible with life)

Response to comments during the first round of the survey

1. We have modified the examples and relate them to a single scenario (sepsis) as suggested.
2. Although we considered using the term “consistent with common knowledge”, we avoided this phrase because it might create confusion with another dimension (consistency).

Please indicate whether you agree with these changes.

☐ Yes

☐ No

Please state any further modification you would like to suggest regarding definition and assessment of plausibility.

Trustworthiness: Is the source of the information trustworthy and verifiable?

☐ **Trustworthy:** The information is from a trustworthy source (e.g., WHO, government agencies, academic institutions, healthcare institutions, peer-reviewed medical journals).

☐ **Partly trustworthy:** The information is only partly from a verifiable source (e.g., some claims are without evidence-base).

☐ **Untrustworthy:** The information is from unverifiable and non-peer reviewed sources (e.g., social media).

Response to comments during the first round of the survey

1. We have replaced the term “provenance” with trustworthiness as the latter is easier to understand by healthcare professionals without informatics background.
2. We have used the term healthcare institutions and avoided the term “NHS Trust” which is specific to the UK.
3. We have retained multiple examples to make the classification more apparent.

Please indicate whether you agree with these changes.

☐ Yes

☐ No

Please state any further modification you would like to suggest regarding definition and assessment of trustworthiness.

Relevance: Is the information relevant to patient care?

- ☐ Relevant: The information is useful, directly connected with or related to patient care (e.g., useful for diagnosis, monitoring and treatment).
- ☐ Partly relevant: The information is useful, directly connected with or related to some aspects of patient care (e.g., useful only for discharge planning).
- ☐ Irrelevant: The information is not useful, directly connected with or related to any aspect of patient care.

Response to comments during the first round of the survey:

1. We have replaced the term ‘intended task’ with ‘patient care’ as the latter is all-encompassing.
2. We have included diagnosis, monitoring and treatment as examples of patient care as suggested.

Please indicate whether you agree with these changes

- ☐ Yes
- ☐ No

Please state any further modification you would like to suggest regarding definition and assessment of relevance.

Accessibility: Can the information be obtained or reached easily?

☐ **Accessible:** The information can be easily obtained at the point of care (e.g., immediate access with username and password).

☐ **Partly accessible:** The information can be obtained with some difficulties (e.g., delayed access due to frequent downtime).

☐ **Inaccessible:** The information is not easily obtainable (e.g., access requires phone calls to IT Department).

Response to comments during the first round of the survey:

1. We have included examples in each option rather than in the question as we agree with the suggestion that this would make it easier to differentiate.
2. We agree with the comments that “phone call to IT department” is an example of inaccessible information.

Please indicate whether you agree with these changes.

☐ Yes

☐ No

Q16 Please state any further modification you would like to suggest regarding definition and assessment of accessibility.

Portability: Is the information easily moved or transferred? Portability is a feature of information that allows a user to take information from one system or part of the system and transfer or “port” it to another part of the system or elsewhere (e.g., community, primary, secondary, tertiary care).

☐ **Portable:** The information is easily moved or transferred (e.g., transferable at the point of care by clinician).

☐ **Partly portable:** The information is transferable partly or transfer requires additional effort (e.g., conversion of values).

☐ **Unportable:** The information is not transferable to other system or other part of the system (e.g., requires printing).

Response to comments during the first round of the survey:

1. We have removed the term “accessible” from the definition to avoid confusion with accessibility dimension.
2. We have included transfer between different systems in addition to levels of healthcare.
3. We have included the community level of healthcare.
4. We have included printing as an example of unportable.
5. We have used the term portability because it describes an attribute of information rather than interoperability which describes an attribute of the digital system. The primary purpose of this instrument is to assess clinical information rather than the digital system.

Please indicate whether you agree with these changes

☐ Yes

☐ No

Please state any further modification you would like to suggest regarding definition and assessment of portability.

Security: Is the information protected from unauthorized access, corruption, damage and loss throughout its lifecycle across all applications and platforms?

☐ **Secure:** The information is protected from unauthorized access, corruption, damage and loss using a comprehensive strategy (this includes but not limited to two-factor authentication, password and smart card, role-based access, encryption, single-sign-on authentication).

☐ **Partly secure:** The information is protected from unauthorized access, corruption, damage and loss by only some rather than comprehensive strategy (e.g., requires only username and password but not role-based access).

☐ **Insecure:** The information is not protected from unauthorized access, corruption and loss (e.g., information obtainable from the hospital system using a generic account).

Response to comments during the first round of the survey

1. We have included different examples suggested such as two-factor authentication, smart card, role-based access etc.
2. We have added the security level that are deemed safe under the “secure” option.
3. We acknowledge that security is quite broad but we have tried to simplify it so that it could be understood by healthcare professionals without informatics expertise.

Please indicate whether you agree with these changes

☐ Yes

☐ No

Please state any further modification you would like to suggest regarding definition and assessment of security.

Conformance: Is the information presented in a format that complies with national standards/guidelines?

Note: Presentation format includes but not limited to units (e.g., Celsius, Fahrenheit), structure (e.g., drop down, free text), scoring system (e.g., GCS- Glasgow Comma Scale). abbreviation (Hb vs Hemoglobin).

☐ **Conformant:** the information complies with national standards/guidelines (e.g., presentation of level of consciousness using GCS stating all the components).

☐ **Partly conformant:** the information partly complies with national standards/guidelines (e.g., presentation of level of consciousness using GCS stating only the total score).

☐ **Non-conformant:** the information does not comply with national standards/guidelines (e.g., presentation of level of consciousness not using GCS or any other recommended scoring system).

Response to comments during the first round of the survey

1. We have tried to define the term conformance using simpler language and common international example to illustrate it.
2. We have included examples of presentation format to make the definition more explicit.
3. We have included drop down and free text as an example of structured and unstructured information.

Please indicate whether you agree with these changes.

☐ Yes

☐ No

Please state any further modification you would like to suggest regarding definition and assessment of conformance.

Consistency of presentation. Does the presentation of information adhere to the same set of principles / consistently in the same format?

Note: Presentation format includes but not limited to units (e.g., Celsius, Fahrenheit), structure (e.g., drop down, free text), scoring system (e.g., GCS- Glasgow Comma Scale). abbreviation (Hb vs Hemoglobin)

☐ **Consistently presented:** The information is presented consistently in the same format (e.g., Adrenaline dose consistently expressed in mg across the system).

☐ **Consistently presented partly:** The information is presented in multiple formats in different parts of the system (Adrenalin dose presented as mg and ml in different parts of the system).

☐ **Inconsistently presented:** The information is presented in multiple formats in the same part of the system (Adrenalin dose presented as mg and ml within the same drop-down).

Response to comments during the first round of the survey

1. We have used examples to illustrate each option
2. We have included examples of presentation format to make the definition more explicit.

Please indicate whether you agree with these changes.

☐ Yes

☐ No

Please state any further modification you would like to suggest regarding definition and assessment of consistency of presentation.

Maintainability: Can the information be easily modified to achieve intended improvement?

Note: Maintainability includes a range of activities such as correction, updating, upgrading, adaptation carried out by healthcare professionals or support staff

☐ **Maintainable:** The information can be modified without any difficulties (e.g., immediate correction of wrong entry in electronic health records automatically approved with audit trail).

☐ **Partly maintainable:** The information can be modified with resolvable difficulties (e.g., correction of wrong entry in the electronic health records requires authorization by another professional who is not its author).

☐ **Unmaintainable:** The information cannot be modified (e.g., wrong entry cannot be corrected but requires additional entry such as an addendum to explain the modifications).

Response to comments during the first round of the survey

1. We have rephrased the definition of maintainability and added a note to make it clearer.
2. We have provided relatable examples.

Please indicate whether you agree with these changes.

☐ Yes

☐ No

Please state any further modification you would like to suggest regarding definition and assessment of maintainability.

Currency: Is the information current?

- ☐ **Current:** The information is current (e.g., current laboratory results available).
- ☐ **Partly current:** The available information is not current, but useful for patient care (e.g., historical laboratory results showing trends of chronic disease management).
- ☐ **Non-current:** The information is outdated (e. g., current laboratory results not in the records of an acutely ill person).

Response to comments during the first round of the survey

1. We have changed the term ‘timeliness’ to ‘currency’ because we believe that the other aspect of timeliness relating to being available when needed is already captured under accessibility dimension.
2. We have changed the examples to reflect the validity of information in the system rather than the accessibility aspect.

How relevant to quality and safety of care do you consider currency of information in the digital health technology?

- ☐ Strongly relevant
- ☐ Somewhat relevant
- ☐ Neither relevant nor irrelevant
- ☐ Somewhat irrelevant
- ☐ Strongly irrelevant

Please state any comments/modification you would like to suggest regarding definition and assessment of currency.

Searchability: Can the information be easily searched for or retrieved?

- ☐ **Searchable:** The information is easily searched for or retrieved at the point of care.
- ☐ **Partly Searchable:** The information can be searched for or retrieved at the point of care with some difficulty.
- ☐ **Not Searchable:** The information cannot be easily searched for or retrieved at the point of care.

Comment: This is a new dimension introduced based on comments on accessibility and timeliness during the first round of survey.

How relevant to quality and safety of care do you consider searchability of information in the digital health technology?

- ☐ Strongly relevant
- ☐ Somewhat relevant
- ☐ Neither relevant nor irrelevant
- ☐ Somewhat irrelevant
- ☐ Strongly irrelevant

Please state any comments/ modification you would like to suggest regarding definition and assessment of searchability

Thank you for taking part in the survey. Please provide your email if you would like to be included as co-author/contributor of the manuscript.

Appendix 9: CLIQ Framework for Digital Health Technologies

Digital Health Technology.....

Date of Assessment.....

For each of the attributes (e.g., accuracy), please select which of the three options (e.g., accurate, partly accurate and inaccurate) best describes clinical information in the digital health technology you are assessing based on your personal clinical experience.

Accuracy: Is the information accurate?

☐ **Accurate.** The information is accurate.

☐ **Partly accurate:** The digital health technology contains some inaccurate information which is unlikely to compromise patient safety or quality of care (i.e., unlikely to cause death, harms or disruption/delay in patient care).

☐ **Inaccurate:** The digital health technology contains some inaccurate information which is likely to compromise patient safety or quality of care (i.e., likely to cause death, harms or disruption/delay in patient care).

Completeness: Is any information missing?

☐ **Complete:** No information reasonably expected to be documented/recorded is missing (e.g., name, dose and indication of medication prescribed).

☐ **Partly complete:** Information reasonably expected to be documented/recorded is partially recorded (e.g., name of medication recorded without the dose).

☐ **Absent:** Information reasonably expected to be documented is absent/missing (e.g., name, dose and indication of medication missing).

Interpretability: Can the information be interpreted?

☐ **Interpretable:** The information can be interpreted without a need for additional resources (e.g., reference range included alongside laboratory results).

☐ **Partly interpretable:** The information can be interpreted only with additional resources or assistance (e.g., reference materials required because reference range not included with laboratory results).

☐ **Uninterpretable:** The information cannot be interpreted even with additional resources (e.g., unable to interpret laboratory results even after consulting reference materials).

Plausibility. Is the information credible, reasonable, or likely?

☐ **Plausible.** The information is credible, reasonable, or likely/probable (e.g., fever in a child with sepsis).

☐ **Partly plausible.** The information is probable only in exceptional circumstances (e.g., normal body temperature in a child with sepsis).

☐ **Implausible:** The information is unlikely to be true (e.g., body temperature of 100 degrees Celsius which is not compatible with life).

Trustworthiness: Is the source of the information trustworthy and verifiable?

☐ **Trustworthy:** The information is from a trustworthy source (e.g., WHO, government agencies, academic institutions, healthcare institutions, peer-reviewed medical journals).

☐ **Partly trustworthy:** The information is only partly from a verifiable source (e.g., some claims are without evidence-base).

☐ **Untrustworthy:** The information is from unverifiable and non-peer reviewed sources (e.g., social media).

Relevance: Is the information relevant to patient care?

☐ **Relevant:** The information is useful, directly connected with or related to patient care (e.g., useful for diagnosis, monitoring and treatment).

☐ **Partly relevant:** The information is useful, directly connected with or related to some aspects of patient care (e.g., useful only for discharge planning).

☐ **Irrelevant:** The information is not useful, directly connected with or related to any aspect of patient care.

Accessibility: Can the information be obtained or reached easily?

☐ **Accessible:** The information can be easily obtained at the point of care (e.g., immediate access with username and password).

☐ **Partly accessible:** The information can be obtained with some difficulties (e.g., delayed access due to frequent downtime).

☐ **Inaccessible:** The information is not easily obtainable (e.g., access requires phone calls to IT Department).

Portability: Is the information easily moved or transferred? Portability is a feature of information that allows a user to take information from one system or part of the system and transfer or “port” it to another part of the system or elsewhere (e.g., community, primary, secondary, tertiary care).

☐ **Portable:** The information is easily moved or transferred (e.g., transferable at the point of care by clinician).

☐ **Partly portable:** The information is transferable partly or transfer requires additional effort (e.g., conversion of values).

☐ **Unportable:** The information is not transferable to other system or other part of the system (e.g., requires printing).

Searchability: Can the information be easily searched for or retrieved?

☐ **Searchable:** The information is easily searched for or retrieved at the point of care.

☐ **Partly Searchable:** The information can be searched for or retrieved at the point of care with some difficulty.

☐ **Not Searchable:** The information cannot be easily searched for or retrieved at the point of care.

Security: Is the information protected from unauthorized access, corruption, damage and loss throughout its lifecycle across all applications and platforms?

☐ **Secure:** The information is protected from unauthorized access, corruption, damage and loss using a comprehensive strategy (this includes but not limited to two-factor authentication, password and smart card, role-based access, encryption, single-sign-on authentication).

☐ **Partly secure:** The information is protected from unauthorized access, corruption, damage and loss by only some rather than comprehensive strategy (e.g., requires only username and password but not role-based access).

☐ **Insecure:** The information is not protected from unauthorized access, corruption and loss (e.g., information obtainable from the hospital system using a generic account).

Timeliness: Is the information constantly updated?

☐ **Timely:** The information is constantly updated (e.g., laboratory results available in real time or near real time).

☐ **Partly timely:** There is delay in new information flowing into the system (e.g., delay in new laboratory results becoming available at the point of care).

☐ **Untimely:** The information is outdated (e. g., current laboratory results not available at the point of care).

Conformance: Is the information presented in a format that complies with national standards/guidelines? Presentation format includes but not limited to units (e.g., Celsius, Fahrenheit), structure (e.g., drop down, free text), scoring system (e.g., GCS- Glasgow Comma Scale). abbreviation (Hb vs Haemoglobin).

☐ **Conformant:** the information complies with national standards/guidelines (e.g., presentation of level of consciousness using GCS stating all the components).

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☐ **Non-conformant:** the information does not comply with national standards/guidelines (e.g., presentation of level of consciousness not using GCS or any other recommended scoring system).

Consistency of presentation. Does the presentation of information adhere to the same set of principles / consistently in the same format? Presentation format includes but not limited to units (e.g., Celsius, Fahrenheit), structure (e.g., drop down, free text), scoring system (e.g., GCS- Glasgow Comma Scale). abbreviation (Hb vs Haemoglobin).

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☐ **Inconsistently presented:** The information is presented in multiple formats in the same part of the system (Adrenalin dose presented as mg and ml within the same drop-down).

Maintainability: Can the information be easily maintained (e.g., corrected, updated, upgraded, adapted) to achieve intended improvement?

☐ **Maintainable:** The information can be maintained without any difficulties (e.g., immediate correction of wrong entry in electronic health records automatically approved with audit trail).

☐ **Partly maintainable:** The information can be maintained with resolvable difficulties (e.g., correction of wrong entry in the electronic health records requires authorization by another professional who is not its author).

☐ **Unmaintainable:** The information cannot be maintained (e.g., wrong entry cannot be corrected but requires additional entry such as an addendum to explain the modification).

Appendix 10: Ethical Approval for the Pilot CLIQ Assessment

**Imperial College
London**

**Imperial College Research Ethics
Committee**

Imperial College London
Room 221
Medical School Building
St Marys Campus
London
W2 1PG
Tel: +44 (0)207 594 1862

researchethicscommittee@imperial.ac.uk

01/02/2022

Dear Dr Josip Car,

Study Title: Clinical Information Quality Assessment of Digital Health Technologies.

ICREC Reference number: 21IC7415

The above study was approved by your Head of Department on 20/12/21 and by the Research Governance and Integrity Team (RGIT) on 01/02/22.

Under the Imperial College Research Ethics Committee process, a study that has been reviewed by the Research Governance and Integrity Team (RGIT) and Head of Division/Department, where no significant ethical issues have been identified in the protocol or ethics application, can be granted RGIT approval without requiring it to go to full committee.

Documents

The documents reviewed were:

- Application form v1.2 12/10/2022
- Protocol v1.1 06/11/2021
- Participant Information Sheet v1.2 11/12/2021
- Survey v1.2 12/01/2021
- Invitation Email v1.1 08/12/2021

Yours sincerely

Ruth Nicholson
Head of Research Governance and Integrity
Imperial College London